VOL. 1

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Plant Sciences
- Forestry
- Plant Protection
- Sericulture
- Horticultural Sciences

भाकृअनुप
ICAR

Education Division
Indian Council of Agricultural Research
New Delhi

www.icar.gov.in

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सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the

syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language.*
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing.*
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

  (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

  (b) An application is made by the student concerned duly supported by the Advisory Committee;

  (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

  (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 1

Plant Sciences

– Genetics and Plant Breeding
– Seed Sciences and Technology
– Plant Genetic Resources

Contents

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Z.S. Solanki
Chairman
and
Former V.C., Agril. Uni., Kota.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Sciences
– Genetics and Plant Breeding

Preamble

(Genetics and Plant Breeding)

Plant improvement has a long history for its growth and development. Plant breeding became established as a science in the twentieth century following the rediscovery of Mendel's laws of inheritance. Nearly 50% of global increase in food production is attributed to plant breeding. Since genetic improvement in an inherent feature, products of plant breeding can have wide global impact as exemplified by the Green Revolution for wheat and rice varieties of 1960s or transgenic crops of recent decades. Therefore developing sufficient human resources in Genetics and Plant Breeding with advanced knowledge and technical skill will further elevate the agricultural sector to attain a new peak in increasing food production matching the requirement of population.

Present agriculture research and international market demand the need for specialised human resource for teaching cutting edge technology with application of biotechnology, nanotechnology, artificial intelligence in crop improvement, increasing entrepreneurship, etc., would warrant students to have strong knowledge of practical and management skills which will help them to face the competitiveness in public and private sector.

Hence, restructuring of course curricula and delivery system to match with the present situation is the need of the time. In this proposed revision of curriculum in Genetics and Plant Breeding, the BSMA sub-group organized a series of meetings and electronic media-led consultations to develop a set of courses suitable for M. Sc. and Ph. D. students of the discipline.

The meetings were focussed on the basic principles as well as the innovative developments in Genetics and Plant Breeding, as the platform building status of Plant Sciences. Built on this platform with the latest state of the art technologies including biotechnology and molecular biology will enable a complete coverage of the subjects. The basic courses have therefore been kept as compulsory courses which need to be taken by all the students irrespective of the subject specialization or stream from which they entered into PG education.

The BSMA Committee had thread bare discussions over four sessions on the topical issues concerning Genetics and Plant Breeding, Seed Science and Technology and Plant Genetic Resources. The curricula and syllabi of all these disciplines were discussed at length in the meetings and workshops. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the committee. The new look and restructured PG programmes in Genetics and Plant Breeding have been designed in considerations based on demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and to enhance the global competitiveness and employability of our students. Considerable efforts have, therefore gone in for the preparation of this document.

Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and social need both at national and international level are Molecular Breeding and Bioinformatics, Breeding for Quality and Special Traits, Seed Production and Certification, Breeding Vegetable Crops, Breeding Fruit Crops, Breeding Ornamental Crops for M.Sc. and IPR and Regulatory Mechanism (e-course) as well as Population Genetics for Ph.D. programme.

Course Title with Credit Load
M.Sc. (Ag) in Genetics and Plant Breeding (GPB)

Course Code	Course Title	Credit Hours
GPB 501*	Principles of Genetics	3 (2+1)
GPB 502*	Principles of Plant Breeding	3 (2+1)
GPB 503*	Fundamentals of Quantitative Genetics	3 (2+1)
GPB 504	Varietal Development and Maintenance Breeding	2 (1+1)
GPB 505	Principles of Cytogenetics	3 (2+1)
GPB 506*	Molecular Breeding and Bioinformatics	3 (2+1)
GPB 507	Breeding for Quality and Special Traits	3 (2+1)
GPB 508	Mutagenesis and Mutation Breeding	3 (2+1)
GPB 509	Hybrid Breeding	3 (2+1)
GPB 510	Seed Production and Certification	2 (1+1)
GPB 511	Crop Breeding-I *(Kharif* Crops)	3 (2+1)
GPB 512	Crop Breeding-II *(Rabi* Crops)	3 (2+1)
GPB 513	Breeding Vegetable Crops	3 (2+1)
GPB 514	Breeding Fruit Crops	3 (2+1)
GPB 515	Breeding Ornamental Crops	3 (2+1)
GPB 516	Breeding for Stress Resistance and Climate Change	3 (2+1)
GPB 517	Germplasm Characterization and Evaluation	2 (1+1)
GPB 518	Genetic enhancement for PGR Utilization	2 (1+1)
	Major courses (minimum 20 credits from above courses including *marked Courses)	**20**
	Minor courses	08
	Supporting courses	06
	Common compulsory courses	05
GPB 591	Seminar	01
GPB 599	Thesis/ Research	30
	Total Credits	70

*Compulsory Major Courses

Course Contents
M.Sc. (Ag) in Genetics and Plant Breeding (GPB)

I. Course Title : Principles of Genetics*
II. Course Code : GPB 501
III. Credit Hours : 3 (2+1)

IV. Why this course?

Genes are the backbone of all crop improvement activities. Their chemical structure and physical inheritance are pivotal for any breeding program. Therefore, it has to be the core course for master's degree in Genetics and Plant Breeding.

V. Aim of the course

This course is aimed at understanding the basic concepts of inheritance of genetic traits, helping students to develop their analytical, quantitative and problem-solving skills from classical to molecular genetics.

VI. Theory

Unit I

Beginning of genetics, early concepts of inheritance, Mendel's laws; Discussion on Mendel's paper, Chromosomal theory of inheritance; Multiple alleles, Gene interactions, Sex determination, differentiation and sex-linkage, Sex-influenced and sex-limited traits; Linkage-detection, estimation; Recombination and genetic mapping in eukaryotes, Somatic cell genetics, Extra chromosomal inheritance.

Unit II

Mendelian population, Random mating population, Frequencies of genes and genotypes, Causes of change: Hardy-Weinberg equilibrium.

Unit III

Nature, structure and replication of the genetic material; Organization of DNA in chromosomes, Genetic code; Protein biosynthesis, Genetic fine structure analysis, Allelic complementation, Split genes, overlapping genes, Pseudogenes, Oncogenes, Gene families and clusters; Regulation of gene activity in prokaryotes and eukaryotes; Molecular mechanisms of mutation, repair and suppression; Bacterial plasmids, insertion (IS) and transposable (Tn) elements; Molecular chaperones and gene expression, RNA editing.

Unit IV

Gene isolation, synthesis and cloning, genomic and cDNA libraries, PCR based cloning, positional cloning; Nucleic acid hybridization and immunochemical detection; DNA sequencing; DNA restriction and modification, Anti-sense RNA and ribozymes; Micro-RNAs (miRNAs).

Unit V

Genomics and proteomics; metagenomics; Transgenic bacteria and bioethics; Gene silencing; genetics of mitochondria and chloroplasts. Concepts of Eugenics, Epigenetics, Genetic disorders.

VII. Practical

- Laboratory exercises in probability and chi-square;
- Demonstration of genetic principles using laboratory organisms;
- Chromosome mapping using three-point test cross;
- Tetrad analysis; Induction and detection of mutations through genetic tests;
- DNA extraction and PCR amplification;
- Electrophoresis: basic principles and running of amplified DNA;
- Extraction of proteins and isozymes;
- Use of *Agrobacterium* mediated method and Biolistic gun;
- Detection of transgenes in the exposed plant material;
- Visit to transgenic glasshouse and learning the practical considerations.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After passing out this course the student will be able to know the difference between the genotype and phenotype, can carry study on inheritance and also know the role of DNA and RNA in genotypic manifestation of characters.

X. Suggested reading

Daniel LH and Maryellen R. 2011. *Genetics:* "*Analysis of Genes and Genomes*".
Gardner EJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley and Sons. 8th ed. 2006
Klug WS and Cummings MR. 2003. *Concepts of Genetics*. Peterson Edu. Pearson Education India; Tenth edition
Lewin B. 2008. *Genes XII*. Jones and Bartlett Publ. (International Edition) Paperback, 2018
Russell PJ. 1998. *Genetics*. The Benzamin/ Cummings Publ. Co
Singh BD. 2009. *Genetics*. Kalyani Publishers (2nd Revised Edition)
Snustad DP and Simmons MJ. 2006. *Genetics*. 4th Ed. John Wiley and Sons. 6th Edition International Student Version edition
Stansfield WD.1991. *Genetics*.Schaum Outline Series Mc Graw Hill
Strickberger MW. 2005. *Genetics* (*III Ed*). Prentice Hall, New Delhi, India; 3rd ed., 2015
Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publs., McGraw Hill Education; 7 edition
Uppal S, Yadav R, Singh S and Saharan RP. 2005. *Practical Manual on Basic and Applied Genetics*. Dept. of Genetics, CCS HAU Hisar.

I. Course Title : Principles of Plant Breeding*

II. Course Code : GPB 502

III. Credit Hours : 3(2+1)

IV. Why this course?

Development of plant variety is the ultimate aim of any plant breeding program. A post graduate in the subject of agriculture must know what are the different selection methods, techniques and related crop improvement strategies. Further, knowledge of genetic resources, evolution and their role in development of noble varieties is the need of the hour.

V. Aim of the course

To impart theoretical knowledge and practical skills about plant breeding objectives, genetic consequences, breeding methods for crop improvement.

VI. Theory

Unit I

Early Plant Breeding; Accomplishments through plant breeding; Objectives of plant breeding; Patterns of Evolution in Crop Plants: Centre of Origin, Agro-biodiversity and its significance. Pre-breeding and plant introduction and role of plant genetic resources in plant breeding.

Unit II

Genetic basis of breeding: self and cross pollinated crops including mating systems and response to selection; Nature of variability, components of variation; Heritability and genetic advance, genotype environment interaction; General and specific combining ability; Types of gene actions and implications in plant breeding.

Unit III

Pure line theory, pure line and mass selection methods; pedigree, bulk, backcross, single seed descent and multiline breeding; Population breeding in self-pollinated crops with special reference to diallel selective mating; Transgressive breeding.

Unit IV

Breeding methods in cross pollinated crops; Population breeding: mass selection and ear-to-row methods; S_1 and S_2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and inter-population improvement and development of synthetics and composites. Hybrid breeding: genetical and physiological basis of heterosis and inbreeding, production of inbreeds, breeding approaches for improvement of inbreeds, predicting hybrid performance; seed production of hybrid and their parent varieties/ inbreeds. Self-incompatibility, male sterility and apomixes in crop plants and their commercial exploitation.

Unit V

Breeding methods in asexually/ clonally propagated crops, clonal selection.

Unit VI

Special breeding techniques: Mutation breeding, Breeding for abiotic and biotic stresses; Concept of plant ideotype and its role in crop improvement, concept of MAS, concept of polyploidy and wide hybridization, doubled haploidy.

Unit VII

Cultivar development: testing, release and notification, maintenance breeding, Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights.

VII. Practical

- Floral biology in self and cross pollinated species;
- Selfing and crossing techniques;
- Selection methods in segregating populations and evaluation of breeding material;
- Analysis of variance (ANOVA);
- Estimation of heritability and genetic advance;
- Maintenance of experimental records;

- Learning techniques in hybrid seed production using male-sterility in field crops;
- Prediction of performance of double cross hybrid.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The knowledge of this course will enable the student to know breeding methods, different hybridization techniques for genomic reshuffling. The course will also acquaint the student with importance of floral biology, mutation breeding and participatory plant breeding, etc.

X. Suggested Reading

Allard RW. 1981. *Principles of Plant Breeding*. John Wiley & Sons.
Chahal GS and Gossal, SS. 2002. *Principles and Procedures of Plant Breeding Biotechnological and Conventional approaches*. Narosa Publishing House.
Chopra VL. 2004. *Plant Breeding*. Oxford & IBH.
George A. 2012. *Principles of Plant Genetics and Breeding*. John Wiley & Sons.
Gupta SK. 2005. *Practical Plant Breeding*. Agribios.
Jain HK and Kharakwal MC. 2004. *Plant Breeding and–Mendelian to Molecular Approach*, Narosa Publications, New Delhi
Roy D. 2003. *Plant Breeding, Analysis and Exploitation of Variation*. Narosa Publ. House.
Sharma JR. 2001. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill.
Sharma JP. 2010. Principles of Vegetable Breeding. Kalyani Publ, New Delhi.
Simmonds NW.1990. *Principles of Crop Improvement*. English Language Book Society.
Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.
Singh S and Pawar IS. 2006. *Genetic Bases and Methods of Plant Breeding*. CBS.

I. Course Title : Fundamentals of Quantitative Genetics*
II. Course Code : GPB 503
III. Credit Hours : 3 (2+1)

IV. Why this course?

Yield and quality characters are controlled by many genes and show the quantitative inheritance. If one has to go for improvement even for the components characters the knowledge of this course is very essential.

V. Aim of the course

To impart theoretical knowledge and computation skills regarding components of variation and variances, scales, mating designs and gene effects.

VI. Theory

Unit I

Introduction and historical background of quantitative genetics, Multiple factor hypothesis, Qualitative and quantitative characters, Analysis of continuous variation mean, range, SD, CV; Components of variation- Phenotypic, Genotypic, Nature of gene action- additive, dominance and epistatic, linkage effect. Principles of analysis of variance and linear model, Expected variance components, Random and fixed effect model, Comparison of means and variances for significance.

Unit II

Designs for plant breeding experiments- principles and applications; Variability parameters, concept of selection, simultaneous selection modes and selection of parents, MANOVA.

Unit III

Association analysis- Genotypic and phenotypic correlation, Path analysis Discriminate function and principal component analysis, Genetic divergence analysis- Metroglyph and D^2, Generation mean analysis, Parent progeny regression analysis

Unit IV

Mating designs- classification, Diallel, partial diallel, L × T, NCDs, and TTC; Concept of combining ability and gene action, G × E interaction-Adaptability and stability; Methods and models for stability analysis; Basic models- principles and interpretation, Bi-plot analysis.

Unit V

QTL mapping, Strategies for QTL mapping- Desired population and statistical methods, QTL mapping in genetic analysis; Markers, Marker assisted selection and factors influencing the MAS, Simultaneous selection based on marker and phenotype.

VII. Practical

- Analysis and interpretation of variability parameters;
- Analysis and interpretation of Index score and Metroglyph;
- Clustering and interpretation of D^2 analysis;
- Genotypic and phenotypic correlation analysis and interpretation;
- Path coefficient analysis and interpretation, Estimation of different types of heterosis, inbreeding depression and interpretation;
- A, B and C Scaling test;
- L × T analysis and interpretation, QTL analysis;
- Use of computer packages;
- Diallel analysis;
- G × E interaction and stability analysis.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures,
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After studying this course, the student will be equipped with the knowledge of additive dominance and epistatic gene action. He will also be introduced with the various designs for analysis of genotypic and phenotypic variance and QTL mapping.

X. Suggested Reading

Bos I and Caligari P. 1995. *Selection Methods in Plant Breeding*. Chapman & Hall.

Falconer DS and Mackay J. 1998. *Introduction to Quantitative Genetics* (3rd Ed.).ELBS/ Longman, London.
Mather K and Jinks JL.1985. *Biometrical Genetics* (3rd Ed.). Chapman and Hall, London.
Nandarajan N and Gunasekaran M. 2008. *Quantitative Genetics and Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
Naryanan SS and Singh P. 2007. *Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
Roy D. 2000. *Plant Breeding: Analysis and Exploitation of Variation*. Narosa Publishing House, New Delhi.
Sharma JR. 2006. *Statistical and Biometrical Techniques in Plant Breeding*. New Age International Pvt. Ltd.
Singh P and Narayanan SS. 1993. *Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
Singh RK and Chaudhary BD. 1987. *Biometrical Methods in Quantitative Genetic* analysis. Kalyani Publishers, New Delhi.
Weir DS. 1990. *Genetic Data Analysis. Methods for Discrete Population Genetic Data*. Sinauer Associates.
Wricke G and Weber WE. 1986. *Quantitative Genetics and Selection in Plant Breeding*. Walter de Gruyter.

e-Suggested Reading

www.iasri.icar.gov.in
www.hau.ac.in/OPstat

I. Course Title : Varietal Development and Maintenance Breeding
II. Course Code : GPB 504
III. Credit Hours : 2(1+1)

IV. Why this course?

It is an indispensable course which apprise the students about various practices and procedures in the development of a variety and steps to maintain the purity of varieties/ hybrids. Further, it provides basics of nucleus and breeder seed production techniques.

V. Aim of the course

The purpose of this course is to make students well acquainted with the techniques and procedures of varietal development. He will be associated with development of variety so the course aims is to provide knowledge on DUS testing, protocols of various breeding techniques, procedures of release of variety, maintenance of the variety and production of nucleus and breeder seed of variety/ hybrids.

VI. Theory

Unit I

Variety Development systemsand Maintenance; Definition- variety, cultivar, extant variety, essentially derived variety, independently derived variety, reference variety, farmers' variety, landraces, hybrid, and population; Variety testing, release and notification systems and norms in India and abroad.

Unit II

DUS testing- DUS Descriptors for major crops; Genetic purity concept and maintenance breeding. Factors responsible for genetic deterioration of varieties - safeguards during seed production.

Unit III

Maintenance of varieties in self and cross pollinated crops, isolation distance; Principles of seed production; Methods of nucleus and breeder seed production; Generation system of seed multiplication -nucleus, breeders, foundation, certified.

Unit IV

Quality seed production technology of self and cross-pollinated crop varieties, viz., cereals and millets (wheat, barley, paddy, pearlmillet, sorghum, maize and ragi, etc.); Pulses (greengram, blackgram, cowpea, pigeonpea, chickpea, fieldpea, lentil); Oilseeds (groundnut, soybean, sesame, castor, sunflower, safflower, linseed, rapeseed and mustard); fibres (cotton/ jute) and forages (guar, forage sorghum, teosinte, oats, berseem, lucerne).

Unit V

Seed certification procedures; Seed laws and acts, plant variety protection regulations in India and international systems.

VII. Practical

- Identification of suitable areas/ locations for seed production;
- Ear-to-row method and nucleus seed production;
- Main characteristics of released and notified varieties, hybrids and parental lines;
- PGMS and TGMS;
- Identification of important weeds/ objectionable weeds;
- Determination of isolation distance and planting ratios in different crops; Seed production techniques of varieties in different crops;
- Hybrid seed production technology of important crops;
- DUS testing and descriptors in major crops;
- Variety release proposal formats in different crops.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

Pass out student will have complete knowledge on the various procedures linked with the development and release of variety. This course will also enable student how to maintain and multiply variety for large scale distribution. It will also make student acquainted with the seed laws and acts related to plant variety protection.

X. Suggested Reading

Agarwal RL. 1997. *Seed Technology*. 2nd Ed. Oxford & IBH.

Kelly AF. 1988. *Seed Production of Agricultural Crops*. Longman.

McDonald MB Jr and Copeland LO. 1997. *Seed Production: Principles and Practices*. Chapman & Hall.

Poehlman JM and Borthakur D. 1969. *Breeding Asian Field Crops*. Oxford & IBH.

Singh BD. 2005. *Plant Breeding: Principles and Methods*. Kalyani. 2015

Thompson JR. 1979. *An Introduction to Seed Technology*. Leonard Hill

I. Course Title : Principles of Cytogenetics

II. Course Code : GPB 505

III. Credit Hours : 3 (2+1)

IV. Why this course?

The very purpose of this course is to acquaint the students with cell cycle and architecture of chromosome in prokaryotes and eukaryotes, special types of chromosomes, techniques for karyotyping. This course aims to impart knowledge of variations in chromosomes numbers and their structures. It acquaints the students for the production and use of haploids, apomictic populations and their role in genetics and breeding.

V. Aim of the course

To provide insight into structure and functions of chromosomes, chromosome mapping, polyploidy and cytogenetic aspects of crop evolution.

VI. Theory

Unit I

Cell cycle and architecture of chromosome in prokaryotes and eukaryotes; Chromonemata, chromosome matrix, chromomeres, centromere, secondary constriction and telomere; artificial chromosome construction and its uses; Special types of chromosomes.Variation in chromosome structure: Evolutionary significance; Introduction to techniques for karyotyping; Chromosome banding and painting -*In situ* hybridization and various applications.

Unit II

Structural and numerical variations of chromosomes and their implications; Symbols and terminologies for chromosome numbers, euploidy, haploids, diploids and polyploids; Utilization of aneuploids in gene location; Variation in chromosome behaviour, somatic segregation and chimeras, endomitosis and somatic reduction; Evolutionary significance of chromosomal aberrations, balanced lethal and chromosome complexes; Inter-varietal chromosome substitutions.

Unit III

Fertilization barriers in crop plants at pre-and postfertilization levels; *In-vitro* techniques to overcome the fertilization barriers in crops; Polyploidy. Genetic consequences of polyploidization and role of polyploids in crop breeding; Evolutionary advantages of autopolyploid *vs* allopolyploids; Role of aneuploids in basic and applied aspects of crop breeding, their maintenance and utilization in gene mapping and gene blocks transfer; Alien addition and substitution lines, creation and utilization; Apomixis, evolutionary and genetic problems in crops with apomixes.

Unit IV

Reversion of autopolyploid to diploids; Genome mapping in polyploids; Interspecific hybridization and allopolyploids; Synthesis of new crops (wheat, *Triticale, Brassica*, and cotton); Hybrids between species with same chromosome number, alien translocations; Hybrids between species with different chromosome number; Gene transfer using amphidiploids, bridge species.

Unit V

Chromosome manipulations in wide hybridization; case studies; Production and use of haploids, dihaploids and doubled haploids in genetics and breeding.

VII. Practical

- Learning the cytogenetical laboratory techniques, various chemicals to be used for fixation, dehydration, embedding, staining, cleaning, etc.;
- Microscopy: various types of microscopes;
- Preparing specimen for observation;
- Fixative preparation and fixing specimen for light microscopy studies in cereals;
- Studies on mitosis and meiosis in crop plants;
- Using micrometres and studying the pollen grain size in various crops. Pollen germination *in vivo* and *in-vitro*;
- Demonstration of polyploidy.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The course will provide full knowledge to the student on the various procedures linked with cell development and chromosome structure and function. This course will also enable student how to tailor and utilize the variation in chromosome number and structures in the development and synthesis of new species and varieties.

X. Suggested Reading

Becker K and Hardin J. 2004. *World of the Cell*. 5th Ed. Pearson Edu. 9th edition.
Carroll M. 1989. *Organelles*. The Guilford Press.
Charles B. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications.
Darlington CD and La Cour LF. 1969. *The Handling of Chromosomes*. George Allen & Unwin Ltd.
Elgin SCR. 1995. *Chromatin Structure and Gene Expression*. IRLPress,Oxford.
Gupta PK and Tsuchiya T. 1991. *Chromosome Engineering in Plants: Genetics, Breeding and Evolution*. Part A.
Gupta PK. 2010. *Cytogenetics*. Rastogi Pubishers.
Johannson DA. 1975. *Plant Micro technique*. McGraw Hill.
Karp G. 1996. *Cell and Molecular Biology: Concepts and Experiments*. John Wiley & Sons.
Khush GS. 1973. *Cytogenetics of aneuploids*. Elsevier. 1 edition.
Roy D.2009. *Cytogenetics*. Alpha Science Intl Ltd.
Schulz SJ.1980. *Cytogenetics- Plant, animals and Humans*. Springer.
Sharma AK and Sharma A. 1988. *Chromosome Techniques: Theory and Practice*. Butterworth-Heinemann publisher 2014.3rd edition
Singh RJ. 2016. Plant *Cytogenetics* 3rd Edition. CRC Press.
Sumner AT. 1982. *Chromosome Banding*. Unwin Hyman Publ. 1 edition, Springer pub.
Swanson CP. 1960. *Cytology and Cytogenetics*. Macmillan & Co.

I. Course Title : Molecular Breeding and Bioinformatics*

II. Course Code : GPB 506

III. Credit Hours : 3(2+1)

IV. Why this course?

The course will provide deep knowledge to the students on genotyping and kinds of markers including biochemical and molecular, mapping populations, allele mining. This will also add ways to perform marker-assisted selection and gene pyramiding to evolve superior varieties.

V. Aim of the course

To impart knowledge and practical skills to use innovative approaches and Bioinformatics in Plant Breeding.

VI. Theory

Unit I

Genotyping; Biochemical and Molecular markers; Morphological, biochemical and DNA-based markers (RFLP, RAPD, AFLP, SSR, SNPs, ESTs, etc.), Functional markers; Mapping populations (F_2s, back crosses, RILs, NILs and DH); Molecular mapping and tagging of agronomically important traits; Statistical tools in marker analysis.

Unit II

Allele mining; Marker-assisted selection for qualitative and quantitative traits; QTLs analysis in crop plants; Marker-assisted backcross breeding for rapid introgression; Genomics- assisted breeding; Generation of EDVs; Gene pyramiding.

Unit III

Introduction to Comparative Genomics; Large scale genome sequencing strategies; Human genome project; Arabidopsis genome project; Rice genome project; Comparative genomics tools; Introduction to proteomics; 2D gel electrophoresis; chromatography and sequencing by Edman degradation and mass spectrometry; Endopeptidases; Nanotechnology and its applications in crop improvement.

Unit IV

Recombinant DNA technology, transgenes, method of transformation, selectable markers and clean transformation techniques, vector-mediated gene transfer, physical methods of gene transfer; Production of transgenic plants in various field crops: cotton, wheat, maize, rice, soybean, oilseeds, sugarcane, etc. and commercial releases; Biotechnology applications in male sterility/ hybrid breeding, molecular farming; Application of Tissue culture in molecular breeding; MOs and related issues (risk and regulations); GMO; International regulations, biosafety issues of GMOs; Regulatory procedures in major countries including India, ethical, legal and social issues; Intellectual property rights; Introduction to bioinformatics: bioinformatics tools, biological data bases (primary and secondary), implications in crop improvement.

VII. Practical

- Requirements for plant tissue culture laboratory;
- Techniques in plant tissue culture;
- Media components and media preparation;
- Aseptic manipulation of various explants, observations on the contaminants occurring in media, interpretations;
- Inoculation of explants, callus induction and plant regeneration; Standardizing the protocols for regeneration;
- Hardening of regenerated plants; Establishing a greenhouse and hardening procedures;

- Visit to commercial micropropagation unit;
- Transformation using Agrobacterium strains;
- GUS assay in transformed cells/ tissues;
- DNA isolation, DNA purity and quantification tests;
- Gel electrophoresis of proteins and isozymes, PCR-based DNA markers, gel scoring and data analysis for tagging and phylogenetic relationship;
- Construction of genetic linkage maps using computer software;
- NCBI Genomic Resources, GBFF, Swiss Prot, Blast n/ Blast p, Gene Prediction Tool, Expasy Resources, PUBMED and PMC, OMIM and OMIA, ORF finder;
- Comparative Genomic Resources: - Map Viewer (UCSC Browser and Ensembl);
- Primer designing- Primer 3/ Primer BLAST.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The knowledge of this course will enable the student to know about various molecular tools and approaches for genotyping and marker assisted breeding, intellectual property rights, bioinformatics tools and their uses in crop improvement.

X. Suggested Reading

Azuaje F and Dopazo J. 2005. *Data Analysis and Visualization in Genomics and Proteomics*. John Wiley and Sons.

Brown TA. 1991. *Essential Molecular Biology: a practical Approach*. Oxford university press, 2002, 2nd edition

Chawala HS. 2000. *Introduction to Plant Biotechnology*. Oxford & IBH Publishing Co. Pvt. Ltd.

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology: Concepts, Methods and Applications*. Oxford & IBH.

Gupta PK. 1997. *Elements of Biotechnology*. Rastogi Publ.

Hackett PB, Fuchs JA and Messing JW. 1988. *An Introduction to Recombinant DNA Technology - Basic Experiments in Gene Manipulation*. 2nd Ed. Benjamin Publ. Co.

Jollès P and Jörnvall H. 2000. *Proteomics in Functional Genomics: Protein Structure Analysis*. Birkhäuser.

Lewin B. 2017. *Genes XII*. Jones & Bartlett learning, 2017.

Robert NT and Dennis JG. 2010. *Plant Tissue Culture, Development, and Biotechnology*. CRC Press.

Sambrook J and Russel D. 2001. *Molecular Cloning - a Laboratory Manual*. 3rd Ed. Cold Spring Harbor Lab. Press.

Singh BD. 2005. *Biotechnology, Expanding Horizons*. Kalyani Publishers, New Delhi.

Watson J. 2006. *Recombinant DNA*. Cold Spring harbor laboratory press.

I. Course Title : Breeding for Quality and Special Traits

II. Course Code : GPB 507

III. Credit Hours : 3(2+1)

IV. Why this course?

Quality consciousness is growing in the society and only quality products are in demand in the market so has to be the new varieties. This course acquaints breeding for grain quality parameters in field crops. It will also teach about the genetic engineering protocols for quality improvement: Biofortification in crops and Nutritional genomics and Second generation transgenics.

V. Aim of the course

To provide insight into recent advances in improvement of quality traits in cereals, millets, legumes, oilseeds, forage and industrial crops using conventional and modern biotechnological approaches.

VI. Theory

Unit I

Developmental biochemistry and genetics of carbohydrates, proteins, fats, vitamins, amino acids and anti-nutritional factors; Nutritional improvement - A human perspective.

Unit II

Breeding for grain quality parameters in rice and its analysis; Golden rice and aromatic rice: Breeding strategies, achievements and application in Indian context; Molecular basis of quality traits and their manipulation in rice; Post harvest manipulation for quality improvement; Breeding for baking qualities in wheat, characters to be considered and breeding strategies, molecular and cytogenetic manipulation for quality improvement in wheat.

Unit III

Breeding for quality improvement in Sorghum, pearl millet, barley and oats; Quality protein maize, specialty corns, concept and breeding strategies; Breeding for quality improvement in important forage crops for stay green traits; Genetic resource management for sustaining nutritive quality in crops.

Unit IV

Breeding for quality improvement in pulses – Chickpea, pigeonpea, green gram and black gram cooking quality; Breeding for quality in oilseeds -groundnut, mustard, soybean, sesame, sunflower and minor oilseeds; Molecular basis of fat formation and manipulation to achieve more PUFA in oil crops; Genetic manipulation for quality improvement in cotton. Breeding for quality improvement in Sugarcane, potato.

Unit V

Genetic engineering protocols for quality improvement: Achievements made; Biofortification in crops; Classification and importance, Nutritional genomics and Second generation transgenics.

VII. Practical

- Grain quality evaluation in rice; Correlating ageing and quality improvement in rice;
- Quality analysis in millets;
- Estimation of anti-nutritional factors like tannins in different varieties/ hybrids: A comparison;
- Quality parameters evaluation in wheat, pulses and oilseeds;
- Evaluation of quality parameters in cotton, sugarcane and potato;
- Value addition in crop plants;

- Post-harvest processing of major field crops;
- Quality improvement in crops through tissue culture techniques;
- Evaluating the available populations like RIL, NIL, etc. for quality improvement using MAS procedures;
- Successful example of application of MAS for quality trait in rice, mustard, maize, etc.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The knowledge of this course will expose the student to know about various conventional and genetic engineering techniques for the improvement of quality characters in agricultural and horticultural field crops.

X. Suggested Reading

Chahal GS and SS Ghosal. 2002. *Principles and procedures of plant breeding - Biotechnological and Conventional approaches*, Narosa Publications Chopra VL. 1997. *Plant Breeding*. Oxford & IBH. 2018.

FAO 2001. *SpecialityRices of the World - Breeding, Production and Marketing*. Oxford & IBH,1 Nov 2001.

Ghosh P. 2004. *Fibre Science and Technology*. Tata McGraw Hill.

Gupta SK. 2007. *Advances in Botanical Research* Vol. 45 Academic Press USA.

Hay RK. 2006. *Physiology of Crop Yield*. 2nd Ed. Blackwell.

Nigam J. 1996. *Genetic Improvement of Oilseed Crops*. Oxford & IBH.

Singh BD. 1997. *Plant Breeding*. Kalyani Publishers, New Delhi.

Singh RK, Singh UK and Khush GS. 2000. *Aromatic Rices*. Oxford & IBH.

I. Course Title : Mutagenesis and Mutation Breeding

II. Course Code : GPB 508

III. Credit Hours : 3 (2+1)

IV. Why this course?

The knowledge of this course will enable the students to learn about mutation, various methods of inducing mutations and their utilization in plant breeding. It will also give in depth knowledge about genomics, allele mining, TILLING, etc. and their utilization in crop improvement programmes.

V. Aim of the course

To impart the knowledge about general principles of mutagenesis for crop improvement and various tests/ methods for detection of mutations.

VI. Theory

Unit I

Mutation and its history, nature and classification of mutations: spontaneous and induced mutations, micro and macro mutations, pre and post adaptive mutations; Detection of mutations. Paramutations in crops plants.

Unit II

Mutagenic agents: physical – radiation types and sources: Ionizing and non-ionizing radiations. Radiobiology: mechanism of action of various radiations (photoelectric absorption, Compton scattering and pair production) and their biological effects – RBE and LET relationships; Effect of mutations on DNA – repair mechanisms operating at DNA, chromosome, cell and organism level to counteract the mutation effects; Dosimetry -Objects and methods of treatment; Factors influencing mutation: dose rate, acute vs chronic irradiation, recurrent irradiation, enhancement of thermal neutron effects; Radiation sensitivity and modifying factors: External and internal sources – Oxygen, water content, temperature and nuclear volume.

Unit III

Chemical mutagens: Classification – base analogues, antibiotics, alkylating agents, acridine dyes and other mutagens: their properties and mode of action; Dose determination and factors influencing chemical mutagenesis; Treatment methods using physical and chemical mutagens, Combination treatments; other causes of mutation – direct and indirect action, comparative evaluation of physical and chemical mutagens.

Unit IV

Observing mutagen effects in M_1 generation: plant injury, lethality, sterility, chimeras, etc.; Observing mutagen effects in M_2 generation; Estimation of mutagenic efficiency and effectiveness – spectrum of chlorophyll and viable mutations; Mutations in traits with continuous variation; Factors influencing the mutant spectrum: genotype, type of mutagen and dose, pleiotropy and linkage, etc.; Individual plant based mutation analysis and working out effectiveness and efficiency in M_3 generation; Comparative evaluation of physical and chemical mutagens for creation of variability in the some species- Case studies.

Unit V

Use of mutagens in creating oligogenic and polygenic variations – Case studies; *In-vitro* mutagenesis – Callus and pollen irradiation; Handling of segregating M_2 generations and selection procedures; Validation of mutants; Mutation breeding for various traits (disease resistance, insect resistance, quality improvement, etc.) in different crops; Procedures for micromutations breeding/ polygenic mutations; Achievements of mutation breeding- varieties released across the world, problems associated with mutation breeding. Use of mutagens in genomics, allele mining, TILLING.

VII. Practical

- Precautions on handling of mutagens; Dosimetry-Studies of different mutagenic agents:Physical mutagens and Chemical mutagens;
- Learning on Radioactivity- Production source and isotopes at BRIT, Trombay, Learning about gamma chamber;
- Radiation hazards: Monitoring – safety regulations and safe transportation of radioisotopes, visit to radio isotope laboratory; learning on safe disposal of radioisotopes;
- Hazards due to chemical mutagens – Treating the plant propagules at different doses of physical and chemical mutagens;
- Procedures in combined mutagenic treatments;
- Raising the crop for observation; Mutagenic effectiveness and efficiency, calculating the same from earlier literature;

- Study of M_1 generation – Parameters;
- Study of M_2 generation – Parameters;
- Mutation breeding in cereals and pulses-achievements made and an analysis;
- Mutation breeding in oilseeds and cotton- achievements and opportunities;
- Mutation breeding in forage crops and vegetatively propagated crops;
- Procedure for detection of mutations for polygenic traits in M_2 and M_3 generations.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

This course will make the student well versed with the process of mutation and its use in crop improvement. This course will also give in depth knowledge of mutations in genomics, allele mining and TILLING.

X. Suggested Reading

Alper T. 1979. *Cellular Radiobiology*. Cambridge Univ. Press, London.

Chadwick KH and Leenhouts HP. 1981. *The Molecular Theory of Radiation Biology*. Springer-Verlag.

Cotton R, Edkin E and Forrest S. 2000. *Mutation Detection: A Practical Approach*. Oxford Univ. Press.

International Atomic Energy Agency. 1970. *Manual on Mutation Breeding*. International Atomic Energey Agency, Vienna, Italy.

Shu QY, Forster BP and Nakagawa N. 2012. *Plant Mutation Breeding and Biotechnology*. Gutecnberg Press Ltd. Rome Italy ISBN:978-925107-022-2 (FAO).

Singh BD. 2003. *Genetics*. Kalyani Publishers, New Delhi.

Strickberger MW. 2005. *Genetics*. 3rd Ed. Prentice Hall.

www.barc.gov.in

I. Course Title : Hybrid Breeding

II. Course Code : GPB 509

III. Credit Hours : 3(2+1)

IV. Why this course?

This course will expose the students with the basic concepts of hybrid varietiesand various techniques for development of hybrids in crop plants. This will also give an overview of various kinds of male sterility and their utilization in hybrid seed production of important field crops.

V. Aim of the course

To provide knowledge of understanding about mechanisms of heterosis and its exploitation for yield improvement through conventional and biotechnological approaches.

VI. Theory

Unit I

Historical aspect of heterosis, nomenclature and definitions of heterosis; Heterosis in natural population and inbred population; Evolutionary aspects – Genetic consequences of selfing, sibbing and crossing in self-and cross-pollinated and asexually propagated crops; Pre-Mendelian and Post-Mendelian ideas – Evolutionary concepts of heterosis; Genetic theories of heterosis – Physiological, Biochemical and molecular factors underlining heterosis; theories and their estimation; Biometrical basis of heterosis.

Unit II

Prediction of heterosis from various crosses, inbreeding depression, coefficient of inbreeding and its estimation, residual heterosis in F_2 and segregating populations, importance of inbreeding in exploitation of heterosis – case studies.; Relationship between genetic distance and expression of heterosis, case studies; Divergence and genetic distance analyses, morphological and molecular genetic distance in predicting heterosis; Development of heterotic pools in germplasm/ genetic stocks and inbreeds, their improvement for increasing heterosis.

Unit III

Male sterility and use in heterosis breeding; Male sterile line creation and diversification in self-pollinated, cross pollinated and asexually propagated crops; Creation of male sterility through genetic engineering and its exploitation in heterosis; Maintenance, transfer and restoration of different types of male sterility; Use of self-incompatibility in development of hybrids.

Unit IV

Hybrid seed production system: 3-line, 2-line and 1-line system; Development of inbreeds and parental lines- A, B and R lines – functional male sterility; Commercial exploitation of heterosis, maintenance breeding of parental lines in hybrids; Fixation of heterosis in self, cross and often cross pollinated crops, asexually/ clonally propagated crops, problems and prospects; Apomixis in fixing heterosis-concept of single line hybrid; Organellar heterosis and complementation.

Unit V

Hybrid breeding in wheat, rice, cotton, maize, pearl millet, sorghum and rapeseed-mustard, sunflower, safflower and castor oilseed crops and pigeonpea.

VII. Practical

- Characterization of male sterile lines using morphological descriptors;
- Restorer line identification and diversification of male sterile sources;
- Male sterile line creation in crop plants, problems in creation of CGMS system, ways of overcoming them;
- Diversification and restoration;
- Success stories of hybrid breeding in Maize, Rice, Pearl millet, Sorghum and Pigeon pea;
- Understanding the difficulties in breeding apomicts;
- Estimation of heterotic parameters in self, cross and asexually propagated crops;
- Estimation from the various models for heterosis parameters;
- Hybrid seed production in field crops—an account on the released hybrids, their potential, problems and ways of overcoming it;
- Hybrid breeding at National and International level,opportunities ahead.

VIII. Teaching methods

- Power point presentation

- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course, the student will be able to know about importance of heterosis, the various conventional and biotechnological approaches for the development of hybrids. This will also enable student to know about the use of male sterility in hybrid seed production of important field crops.

X. Suggested Reading

Agarwal RL. 1998. *Fundamental of Plant Breeding and hybrid Seed Production*. Science Publisher London.

Akin E. 1979. *The Geometry of Population Genetics*. Springer-Verlag.

Ben HL. 1998. *Statistical Genomics – Linkage, Mapping and QTL Analysis*. CRC Press.

Chal GS and Gossal SS. 2002. *Principles and procedures of Plant Breeding, Biotechnology and Convetional Approaches*. Narosa Publishing House. New Delhi

De JG. 1988. *Population Genetics and Evolution*. Springer-Verlag. 30 January 2012

Hartl DL. 2000. *A Primer of Population Genetics*. 3rd Ed. Sinauer Assoc.

Mettler LE and Gregg TG. 1969. *Population Genetics and Evolution*. Prentice-Hall. 25 April 1988

Montgomery DC. 2001. *Design and Analysis of Experiments*. 5th Ed., Wiley & Sons. 2013

Mukherjee BK. 1995.*The Heterosis Phenomenon*. Kalyani Publishers, New Delhi.

Proceedings of *Genetics and Exploitation of Heterosis in Crops* – An International Symposium CIMMYT, 1998.

Richards AJ. 1986. *Plant Breeding Systems*. George Allen & Unwin. 30 May 1997

Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.

Srivastava S and Tyagi R. 1997. *Selected Problems in Genetics*. Vols. I, II. Anmol Publ.

Virmani SS. 1994. *Heterosis and Hybrid Rice Breeding. Monographs of "Theoretical and Applied Genetics*", Springer-Verlag.

I. Course Title : Seed Production and Certification

II. Course Code : GPB 510

III. Credit Hours : 2(1+1)

IV. Why this course?

Seed is the essence of life. Its improvement, production and maintenance is an essential feature of any variety. Seed chain concept is highly relevant in commercial promotion of new varieties whereas process of certification is mandatory for quality assurance of seed.

V. Aim of the course

To impart knowledge on principles of seed production and certification. This will help the students to understand seed production practices and seed certification procedures in different crops.

VI. Theory

Unit I

Importance of seed as basic input in agriculture; Seed quality concept and importance; Generation system of seed multiplication -Varietal replacement rate, Seed multiplication ratios, Seed replacement rate, Seed renewal period and seed demand

and supply; Various factors influencing seed production –Physical and Genetic purity in seed production; Factors responsible for varietal and genetic deterioration.

Unit II

Nucleus seed production and its maintenance - Maintenance of parental lines of hybrids, Production of breeder, foundation and certified seed and their quality maintenance; Principles of seed production in self- and cross-pollinated crops; Hybrid seed production - system and techniques involved in Seed village concept; Organic seed production and certification.

Unit III

Principles of seed production in field crops; Floral structure, pollination mechanism and seed production techniques in self- and cross-pollinated cereals and millets.

Unit IV

Floral structure, pollination mechanism and methods and techniques of seed production in major pulses and oilseed crops; Varietal and hybrid seed production techniques in Pigeon pea, Mustard, Castor and Sunflower.

Unit V

Floral structure, pollination mechanism and methods and techniques of seed production in major commercial fibres. Hybrid-seed production techniques in major vegetatively propagated crops.

Unit VI

Seed certification - history, concept, objectives;Central seed certification board Seed certification agency/ organization and staff requirement; Legal status - Phases of seed certification, formulation, revision and publication of seed certification standards; Minimum Seed Certification Standards (MSCS) for different crops - General and specific crop standards, Field and seed standards; Planning and management of seed certification programs; Eligibility of a variety for certification, area assessment, cropping history of the seed field.

VII. Practical

- Planting design for variety- hybrid seed production techniques, planting ratio of male and female lines, synchronization of parental lines and methods to achieve synchrony;
- Identification of rogues and pollen shedders, supplementary pollination, detasseling, hand emasculation and pollination;
- Pollen collection and storage methods, pollen viability and stigma receptivity;
- Pre-harvest sanitation, maturity symptoms, harvesting techniques;
- Visits to seed production plots - visit to seed industries;
- Planning for seed production: cost benefit ratio, seed multiplication ratio and seed replacement rate;
- General procedure of seed certification, identification of weed and other crop seeds as per specific crops, field inspection at different stages of a crop and observations recorded on contaminants and reporting of results, inspection and sampling, harvesting/ threshing, processing and after processing for seed law enforcement;
- Specifications for tags and labels to be used for certification purpose.

VIII. Teaching methods

- Power point presentation

- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course the student will be able to know about seed production of different crop varieties and hybrids, their processing, marketing and seed laws.

X. Suggested Reading

Agrawal PK and Dadlani M. 1987. *Techniques in Seed Science and Technology*, South Asian Publishers, Delhi.
Agrawal RL. 1997. *Seed Technology,* Oxford & IBH Publishing.
Anon, 1965. *Field Inspection Manual and Minimum Seed Certification Standards*, NSC Publication, New Delhi.
Anon. 1999. *Manual of Seed Certification procedures*. Directorate of Seed Certification, Coimbatore, Tamil Nadu.
Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi.
Kelly AF. 1988. *Seed Production of Agricultural Crops*. John Wiley, New York.
Mc Donald MB and Copeland LO. 1997. *Seed Science and Technology*, Scientific Publisher, Jodhpur.
Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India*. Agrobios (India), Jodhpur, Rajasthan.
Singhal NC. 2003. *Hybrid Seed Production in Field Crops*, Kalyani Publications, New Delhi
Tunwar NS and Singh SV. 1988. *Indian Minimum Seed Certification Standards*. Central Seed Certification Board, Ministry of Agriculture, New Delhi.

e-Resources

www.gov.mb.ca
www.agricoop.nic.in
www.agri.nic.in
www.fao.org
www.seednet.gov.in

I. Course Title : Crop Breeding I (*Kharif* Crops)
II. Course Code : GPB 511
III. Credit Hours : 3(2+1)

IV. Why this course?

Botanical features, reproductive systems, genetics involved and important breeding techniques are essential to undertake any crop improvement programme. This course is designed for important/ major *Kharif* field crops.

V. Aim of the course

To provide insight into recent advances in improvement of kharif cereals, legumes, oilseeds, fibre, sugarcane and vegetative propagated crops using conventional and modern biotechnological approaches.

VI. Theory

Unit I

Rice: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Aerobic rice, its implications and drought resistance breeding.

Maize: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, releasedvarieties, examples of MAS used for improvement- QPM and Bt maize – strategies and implications.

Small millets: Evolution and distribution of species and forms - wild relatives and germplasm; Cytogenetics and genome relationship - breeding objectives yield, quality characters, biotic and abiotic stress resistance, etc.

Unit II

Pigeon pea: evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement - Hybrid technology; maintenance of male sterile, fertile and restorer lines, progress made at National and International institutes.

Groundnut: Origin, evolution mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship, breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Other pulses: Urdbean, mungbean, cowpea,: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship, breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), released varieties, examples of MAS used for improvement. Interspecific crosses attempted and its implications, reasons for failure, ways of overcoming them.

Unit III

Soybean: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Castor and Sesame: Origin, evolution mode of reproduction, chromosome number; Genetics –cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), released varieties, examples of MAS used for improvement; Hybrid breeding in castor – opportunities, constraints and achievements.

Unit IV

Cotton: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Development and maintenance of male sterile lines – Hybrid development and seed production – Scenario of Bt cottons, evaluation procedures for Bt cotton.

Jute: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Unit V

Sugarcane: Evolution and distribution of species and forms, wild relatives and germplasm; Cytogenetics and genome relationship – Breeding objectives- yield, quality characters, biotic and abiotic stress resistance, etc.

Forage crops: Evolution and distribution of species and forms – Wild relatives and germplasm; Cytogenetics and genome relationship; Breeding objectives- yield, quality characters and palatability studies; Biotic and abiotic stress resistance, etc.

Seed spices: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement; Achievements of important spice crops.

VII. Practical

- Floral biology, emasculation, pollination techniques in rice, maize, pigeon pea, soybean, sesame, cotton;
- Study of range of variation for yield and yield components;
- Study of segregating populations in cereal, pulses and oilseed crops;
- Learning on the crosses between different species; attempting crosses between black gram and green gram;
- Evaluating the germplasm of cotton for yield, quality and resistance parameters, learning the procedures on development of Bt cotton;
- Visit to Cotton Technology Laboratory and Spinning Mills;
- Learning on the Standard Evaluation System (SES) and descriptors; Use of software for database management and retrieval;
- Practical learning on the cultivation of fodder crop species on sewage water, analysing them for yield components and palatability;
- Laboratory analysis of forage crops for crude protein, digestibility percent and other quality attributes;
- Visit to animal feed producing factories;
- Learning the practice of value addition; Visiting the animal husbandry unit and learning the animal experiments related with palatability and digestibility of fodder.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures

- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course, the student will be able to know about important botanical status and reproductive structures of crops and genetics of important kharif field crops.

X. Suggested Reading

Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.

Bahl PN and Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.

Chandraratna MF. 1964. *Genetics and Breeding of Rice*. Longmans.

Chopra VL and Prakash S. 2002. *Evolution and Adaptation of Cereal Crops*. Oxford & IBH.

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IRRI. 1991. *Rice Genetics II*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.

IRRI. 1996. *Rice Genetics III*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.

IRRI. 2000. *Rice Genetics IV*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.

Jennings PR, Coffman WR and Kauffman HE. 1979. *Rice Improvement*. IRRI, Los Banos, Manila, Philippines.

Kannaiyan S, Uthamasamy S, Theodore RK and Palaniswamy S. 2002. *New Dimensions and Approaches for Sustainable Agriculture*. Directorate of Extension Education, TNAU, Coimbatore.

Murty DS, Tabo R and Ajayi O. 1994. *Sorghum Hybrid Seed Production and Management*. ICRISAT, Patancheru, India.

Nanda JS. 1997. *Manual on Rice Breeding*. Kalyani Publishers.

Parthasarathy VA. 2017. *Spices and Plantation Crops Vol.1* (*Part A*) *Breeding of Horticultural Crops* Vol.1 (Part-B), Today and Tomorrow Printers and Publishers

Poehlman, JM. 1987. *Breeding of Field Crops*. AVI Publishing Co. Inc. East Post Connecticut, USA.

Ram HH and Singh HG. 1993. *Crop Breeding and Genetics*. Kalyani.

Sharma, AK. 2005. *Breeding Technology of Crop Plant*. Yesh Publishing House, Bikaner

Slafer GA. (Ed.). 1994. *Genetic Improvement of Field Crops*. Marcel Dekker.

Singh HG, Mishra SN, Singh TB, Ram HH and Singh DP. (Eds.). 1994. *Crop Breeding in India*. International Book Distributing Co.

Walden DB. 1978. *Maize Breeding and Genetics*. John Wiley & Sons.

I. Course Title : Crop Breeding-II (*Rabi* Crops)

II. Course Code : GPB 512

III. Credit Hours : 3(2+1)

IV. Why this course?

Botanical features, reproductive systems, genetics involved and important breeding techniques are essential to undertake any crop improvement programme. This course is designed for important/ major Rabi field crops.

V. Aim of the course

To provide insight into recent advances in improvement of *Rabi* cereals, legumes, oilseeds, fibre and vegetative propagated crops using conventional and modern biotechnological approaches

VI. Theory

Unit I

Wheat: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Oats: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Barley: Origin, evolution, center of origin, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Unit II

Chickpea: Origin, evolution mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Other pulses: Lentil, field pea, Rajma, Horse gram: Origin, evolution, mode of reproduction, chromosome number; Genetics. cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement. Interspecific crosses attempted and its implications, reasons for failure, ways of overcoming them.

Unit III

Rapeseed and Mustard: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives; yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Oil quality, Improvement for oil quality.

Sunflower, Safflower: Origin, mode of reproduction, chromosome number; Genetics, cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Unit IV

Mesta and minor fibre crops: Origin, mode of reproduction, chromosome number;

Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Forage crops: Origin, evolution mode of reproduction, chromosome number; Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance.

Unit V

Seed spices: Origin, evolution, mode of reproduction, chromosome number; Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, scope of heterosis breeding, released varieties, examples of MAS used for crop improvement.

VII. Practical

- Floral biology, emasculation and pollination techniques in wheat, oats, barley, chickpea, rajma, rapeseed mustard, sunflower;
- Study of range of variation for yield and yield components;
- Study of segregating populations in cereal, pulses and oilseed crops;
- Use of descriptors for cataloguing; Learning on the crosses between different species;
- Trait based screening for stress resistance;
- Learning on the Standard Evaluation System (SES) and descriptors;
- Use of software for database management and retrieval.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the student will be able to know about the different breeding methods and genetics of major *Rabi* field crops.

X. Suggested Reading

Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.

Bahl PN and Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.

Gupta SK. 2012. *Technological Innovations in Major World Oil crops*. Vol. I. Springer, USA.

Gupta SK. 2012. *Technological Innovations in Major World Oil crops*. Vol. II. Springer, USA.

Gupta SK. 2016. *Breeding of Oilseed Crops for Sustainable Production*. Academic Press, USA.

Kannaiyan S, Uthamasamy S, Theodore RK and Palaniswamy S. 2002. *New Dimensions and Approaches for Sustainable Agriculture*. Directorate of Extension Education, TNAU, Coimbatore.

Parthasarathy VA. 2017. *Spices and Plantation Crops* Vol.1 (Part A) *Breeding of Breeding and Genetics*. John Wiley & Sons.

I. Course Title : Breeding Vegetable Crops
II. Course Code : GPB 513
III. Credit Hours : 3(2+1)

IV. Why this course?

This course enables the students to learn about breeding objectives, methodologies and genetics involved for the improvement of major vegetable crops.

V. Aim of the course

To educate about principles and practices adopted for breeding of vegetable crops.

VI. Theory

Unit I

Breeding for Leafy vegetables: Amaranth, chenopods and lettuce.

Unit II

Breeding for Cucurbits: Gourds, melons, pumpkins and squashes.

Unit III

Breeding for Solanaceae: Potato and tomato, eggplant, hot pepper, sweet pepper

Unit IV

Breeding for Cole crops: Cabbage, cauliflower, broccoli and knolkhol.
Breeding for Root vegetables: Carrot, beetroot, radish, sweet potato and tapioca.

Unit V

Breeding for other vegetable crops: Peas, beans, onion, garlic and okra.

VII. Practical

- Selection of desirable plants from breeding population, observations and analysis of various qualitative and quantitative traits in germplasm;
- Hybridization and handling segregating generations;
- Induction of flowering, palanological studies, selfing and crossing techniques in vegetable crops;
- Hybrid seed production of vegetable crops in bulk;
- Screening techniques for insect-pests, disease and environmental stress resistance in vegetable crops;
- Demonstration of sib-mating and mixed population;
- Molecular marker techniques to identify useful traits in the vegetable crops and special breeding techniques;
- Visit to breeding blocks, MAS for incorporating traits governed by major and polygenes.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able to know about the different breeding methods and genetics of major vegetable crops.

X. Suggested Reading

Allard RW. 1999. *Principles of Plant Breeding*. John Wiley & Sons.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable Crops: Breeding and Seed Production*. Vol. I. Kalyani Publishers, New Delhi.

Kalloo G. 1988. *Vegetable Breeding*. Vols. I-III. CRC Press.

Kalloo G. 1998. *Vegetable Breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency.

Peter KV and Pradeep KT. 2008. *Genetics and Breeding of Vegetables*. ICAR.

Rai N and Rai M. 2006. *Heterosis Breeding in Vegetable Crops*. New India Publication Agency.

Ram HH. 2005. *Vegetable Breeding-Principles and Practices*. Kalyani Publishers

Sharma JP. 2010. *Principles of Vegetable Breeding*. Kalyani Publishers, New Delhi.

Singh BD. 1983. *Plant Breeding*. Kalyani Publishers

I. Course Title : Breeding Fruit Crops

II. Course Code : GPB 514

III. Credit Hours : 3(2+1)

IV. Why this course?

This course is aimed to educate the students about the breeding strategies and avenues in Fruit crops.

V. Aim of the course

To educate students about principles and practices adopted for breeding of fruit crops.

VI. Theory

Unit I

Fruit crop breeding: History, importance of fruit breeding, centers of diversity, distribution, domestication and adaptation of commercially important fruits.

Unit II

Issues in fruit crop breeding – heterozygosity, polyploidy, polyembryony, parthenocarpy and seed lessness, incompatibility and sterility systems.

Unit III

Apomixis - merits and demerits, types, variability for economic traits, role of genetic engineering and biotechnology in improvement of fruit crops.

Unit IV

Crop improvement in Mango, Banana, Citrus, Grapes, Papaya, Sapota and Pomegranate, Pineapple and Guava, Apple and other Rosaceous crops andregion specific fruit crops.

VII. Practical

- Germplasm documentation;
- Floral biology of mango, guava, citrus, grape, pomegranate, pollen viability in major fruit crops;
- Pollen germination to study time of anthesis and stigma receptivity;
- Hybridization technique in important fruit crops, hybrid seed collection and raising;
- Colchicine treatment for induction of polyploidy;
- Exposure to resistance breeding and screening techniques;

- Mutation breeding practices raising and evaluation of segregating populations;
- Use of mutagens to induce mutations and polyploidy;
- Visit to Biotechnology Lab and study of *in-vitro* breeding techniques.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able do the breeding of fruit crops through various conventional and biotechnological methods besides mutation breeding.

X. Suggested Reading

Bhojwani SS and Razdan MK. 2006. *Plant Tissue Culture -Theory and Practice*. Elsevier Publication, Amesterdam.

Chadha KL and Pareek, OP. 1996. (Eds.). *Advances in Horticulture*. Vol. I to IV. Malhotra Publ. House, New Delhi.

Chadha KL and Shikhamany SD. 1999. *The Grape: Improvement, Production and Post-Harvest Management*. Malhotra Publ. House, New Delhi.

Janick and Moore JN. 1996. *Advances in Fruit Breeding*, AVI Pub., USA.

Janick J and Moore JN. 1996. *Fruit Breeding*. Vols. I to III. John Wiley & Sons.

Kumar N. 2006. *Breeding of Horticultural Crops - Principles and Practices*. New India Publishing Agency, New Delhi.

Moore JN and Janick Jules. 1996. *Methods in Fruit Breeding*. Purdue University Press, South Campus Court D., USA.

Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK. and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vols. I-III. Naya Prokash, Kolkata.

Ray PK. 2002. *Breeding of Tropical and Sub-tropical Fruits*. Narosa Publishing House, New Delhi.

Simmonds NW. 1976. *Evolution of Crop Plants*, Orient Longman, London.

I. Course Title : Breeding Ornamental Crops

II. Course Code : GPB 515

III. Credit Hours : 3(2+1)

IV. Why this course?

The course will impart knowledge to student about breeding of Ornamental Crops through conventional and biotechnological interventions.

V. Aim of the course

To educate about principles and practices adopted for breeding of ornamental crops.

VI. Theory

Unit I

History of improvement of ornamental plants; Centre of origin of ornamental crop; Objectives and techniques in ornamental plant breeding.

Unit II

Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops, viz., Rose, Jasmine, *Chrysanthemum*, Tuberose, *Gerbera*, *Gladiolus*, *Dahlia*, *Lilium*, *Gaillardia*, *Petunia*, *Bouganvillea*, Pansy, Marigold, *Geranium*, *Antirrhinum*, China aster, Orchids, *Carnation*, *Hibiscus,* etc.

Unit III

Development of promising cultivars of important ornamental and flower crops; Role of Heterosis and its exploitation, production of F_1 hybrids and utilization of male sterility.

Unit IV

Production of open pollinated seeds, harvesting, processing and storage of seeds; Seed certification.

VII. Practical

- Study of floral biology and pollination in important species and cultivars of ornamental crops;
- Techniques of inducing polyploidy and mutation;
- Production of pure and hybrid seed;
- Methods of breeding suited to seed propagated plants;
- Polyploidy and mutations to evolve new varieties;
- Breeding methods for biotic and abiotic stresses;
- Visit to research institutes involved in ornamental crop breeding.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able to do the breeding of ornamental crops by conventional breeding and biotechnological methods and to know the genetics of major ornamental crops.

X. Suggested Reading

Alexander V. 2002. *Breeding for ornamentals: Classical and Molecular Approaches*. Kluwer Academic Publishers, London.

Allard RW. 1999. *Principles of Plant Breeding*. John Wiley & Sons. INC. New York.

Bhattacharjee SK and De LC. 2003. *Advanced Commercial Floriculture* Vol. 1. Aavishkar Publishers & Distributors, Jaipur.

Bose TK and Yadav LP. 2003. *Commercial Flowers*. Naya Prokash Publishers, Kolkata.

Chadha KL and Bhattacharjee SK. *Advances in Horticulture* Vol. 12, Malhotra Publishing House, New Delhi.

Mc Donald MB and Kwong FY. 2005. *Flower Seeds Biology and Technology*, CABI Publishing, Oxfordshire, UK.

Watts L.1980. *Flower and Vegetable Plant Breeding*. Grower Books

I. Course Title : Breeding for Stress Resistance and Climate Change
II. Course Code : GPB 516
III. Credit Hours : 3(2+1)

IV. Why this course?

Climate change is a big challenge to sustain higher crop productivity and nutritional quality. Concept of breeding for stress tolerance and development of hybrids/ varieties for climate change is of prime importance in plant breeding. Therefore this course is essential for budding plant breeders.

V. Aim of the course

To apprise about various abiotic and biotic stresses influencing crop yield, mechanisms and genetics of resistance and methods to breed stress tolerant varieties.

VI. Theory

Unit I

Concept and impact of climatic change; Importance of plant breeding with special reference to biotic and abiotic stress resistance; Classification of biotic stresses – major pests and diseases of economically important crops.

Unit II

Concepts of resistance to insect and pathogen resistance; Analysis and inheritance of resistance variation; Host defence responses to pathogen invasions- Biochemical and molecular mechanisms; Acquired and induced immunity and systemic acquired resistance (SAR); Host-pathogen interaction, gene-for-gene hypothesis, molecular evidence for its operation and exceptions; Concept of signal transduction and other host-defence mechanisms against viruses and bacteria.

Unit III

Types and genetic mechanisms of resistance to biotic stresses –Horizontal and vertical resistance in crop plants; Quantitative resistance/ adult plant resistance and slow rusting resistance; Classical and molecular breeding methods - Measuring plant resistance using plant fitness; Behavioural, physiological and insect gain studies; Phenotypic screening methods for major pests and diseases; Recording of observations; Correlating the observations using marker data – Gene pyramiding methods and their implications.

Classification of abiotic stresses - Stress inducing factors, moisture stress/ drought and water logging and submergence; Acidity, salinity/ alkalinity/ sodicity; High/ low temperature, wind, etc.; Stress due to soil factors and mineral toxicity; Physiological and Phenological responses; Emphasis of abiotic stresses in developing breeding methodologies.

Unit IV

Genetics of abiotic stress resistance; Genes and genomics in breeding cultivars suitable to low water regimes and water logging and submergence, high and low/ freezing temperatures; Utilizing MAS procedures for identifying resistant types in important crops like rice, sorghum, wheat, cotton, etc.; Breeding for resistance to stresses caused by toxicity, deficiency and pollutants/ contaminants in soil, water and environment.

Unit V

Use of crop wild relatives as a source of resistance to biotic and abiotic factors in major field crops; Transgenics in management of biotic and abiotic stresses, use of toxins, protease inhibitors, lectins, chitinases and Bt for diseases and insect pest management.

VII. Practical

- Understanding the climatological parameters and predisposal of biotic and abiotic stress factors- ways of combating them for diseases caused by fungi and bacteria;
- Symptoms and data recording; use of MAS procedures;
- Phenotypic screening techniques for sucking pests and chewing pests – Traits to be observed at plant and insect level;
- Phenotypic screening techniques for nematodes and borers; Ways of combating them;
- Evaluating the available populations like RIL, NIL, etc. for pest resistance;
- Use of standard MAS procedures. Breeding strategies - Weeds – ecological, environmental impacts on the crops;
- Breeding for herbicide resistance;
- Screening crops for drought and flood resistance; factors to be considered and breeding strategies;
- Screening varieties of major crops for acidity and alkalinity- their effects and breeding strategies;
- Screening forage crops for resistance to sewage water and tannery effluents; Quality parameters evaluation.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the student will be able to well verse with the stress and its causes. This will enable the students for the development of RIL, NIL, etc. for pest resistance and Use of standard MAS procedures

X. Suggested Reading

Blum A. 1988. *Plant Breeding for Stress Environments*. CRC Press.

Christiansen MN and Lewis CF. 1982. *Breeding Plants for Less Favourable Environments*. Wiley International.

Fritz RS and Simms EL. (Eds.). 1992. *Plant Resistance to Herbivores and Pathogens: Ecology, Evolution and Genetics*. The University of Chicago Press.

Li PH and Sakai A. 1987. *Plant Cold Hardiness*. Liss, New York Springer

Luginpill P. 1969. *Developing Resistant Plants - The Ideal Method of Controlling Insects*. USDA, ARS, Washington DC.

Maxwell FG and Jennings PR. (Eds.). 1980. *Breeding Plants Resistant to Insects*. John Wiley & Sons. Wiley-Blackwell.

Roberto F. 2018. *Plant Breeding for Biotic and Abiotic Stress Tolerance*. Springer.

Russel GE. 1978. *Plant Breeding for Pest and Disease Resistance*. Butterworths.

Sakai A and Larcher W. 1987. *Frost Survival in Plants*. Springer-Verlag.

Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.
Turener NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons.
van der Plank JE. 1982. *Host-Pathogen Interactions in Plant Disease*. Academic Press.

I. Course Title : Germplasm Characterization and Evaluation
II. Course Code : GPB 517
III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to learn about morphological and quality agronomic traits of accessions as well as their reaction to biotic and abiotic stresses. This will increase the importance of the germplasm.

V. Aim of the course

Students will gain knowledge on germplasm characterisation, evaluation and documentation of information. Recording of morphological and agronomic traits, including quality, as well as those for resilience to biotic and abiotic stresses that will promote utilisation. Exposure to development of web based tools for systematic description for efficient use of germplasm.

VI. Theory

Unit I

Understanding genetic diversity in crop plants; Crop descriptors, descriptor states; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits; Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation, markers and their use in PGR, evaluation of biotic and abiotic stresses, Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.

Unit II

Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces, evaluation and maintenance of wild relatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement.

Unit III

High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping) – evaluation for nutritional traits, resistance traits -Biochemical and molecular markers for characterization.

VII. Practical

- Field layout and experimental designs;
- Recording field data on germplasm evaluation in different agri-horticultural crops,
- post harvest handling;
- Evaluating quality traits, biochemical and phyto-chemical evaluation of crop germplasm, data processing;
- Documentation, analysis of diversity and cataloguing, data analysis, viability equations, sampling strategies, data documentation, cataloguing, biochemical analyses of samples.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

To educate students about science of managing genetic resources including principles involved in maintaining genetic integrity during regeneration, germplasm characterization and evaluation.

X. Suggested Reading

Brown AHD, Clegg MT, Kahler AL, Weir BS (eds.) 1990. *Plant Population Genetics, Breeding, and Genetic Resources*, Sinauer Associates, USA.

Frankel R and Galun E 1977. *Pollination Mechanisms, Reproduction and Plant Breeding. Monographs on Theoretical and Applied Genetics*, Springer-Verlag, Berlin, Heidelberg.

Hayward MD, Bosemak NO and Romagosa I. 1993. *Plant Breeding: Principles and Practices*, Chapman & Hall.

Holden JHN and Williams JT 1984. *Crop genetic resources: conservation and evaluation*, IBPGR.

Puzone, L and Th. Hazekamp 1996. *Characterization and Documentation of Genetic Resources Utilizing Multimedia Database*. NBPGR, New Delhi.

Rana RS, Sapra RL, Agrawal RC and Gambhir R 1991. Plant Genetic Resources, *Documentation and Information Management*. NBPGR, New Delhi.

Stoskopf NC 1993. *Plant Breeding: Theory and Practice*, Westview Press.

Sundeep Kumar, *et al.* 2016. *Evaluation of 19,460 wheat accessions conserved in the Indian national genebank to identify new sources of resistance to rust and spot blotch diseases*. PloS One Vol 11, pages 0167702.

Tripathi K, Bhardwaj R, Bhalla S, Kaur V, Bansal R, Yadav R, Gangopadhyay KK, Kumar A and Chaudhury R. 2018. *Plant Genetic Resources Evaluation: Principles and Procedures*, Indian Council of Agricultural Research - National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi. vi+50 p.

I. Course Title : Genetic enhancement for PGR Utilization

II. Course Code : GPB 518

III. Credit Hours : 2(1+1)

IV. Why this course ?

Pre-breeding is a vital step in the link between plant genetic resources conservation and its use; Hence, this course is designed to inculcate theoretical and practical know how to understand and use classical and advanced plant breeding methods for planning and execution of prebreeding programmes so that the PGR is put into effective use for food and agriculture.

V. Aim of the course

To teach theoretical and practical know how on CWRs reproductive behavior, acclimatization and adaptation for utilization in prebreeding programmes usig advanced tools.

VI. Theory

Unit I

Concepts of gene pools; Introduction, potential of pre-breeding. Role of crop wild relatives, semi exotics, creating and managing variation, basic concepts to set up a successful pre-breeding programme.

Unit II

Understanding crop adaptation, handling and maintenance of CWRs, synchronization of flowering, overcoming impediments to flowering through photoperiodic adjustments, role of other barriers to flowering, role of amphidiploids, semi exotics and other unadapted germplasm, identifying desirable traits in natural populations, screening for biotic and abiotic stress resistance traits; screening of nutritionally important traits, genetic analysis to understand the inheritance of novel traits.

Unit III

Parental selection for prebreeding, search for superior genotypes, breeding methods for trait transfer; moving the genes - unadapted to adapted, wide hybridization, Incongruity and its management, modern tools for incongruity management, cytogenetical approaches for gene transfer such as alien addition and substitution, segregating populations and their management in wide crosses, purging the undesirable traits, testing and improving the adaptability of wide cross derivatives, cytological studies, florescence microscopy, embryo rescue methods, pollen physiology and storage, pollen storage methods to facilitate wide hybridization, pre- and post-zygotic barriers.

VII. Practical

- Characterization of CWRs by visiting the fields;
- Screening methods for special traits-biotic and abiotic resistance;
- Screening for nutritional traits;
- Crossability studies in CWRs of cereals, legumes, oilseeds, vegetables. Assessment of pre and post-zygotic barriers in wide hybridization crosses;
- Pollen storage studies;
- Special requirements for growing CWRs, inducing flowering by manipulating day length, temperature, chemical spraying, etc.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

Students would be conversant with handling of unadapted germplasm, screening methods for special traits-biotic and abiotic resistance, nutritional traits, characterization of CWR, breeding, etc.

X. Suggested Reading

Andey Pereira. 2006. *Plant Reverse Genetics*, Methods and Protocols, Humana Press

Bisht *et al*. 2004. Broadening the genetic base of sesame (*Sesamum indicum* L.) through genetic enhancement. *Plant Genetic Resources* **2**(3): 143–151.

Dale JW and von Schantz M. 2007. *From genes to genomes. Concepts and applications of DNA technology*. John Wiley & Sons Ltd., Chichester, England.

Duvick DN. 1990. Genetic enhancement and plant breeding. p. 90–96. In: J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland.

Goodman, RM. 2004. *Encyclopedia of plant and crop science*. Marcel Dekker Inc., Switzerland.

Kimber, G and Feldman, M. 1987. *Wild Wheat: An introduction*. Special report 353, College of Agriculture, University of Missouri-Columbia.

Lynch M. and Walsh B. 1998. *Genetics and analysis of quantitative traits*. Sinauer Associates Inc., MA, USA.
Murphy D. 2007. *Plant breeding and biotechnology: Societal context and the future of agriculture*. Cambridge University Press, Cambridge, UK.
Ram JS. 2010. *Plant Cytogenetics*. CRC Press.
Ramanatha Rao V, Brown AHD, Jackson M. 2001. *Managing Plant Genetic Diversity*. CABI publication.
Sharma S, Upadhyaya HD, Varshney RK, *et al*. 2013. Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes. *Front. Plant Sci*. **4**: 309.
Yunbi Xu. 2010. Molecular plant breeding, CABI publishers

e-Resources

https://www.integratedbreedPlaning.net/ pre-breeding-effective-use-plant-genetic-resources
http://www.croptrust.org/
http://www.bioversityinternational.org/training/training_materials/pre_breeding.htm
http://www.grdc.com.au/director/research/prebreeding

Course Title with Credit Load
Ph.D. in Genetics and Plant Breeding (GPB)

Course Code	Course Title	Credit
GPB 601*	Advances in Plant Breeding Systems	3(3+0)
GPB 602	Advances in Biometrical Genetics	3(2+1)
GPB 603	Molecular Cytogenetics for Crop Improvement	2(2+0)
GPB 604	Plant Genetics Resources, Conservation and Utilization	2(2+0)
GPB 605*	Genomics in Plant Breeding	3(3+0)
GPB 606	Population Genetics	2(2+0)
GPB 607	Crop Evolution	3(3+0)
GPB 608	Breeding Designer Crops	2(1+1)
GPB 609*	IPR and Regulatory Mechanism (e-course)	1(1+0)
	Major courses (Minimum 12 credits from above courses including *marked Courses)	12
	Minor courses	06
	Supporting courses	05
GPB 691	Seminar I	01
GPB 692	Seminar II	01
GPB 699	Thesis/ Research	75
	Total Credits	100

Comprehensive (Pre-qualifying) Examination (Non-credit of 100 marks) Satisfactory/ Not satisfactory

*Compulsory Major Courses

Course Contents
Ph.D. in Genetics and Plant Breeding (GPB)

I. Course Title : Advances in Plant Breeding Systems*

II. Course Code : GPB 601

III. Credit Hours : 3(3+0)

IV. Why this course?

This course is an advancement of principles, various plant breeding methodologies and procedures in the development of a complex population; MAS for selection of qualitative and quantitative traits, Gene pyramiding, marker-based utilization of exotic Germplasm and introgression libraries.

V. Aim of the course

To impart theoretical knowledge about advances in plant breeding.

VI. Theory

Unit I

Advances in reproductive biology of crops; Genes governing the whorls formation and various models proposed; Pollen pistil interaction: biochemical and molecular basis, environmental factors governing anthesis and bottlenecks for gene transfer.

Unit II

Plant Breeding methodologies: Classic versus modern; Over view of Pre and Post Mendelian breeding methods in self and cross pollinated crops; Molecular and transgenic breeding approaches; doubled haploid breeding, shuttle breeding, forward and reverse breeding, speed breeding, participatory plant breeding, breeding for organic situations.

Unit III

Principles and procedures in the formation of a complex population; Genetic basis of population improvement in crop plants; Recurrent selection methods in self and cross pollinated crops and their modifications; Convergent selection, divergent selection; Recurrent selection, usefulness in hybrid breeding programs; Reciprocal recurrent selection; Selection in clonally propagated crops – Assumptions and realities.

Unit IV

Choice of molecular markers for plant breeding efficiency, fingerprinting and genetic diversity assessment, application of MAS for selection of qualitative and quantitative traits; Gene pyramiding, accelerated backcrossing, marker-based utilization of exotic germplasm, introgression libraries.

Unit V

Genetic resources: primary, secondary, tertiary and alien trans gene pool; Molecular and biochemical basis of self-incompatibility and male sterility, nucleocytoplasmic interactions with special reference to male sterility – genetic, biochemical and molecular bases.

Unit VI

Genetic engineering technologies to create male sterility, prospects and problems, use of self-incompatibility and sterility in plant breeding – case studies; Fertility restoration in male sterile lines and restorer diversification programs; Conversion of agronomically ideal genotypes into male sterile: Concepts and breeding strategies; Case studies - Generating new cyto-nuclear interaction system for diversification of male sterile; Stability of male sterile lines – Environmental influence on sterility, Environmentally Induced Genic Male Sterility (EGMS) – Types of EGMS; Influence on their expression, genetic studies; Photo and thermo sensitive genetic male sterility and its use in heterosis breeding; Temperature sensitive genetic male sterility and its use heterosis breeding; Apomixis and its use in heterosis breeding; Incongruity: Factors influencing incongruity Methods to overcome incongruity mechanisms.

Unit VII

Breeding for climate change -Improving root systems, abiotic stress tolerance, water use efficiency, flooding and sub-mergence tolerance; Biotic stress tolerance; Nutrient use efficiency, nitrogen fixation and assimilation, greenhouse gases and carbon sequestration; Breeding for bio-fortification.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After completion of this course the student will be able to know variousplant breeding methodologies, principles and procedures for the formation of a complex population; MAS for selection of qualitative and quantitative traits, Gene pyramiding, marker based utilization of exotic Germplasm and Breeding for climate change

IX. Suggested Reading

Agarwal RL. 1996. *Fundamentals of Plant Breeding and Hybrid Seed Production*. Oxford & IBH.

Allard RW. 1966. *Principles of Plant Breeding*. John Wiley & Sons.

Briggs FN and Knowles PF. 1967. *Introduction to Plant Breeding*. Reinhold.

Fehr WR. 1987. *Principles of Cultivar Development: Theory and Technique*. Vol I. Macmillan.

Hayes HK, Immer FR and Smith DC. 1955. *Methods of Plant Breeding*. McGraw-Hill.

Kang MS and Priyadarshan PM (Edit.). 2007. *Breeding Major Food Staples*. Blackwell Publishing.

Kole C. 2013. *Genomics and Breeding for Climate-Resilient Crops*. Springer. Volume 2-Target Traits.

Mandal AK, Ganguli PK and Banerji SP. 1995. *Advances in Plant Breeding*. Vol. I, II. CBS.

Richards AJ. 1986. *Plant Breeding Systems*. George Allen & Unwin.

Sharma JR. 1994. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill.

Simmonds NW. 1979. *Principles of Crop Improvement*. Longman.

Singh BD. 1997. *Plant Breeding: Principles and Methods*. 5th Ed., Kalyani Publishers, New Delhi.

Singh P. 1996. *Essentials of Plant Breeding*. Kalyani Publishers, New Delhi.

Welsh JR. 1981. *Fundamentals of Plant Genetic and Breeding*. John Wiley.

I. Course Title : Advances in Biometrical Genetics

II. Course Code : GPB 602

III. Credit Hours : 3(2+1)

IV. Why this course?

This course is essential to understand various qualitative, quantitative systems/ techniques related to genetic improvement of crops, G x E Interaction, Construction of saturated linkage maps and Marker Assisted Selection (MAS).

V. Aim of the course

To impart theoretical knowledge and computation methods for non-allelic interactions, mating designs and component analysis and their significance in plant breeding.

VI. Theory

Unit I

Continuous variation-evolutionary studies; Genetic principles of continuous variation, Qualitative and quantitative techniques-differences, population types, approaches; various types of metrics, F_2, Fα and mixed; Selection of parents Simultaneous selection models; Use of Multiple regression analysis in selection of genotypes.

Unit II

Components of mean- Additive effect, breeding value, coefficient of gene dispersion, dominance; Simple scaling test, expectation of mean of character in various types of families in coupling and dispersed phase; Epistasis- Specification, weighted and un-weighted joint scaling test; Effect of linkage to generation mean, specification of mean to G × E interaction.

Unit III

Component of variances-advantages, variances of different generations, balance sheet of variance; estimation of parameters-weighted and unweighted, least square analysis; random mating population; experimental population-BIPs, NCD-I, II, III, Triple test cross for random mating population and inbreds; Estimates of linkage and non-allelic interactions; Combining ability analysis, Hayman's Approach.

Unit IV

G × E Interaction, stability and adaptability; Advanced models in stability analysis - Pattern analysis - Additive Main Effect and Multiplicative Interaction (AMMI) analysis and other related models; Merits and limitation of different stability analysis methods; Analysis and selection of genotypes; Methods and steps to select the best model - Biplots and mapping genotypes.

Unit V

Construction of saturated linkage maps, concept of framework map development; QTLs-different types of markers and mapping populations, linkage maps, mapping-Strategies for QTL mapping - desired populations, statistical methods; MAGIC populations, Marker Assisted Selection (MAS) - Approaches to apply MAS in Plant breeding - selection based on markers - simultaneous selection based on marker and phenotype - Factors influencing MAS; Heritability of the trait, proportion of genetic variance, linkage disequilibrium between markers and traits and selection methods; Use of advanced software packages for biometrical analysis, interpretation of analysed data.

VII. Practical

- Generation mean analysis: ABC scaling test and Joint scaling test- Analysis and interpretation;
- Estimation of variance of different filial generations and interpretations;
- Diallel analysis: Numerical, graphical and combining ability analysis; Triallel analysis;
- NC Designs: Triple test cross analysis;
- Stability analysis: Eberhart and Russel model;
- AMMI model - Principal Component Analysis model - Additive and multiplicative model - Shifted multiplicative model - Analysis and selection of genotypes - Methods and steps to select the best model - Selection systems - Biplots and mapping genotypes;
- Construction of linkage maps and QTL mapping - Strategies for QTL mapping; statistical methods in QTL mapping;
- Phenotype and Marker linkage studies;
- Use of advanced software in biometrical analysis.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After the completion of this course student will be able to understand various Qualitative and quantitative techniques, G x E Interaction, Construction of saturated linkage maps and Marker Assisted Selection, Use of advanced software packages for biometrical analysis, interpretation of analysed data.

X. Suggested Reading

Bos I and Caligari P. 1995. *Selection Methods in Plant Breeding*. Chapman & Hall.

Dabholkar AR.1993. *Elements of Biometrical Genetics.* Concept Publishing Co. New Delhi.

Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics* (4 Ed.). ELBS/ Longman, London.

Mather K and Jinks JL. 1985. *Biometrical Genetics* (3rd Ed.). Chapman and Hall, London.

Nandarajan N and Gunasekaran M. 2008. *Quantitative Genetics and Biometrical Techniques in Plant Breeding.* Kalyani Publishers, New Delhi.

Roy D. 2000. *Plant Breeding, Analysis and Exploitation of Variation.* Narosa Publishing House, New Delhi.

Singh P and Narayanan SS. 1993. *Biometrical Techniques in Plant Breeding.* Kalyani Publishers, New Delhi.

Singh RK and Choudhary BD. 1987. *Biometrical Methods in Quantitative Genetics*. Kalyani Publishers, New Delhi.

Weir DS. 1990. *Genetic Data Analysis. Methods for Discrete Population Genetic Dat*a. Sinauer Associates.

Wricke G and Weber WE. 1986. *Quantitative Genetics and Selection in Plant Breeding*. Walter de Gruyter.

I. **Course Title : Molecular Cytogenetics for Crop Improvement**

II. **Course Code : GPB 603**

III. **Credit Hours : 2(2+0)**

IV. **Why this course?**

This course is needed to understand organization and structure of genome, karyotyping, Pre-breeding and applications of cytogenetically methods for crop improvement

V. **Aim of the course**

This course focuses on applications of cytogenetic techniques for crop improvement.

VI. **Theory**

Unit I

Organization and structure of genome, Genome size, Organization of organellar genomes, Nuclear DNA organization, Nuclear and Cytoplasmic genome interactions and signal transduction; Inheritance and expression of organellar DNA; Variation in DNA content - C value paradox; Sequence complexity – Introns and Exons, Repetitive sequences, Role of repetitive sequence.

Unit II

Karyotyping – Chromosome banding and chromosome painting; Tracking introgressions using FISH, GISH, localization and mapping of genes/ genomic segments.

Unit III

Pre-breeding and applications of cytogenetical methods for crop improvement; Location and mapping of genes on chromosomes: deficiency method; Interchange genetic consequence, identification of chromosomes involved and gene location; balanced lethal systems, their maintenance and utility; Multiple interchanges-use in producing inbreds, transfer of genes- linked marker methods; Duplication - production and use; Inversions and location of genes; B/ A chromosome translocations and gene location.

Unit IV

Trisomics- types, production, breeding behavior and location of genes, use of balanced tertiary trisomics in hybrid seed production; Monosomics methods of production, breeding behavior and location of genes; Intervarietal substitutions-allelic and non-allelic interactions; Telocentric method of mapping.

Unit V

Cytogenomics: Concept, tools and techniques for crop improvement; Chromosome sorting: Isolation of specific chromosome for development of molecular maps and gene location.

Unit VI

Role of polyploidy in crop evolution and breeding. Auto- and allopolyploids; Distant hybridization, barriers to interspecific and intergeneric hybridization; Behaviour of interspecific and intergeneric crosses.

VII. **Teaching methods**

- Power point presentation
- Chalk and Board

- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning Outcome

After the completion of this course the student will be able to understand Organization and structure of genome, karyotyping, Pre-breeding, polyploidy and applications of cytogenetically methods for crop improvement.

IX. Suggested Reading

Clark MS and Wall WJ. 1996. *Chromosomes: The Complex Code*. Chapman & Hall. 30 June 1996

Conger BV. (Ed.). 1981. *Cloning Agricultural Plants via in-vitro Techniques*. CRC Press. 31 January 2018

Constabel F and Vasil IK. (Eds.). 1988. *Cell Culture and Somatic Cell Genetics of Plants*. Vol. V. Cell Culture and Phytochemicals in Plant Cell Cultures. Academic Press.

Gupta P K. 2006. *Cytogenetics*. Rastogi Publisher

Lal R and Lal S. (Eds.). 1990. *Crop Improvement Utilizing Biotechnology*. CRC Press.

Mantel SH and Smith H. 1983. *Plant Biotechnology*. Cambridge University Press.

Sen SK and Giles KL. (Eds.). 1983. *Plant Cell Culture in Crop Improvement*. Plenum Press. 13 July 2013

Yao-Shan F. 2002. *Molecular Cytogenetics: Protocols and Application*. Human Press

I. Course Title : Plant Genetic Resources, Conservation and Utilization

II. Course Code : GPB 604

III. Credit Hours : 2(2+0)

IV. Why this course?

This course is needed to make the student aware about the importance of Plant Genetic Resources its Conservation and Utilization in crop improvement.

V. Aim of the course

To impart knowledge on the methods of germplasm conservation and its utilization

VI. Theory

Unit I

Concept of natural reserves and natural gene banks; *In situ* conservation of wild species in nature reserves: *in situ* conservation components, factors influencing conservation value, national plan for *in situ* conservation; *in situ* conservation of agro-biodiversity on-farm; scientific basis of *in situ* conservation on-farm, building on-farm conservation initiatives, implementation of on-farm conservation, management of *in situ* conserved genetic diversity on-farm, enhancing benefits for farmers from local crop diversity.

Unit II

Ex situ conservation: components, plant genetic resources conservation in gene banks, national gene banks, gene repositories, preservation of genetic materials under natural conditions, perma-frost conservation, guidelines for seed multiplication and exchange to network of active/ working collections, orthodox, recalcitrant seeds- differences in handling, clonal repositories, genetic stability under long term storage condition.

Unit III

In-vitro storage, maintenance of *in-vitro* culture under different conditions, *in-vitro* bank maintenance for temperate and tropical fruit crop species, spices, tubers, bulbous crops, medicinal and endangered plant species, conservation of embryos and ovules, cell/ suspension cultures, protoplast and callus cultures, pollen culture, micropropagation techniques, problems, prospects of *in-vitro* gene bank.

Unit IV

Cryopreservation- procedure for handling seeds of orthodox and recalcitrant-cryo-protectants, desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation/ dehydration techniques, national facilities, achievements, application of cryopreservation in agricultural, horticultural and forestry crops. Problems and prospects; challenges ahead.

Unit V

Concept and procedure for PGR management, germplasm characterization, evaluation and utilization; Concept of core and mini core; collections and registration of plant germplasm.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will be able to know about the various techniques of conservation of Plant Genetic Resources and its Utilization in crop improvement.

IX. Suggested Reading

Ellis RH, Roberts EH and White Head J. 1980. *A New More Economic and Accurate Approach to Monitor the Viability of Accessions During Storage in Seed Banks*. FAO/ IBPGR Pl. Genet. Resources News 41-3-18.

Frankel OH and Hawkes JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press, Cambridge.

Paroda RS and Arora RK.1991. *Plant Genetic resource Conservation and management*, NBPGR, New-Delhi.

Simmonds NW. 1979. *Principles of Crop Improvement,* Longman.

Westwood MN. 1986. *Operation Manual for National Clonal Germplasm Repository*. Processed Report. USDA-ARS and Oregon State Univ. Oregon, USA.

Withers LA. 1980. *Tissue Culture Storage for Genetic Conservation*. IBPGR Tech. Rep. IBPGR, Rome, Italy.

I. Course Title : Genomics in Plant Breeding*

II. Course Code : GPB 605

III. Credit Hours : 3(3+0)

IV. Why this course?

The knowledge of recent trends in plant genomics, genome sequencing, molecular maps, and concepts of high-throughput proteomics, metabolomics and phenomics is essential in rapid crop improvement programmes.

V. Aim of the course

To impart practical skills in advanced molecular techniques in genome mapping structural/ functional genomics.

VI. Theory

Unit I

Introduction to the plant genomes: nuclear, chloroplast and mitochondrial genomes; Concept of genome size and complexity: C-value paradox, repetitive and unique DNA.

Unit II

Genome sequencing: Principles and techniques of conventional approaches and next generation sequencing including sequencing-by-synthesis/ ligation and single molecule real time (SMRT) technologies; Applications of sequence information: structural, functional and comparative genomics; Plant genome projects: Strategies for genome sequencing including shot gun and clone-by-clone method.

Unit III

Molecular maps: Use of molecular markers/ SNPs for development of genetic and physical maps; Linkage and LD-based gene mapping approaches including gene/ QTL mapping, genome wide association studies (GWAS) and association analysis; Integration of genetic and physical map for map-based cloning of economically important genes. Concept of allele mining; Diversity array technology: concepts and applications.

Unit IV

Functional genomics: concept of reverse and forward genetics; Use of activation tagging, transposon tagging, insertional mutagenesis, TILLING and ecoTILLING for crop improvement; Genome-wide and gene-specific transcriptomics approaches: serial analysis of gene expression, massively parallel signature sequencing, next generation sequencing, microarray, northern hybridization, RT-PCR, qRT-PCR and molecular beacon.

Unit V

Development and management of database; Applications of bioinformatics tools/ software in genomics for crop improvement. Basic concepts of high-throughput proteomics, metabolomics and phenomics.

Unit VI

Recent transgene free genome editing tools such as CRISPR-Cas9 system, TALENS and ZFNs for crop improvement. Cisgenesis and Intragenesis tools as twin sisters for Crop Improvement; Genomics-based plant breeding: Genome-Wide Genetic Diversity Studies, Identification of molecular markers linked to single Genes and QTL, Marker Assisted Selection (Marker Assisted Backcross Selection, Association mapping, Breeding by Design, Genome selection).

VII. Teaching methods

- Power point presentation
- Chalk and Board

- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion ofthis course, the student will have expertise on about different techniques for genome sequencing, molecular maps, and concepts of high-throughput proteomics, metabolomics and phenomics in crop improvement

IX. Suggested Reading

Alonso JM, Stepanova AN. 2015. *Plant Functional Genomics: Methods and Protocols*. Springer.

Chopra VL, Sharma RP, Bhat SR and Prasanna BM. 2007. *Search for New Genes*. Academic Foundation, New Delhi.

Hackett PB, Fuchs JA and Messing JW. 1988. *An Introduction to Recombinant DNA Technology—Basic Experiments in Gene and Manipulation*. 2nd Ed. Benjamin Publication Co.

Primose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics*. 7th Ed. Wiley-Blackwell Publishing.

Sambrook J and Russel D. 2001. *Molecular Cloning - a Laboratory Manual*. 3rd Ed. Cold Spring Harbor Laboratory Press.

Singh BD. 2005. *Biotechnology: Expanding Horizons*. Kalyani Publishers, New Delhi.

Somers DJ, Langridge P, Gustafson JP. 2009. *Plant Genomics: Methods and Protocols*. Springer.

e-Resources

http://gramene.org
https://www.arabidopsis.org
https://wheat.pw.usda.gov
http://ncbi.nlm.nih.gov
http://www.maizegenetics.net

I. Course Title : Population Genetics
II. Course Code : GPB 606
III. Credit Hours : 2(2+0)

IV. Why this course?

Population improvement programmes are the basis of genetic enhancement in cross pollinated crops. This course is needed to make the students aware about the population genetics and its role in crop improvement.

V. Aim of the course

To impart knowledge on structure, properties and their breeding values of different population.

VI. Theory

Unit I

Population: Properties of population, Mendelian population; Genetic constitution of a population through time, space, age structure, etc.; Frequencies of genes and genotypes; Causes of change: population size, differences in fertility and viability, migration and mutation.

Unit II

Hardy-Weinberg equilibrium, Hardy-Weinberg law, Proof and applications of the Hardy-Weinberg law, Test of Hardy-Weinberg equilibrium; Mating frequencies:

Non-dominance, Codominance, Snyder's ratio, importance and its effect over random mating in succeeding generations.

Unit III

Multiple alleles, More than one locus, Sex linked genes; Use of gene and genotypic frequencies evaluation in field population level; Interpretations - Changes of gene frequency, Migration, Mutation, Recurrent and non-recurrent Selection; Balance between selection and mutation; Selection favoring heterozygotes; Overdominance for fitness.

Unit IV

Mating systems, Random mating population, Nonrandom mating: selfing –inbreeding coefficient, panmictic index, sibmating, Assortative mating and disassortative mating; Pedigree populations and close inbreeding, Estimation of linkage disequilibrium, Correlation between relatives and estimation of F; Effect of inbreeding and sibbing in cross pollinated crops; Gene substitution and average effects; Breeding value- Genetic drift; Genetic slippage, Co-adapted gene complexes; Homoeostasis- Adaptive organization of gene pools; Polymorphism- Balanced and Non-balanced polymorphism, heterozygous advantage- Survival of recessive and deleterious alleles in populations.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will be well versed with population genetics, its components and applications in crop improvement.

IX. Suggested Reading

Chawla V and Yadava RK. 2006. *Principles of Population Genetics – A Practical Manual*. Dept. of Genetics, CCS HAU Hisar.
Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics*. Longman.
Jain JP, Jain J and Parbhakaran VT. 1992. *Genetics of Populations*. South Asia Books.
Li CC. 1955. *Population Genetics*. The Univ. of Chicago Press.
Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.
Sorrens D and Doniel G. 2007. *Methods in Quantitative Genetics*. Series: *Statistics for Biology and Health*. Likelihood.
Tomar SS. 1992. *Text Book of Population Genetics*. Universal Publication.

I. Course Title : Crop Evolution
II. Course Code : GPB 607
III. Credit Hours : 3(3+0)

IV. Why this course?

This course imparts knowledge about the origin and evolution of species, centres of diversity, speciation, domestication and significance of polyploidy.

V. Aim of the course

To impart knowledge on crop evolutionary aspects and role of mutations, hybridizations and polyploidy in crop evolution and improvement.

VI. Theory

Unit I

Origin and evolution of species; Centres of diversity/ origin, diffused centres; Time and place of domestication; Patterns of evolution and domestication-examples and Case studies; Domestication and uniformity – Characteristics of early domestication and changes – Concept of gene pools and crop evolution; Selection and Genetic drift – Consequences.

Unit II

Speciation and domestication–The process of speciation, Reproductive isolation barriers; Genetic differentiation during speciation; Hybridization - speciation and extinction; Exploitation of natural variation: Early attempts to increase variation, Distant hybridization and introgression, Inter-specific, inter-generic hybridization, scope and limitations, techniques to overcome the limitations; Gene transfer into cultivated species, tools and techniques; Validation of transferred genes and their expression; Controlled introgressions.

Unit III

Processes in crop evolution and stabilization of polyploids, cytogenetic and genetic stabilization; Genome organization – Transgenesis in crop evolution, Multifactorial genome, Intragenomic interaction, Intergenomic interaction, Genome introgression; Methods to study crop evolution - Contemporary Methods, Based on morphological features, Cytogenetic analysis, Allozyme variations and crop evolution, DNA markers, genome analysis and comparative genomics.

Unit IV

Evolutionary significance of polyploidy, evolution of crop plants through ploidy manipulations; Polyploids: methods, use of autopolyploids; haploidy and DH-method of production and use, allopolyploids; synthesis of new crops; Case studies – Cereals, Pulses, Oilseeds, vegetables, Fibre crops, Plantation crops, Forage crops, Tuber crops, Medicinal Plants.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will have knowledge of Origin and evolution of species, Centres of diversity, Speciation, domestication and significance of micro-mutations and polyploidy in genetic improvement of crop plants.

IX. Suggested Reading

Hancock JF. 2004. *Plant Evolution and the Origin of Crop Species*. 2nd Ed. CABI.
Ladizinsky G. 1999. *Evolution and Domestication*. Springer.

Miller AJ. 2007. *Crop Plants: Evolution*. John Wiley & Sons.
Smartt J and Simmonds NW. 1995. *Evolution of Crop Plants*. Blackwell.

I. Course Title : Breeding Designer Crops
II. Course Code : GPB 608
III. Credit Hours : 2(1+1)

IV. Why this course?

This course enlightens about developing varieties for special traits, physiological efficiency and nutritional enhancement. It gives concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products.

V. Aim of the course

Breeding crops for higher physiological efficiency and nutritional enhancement.

VI. Theory

Unit I

Breeding of crop ideotypes; Genetic manipulations through recombination breeding, genomics and transgenics for physiological efficiency, nutritional enhancement, special compounds-proteins, vaccines, gums, starch and fats.

Unit II

Physiological efficiency as a concept, parametric and whole plant physiology in integrated mode; Physiological mechanism of improvement in nutrient use efficiency, water use efficiency, osmotic adjustment, photosynthetic efficiency, stay green trait and its significance in crop improvement; Breeding for special traits, viz., oil, protein, vitamins, amino acids, etc.; Ecospecific ideotypes, Ideotypes for high and low moisture conditions, low and high input conditions, conversion mechanism of C_3 to C_4 plants; Determination of genetics of above mentioned traits.

Unit III

Improvement in yield potential under sub-optimal conditions by manipulating source and sink, canopy architecture, plant-water relationships, effect of suboptimal conditions on cardinal plant growth and development processes, enhancing input use efficiency through genetic manipulations.

Unit IV

Concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products; Success stories in vaccines, modified sugars, gums and starch through biopharming.

Unit V

Biosafety management, segregation and isolation requirements in designer crop production and post-harvest management.

VII. Practical

- Demonstration of plant responses to stresses through recent techniques;
- Water use efficiency, transpiration efficiency, screening techniques under stress conditions such as electrolyte leakage, TTC, chlorophyll fluorescence, canopy temperature depression, stomatal conductance, chlorophyll estimation, heat/ drought/ salt shock proteins.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome:

Pass outs will have clear understanding of ideotypes of crops under varied agro-climatic situations and breed for physiological efficient genotype. Can develop varieties for special traits having high therapeutic and nutracetrical value.

X. Suggested Reading

Balint A. 1984. *Physiological Genetics of Agricultural Crops*. AK Ademiaikiado.
Hay RK. 2006. *Physiology of Crop Yield*. 2nd Ed. Blackwell.
Pessarakli M. 1995. *Handbook of Plant and Crop Physiology*. Marcel Dekker.
Taiz L and Zeiger E. 2006. *Plant Physiology*. 4th Ed. Sinauer Associates.

I. Course Title : IPR and Regulatory Mechanism (e-course)*
II. Course Code : GPB 609
III. Credit Hours : 1(1+0)

IV. Why this course?

Biodiversity conservation and its judicious utilization are important in sustainable plant breeding programs. Breeders' and farmers' rights are important in scenario of globalization of agriculture so knowledge of IPRs is essential for a plant breeder to protect his varieties.

V. Aim of the course

The main objective of this course is to equip students and stakeholders with knowledge of intellectual property rights (IPR), related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

VI. Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement

VII. Teaching methods

- Power point presentation
- Smart board

- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

The students will have acquaintance of intellectual property rights, national and international laws on biodiversity and sustainable use of plant genetic resources through transfer and sharing. Can assist in follow up of various treatises and laws for research collaborations at international levels.

IX. Suggested Reading

Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.

Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.

Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.

Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. *Technology Generation and IPR Issues*. Academic Foundation.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Sciences
– Seed Science and Technology

Preamble

(Seed Science and Technology)

The proposed curriculum of Seed Science and Technology discipline is designed with the view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. In the present state, students aspire for overseas admissions for education and employment, or even in India they seek placements in seed corporations and multinational seed companies. In order to facilitate easier transitions for post-graduate degree courses and job prospects overseas, there is a need to upgrade the post-graduate syllabus to international standards. Therefore, the present syllabus needs revision so as to prepare the students to cope with current professional scenario with relevance to practical needs and skill requirements. The BSMA (Plant Sciences) committee examined the existing syllabus of Seed Science and Technology and analysed carefully in terms of content, relevance, quality and pattern and then synthesized the present proposed syllabus.

By intensive discussion with the core faculty, experts and based on the feedback from seed industry professionals, the entire syllabus was restructured with the improvement in existing courses as well as addition of new courses. The syllabus was suitably finalized with the view to equip the students to gain knowledge and skills sets and to prepare themselves for global competiveness to meet out their goals.

Seed quality is vital for sustainable crop production and food security. Seed enhancement includes physical, physiological and biological treatments to overcome germination constraints, to maintain uniform plant stands, earlier crop development and better yields. Seed enhancement techniques are designed in such a way to reduce emergence time of seed by earlier start of metabolic activities and resource mobilization for better emergence and seedling vigour. The knowledge of molecular pathways elucidating mode of action of priming agents, reduced longevity of primed seeds, efficiency of physical and biological agents for seed treatments and market availability of high-quality seeds are some of the challenges for scientists and seed industry.

Seed dormancy allows seeds to overcome periods that are unfavourable for seedling establishment and significant role in adaptation and evolution of seed plants, and therefore it is important for plant ecology and agriculture. Seed ecology is the study of ecological strategies by which plants ensure their reproduction by seed. Understanding the dynamics of seed bank, environmental conditions that impose dormancy and induce germination, and factors that influence successful seedling establishment is utmost important. The knowledge on seed dormancy and seed ecology will enhance the effectiveness in planning for control of weeds, successful propagation of native economically important trees, shrubs, vines and grasses, and also reclamation of damaged agro-ecosystems.

Organic seed system when viewed as an alternative to the dominant seed system helps to address the bigger problems in agriculture. Expanding organic seed systems can also increase economic opportunities for farmers who successfully produce organic seed in their farm. Knowledge on the practices of organic seed production, certification and distribution will focus our production system towards the present day needs for quality life.

Seed provides the genetic tools to confront these day-to-day challenges in the field, and breeding plants in the environment of their intended use. Seed Science and Technology therefore represents profound potential for improving our food and agricultural production systems. Hence, the holistic and comprehensive knowledge on these areas of Seed Science and Technology should be taught to the students to make them more efficient in scientific research and also to contribute in building vibrant seed industry. Considering the importance and present requirement in the field of seed science, the proposed syllabus is formulated in such a way that it will enhance the knowledge and skill sets of students.

The existing courses, viz., Seed dormancy and germination, Seed quality testing and enhancement, Seed technology of tree species, Seed industry and marketing management and Seed planning trade and marketing have been completely revised and upgraded. Some new courses, viz., Organic seed production, Physiology and biochemistry of seeds, Seed vigour and crop productivity, Advances in seed quality enhancement and Seed ecology have also been included in the proposed syllabus for post-graduate degree programmes.

Course Title with Credit load
M.Sc. (Ag) in Seed Science and Technology (SST)

Course Code	Course Title	Credit Hours
SST 501*	Seed Developmental Biology	2 (1+1)
SST 502	Seed Dormancy and Germination	2 (1+1)
SST 503*	Seed Production Principles and Techniques in Field Crops	3 (2+1)
SST 504*	Seed Production Principles and Techniques in Vegetable Crops	3 (2+1)
SST 505	Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops	3 (2+1)
SST 506	Seed Production Techniques in Forage, Pasture and Green Manure Crops	2 (1+1)
SST 507*	Seed Legislation and Certification	3 (2+1)
SST 508*	Post Harvest Handling and Storage of Seeds	3 (2+1)
SST 509*	Seed Quality Testing and Enhancement	2 (1+1)
SST 510	Seed Technology of Tree Species	2 (1+1)
SST 511	Seed Industry and Marketing Management	2 (1+1)
SST 512	Seed Health Testing and Management	2 (1+1)
	Major Courses (minimum 20 credits from above courses including *marked Courses)	20
	Minor Courses	08
	Supporting Courses	06
	Common Courses	05
SST 591	Seminar	01
SST 599	Research	30
	Total Credits	**70**

*Compulsory Major Courses

Course Contents
M.Sc. (Ag) in Seed Science and Technology (SST)

I. Course Title : Seed Developmental Biology*

II. Course Code : SST 501

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is the most complex and successful unit of reproduction in flowering plants. Seed contains genetic wisdom of the past and act as an agent of genetic transfer from generation to generation. Basic knowledge on seed developmental biology will enable the learners to understand the structure of seed to take up research in seed science and technology.

V. Aim of the course

To acquire knowledge on development and maturation of essential structures of seed and their influence on seed quality.

VI. Theory

Unit I

Floral biology – types of pollination, mechanisms; sporogenesis – micro and mega sporogenesis; gametogenesis – development of male and female gametes and their structures; pollination and fertilization – mode of pollination, double fertilization, factors affecting pollination, fertilization; self-incompatibility and male sterility.

Unit II

Embryogenesis – development of monocot and dicot embryos – embryo plane formation – development of endosperm, cotyledons and seed coat – hard seed; apomixis – identification, classification, significance and its utilization; poly-embryony – types and significance; haplontic and diplontic sterility system, causes of embryo abortion, embryo rescue technique; somatic embryogenesis.

Unit III

Seed development – source of assimilates – mechanism of translocation; chemical composition – synthesis and deposition of storage reserves – starch, protein, fat and secondary metabolites – hormonal regulation.

Unit IV

Maturation drying – orthodox and recalcitrant seeds – desiccation tolerance – mechanism – structural changes during desiccation – role of LEA protein.

Unit V

Seed maturity indices – physiological and harvestable maturity; biotic and abiotic factors influencing seed development – development of hard seeds.

VII. Practical

- Study on floral biology of monocot;
- Study on floral biology of dicot plants;

- Study on pollen morphology of different crops;
- Pollen germination and viability test in major crops;
- Seed embryo and endosperm development in monocots;
- Seed embryo and cotyledon development in dicots;
- Anatomy and morphology of seed coat during development;
- Hard seed coat development;
- Study on external and internal structures;
- Seed development and maturation in agricultural crops – physical and physiological changes;
- Seed development and maturation in horticultural crops – physical and physiological changes;
- Study of biochemical changes during seed development and maturation in agricultural crops;
- Study of biochemical changes during seed development and maturation in horticultural crops;
- Study on physiological and harvestable maturity and maturity indices in different crops;
- Study on acquisition of seed dormancy and germination at different stages of maturity;
- Preparation of seed album and identification of seeds.

VIII. Teaching methods

- Classroom lectures
- Slide shows
- Student assignments and presentation
- Group tasks
- Field and laboratory experiments
- Field visits

IX. Learning outcome

Successful completion of this course enable student to take up advanced research on seed developmental biology and understanding on fundamental aspects of gametogenesis, seed development and maturity.

X. Suggested Reading

Adkins SW, Ashmore SE and Navi SC. 2007. *Seeds: Biology, Development and Ecology*. CAB International, Oxfordshire, UK.

Bewley JD and Black M. 1994. *Seeds: Physiology of Development and Germination*. Springer, New York.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development, Germination and Dormancy*. Springer, New York.

Black M, Bewley JD and Halmer P. 2006. *The Encyclopedia of Seeds: Science, Technology and Uses*. CAB International publications, UK.

Chhabra AK. 2006. *Practical Manual of Floral Biology of Crop Plants*. Department of Plant Breeding, CCSHAU, Hisar.

Copeland, LO and McDonald MB. 2001. *Principles of Seed Science and Technology*. 4th Ed. Kluwer Academic publishers, USA.

Frankel R and Galun E. 1977. *Pollination Mechanisms, Reproduction and Plant Breeding*. Springer Verlag, New York.

Hesse MH, Haidemarie R, Zettler M, Webber R, Buchner AR, Radivo and Ulrich S. 2009. *Pollen Terminology. An illustrated hand book*. Springer Verlag, New York.

Kozlowski. TT. 2012. *Seed Biology: Importance, Development and Germination*. (Vol. I). Academic Press Inc., New York.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.

XI. Suggested e-books

https://www.springer.com/in/book/9783642810619
https://www.springer.com/in/book/9780792373223
https://www.springer.com/gp/book/9780792346456
https://www.cabi.org/bookshop/book/9780851997230
https://www.worldcat.org/title/seed-development-and-germination/oclc/44954614
https://books.google.co.in/books/about/Seeds.html?id=-Zbzr1F_z74C&redir_esc
https://books.google.co.in/books/about/Seeds.html?id=6S75BwAAQBAJ& printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false

XII. Suggested websites

https://agriinfo.in/botany/18/
http://www.seedbiology.de/structure.asp
http://www.fao.org/3/ad232e/AD232E02.htm
sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/
https://courses.lumenlearning.com/wm-biology2/chapter/development-seeds-fruit
www.iari.res.in/index.php?option=com_content&view=article&id=449& Itemid=137

I. Course Title : Seed Dormancy and Germination
II. Course Code : SST 502
III. Credit Hours : 2 (1+1)

IV. Why this course?

Physiology and bio chemistry of dormancy and germination is basic science in the field of Seed Science and Technology. Complete understanding on the mechanisms of acquisition and release of dormancy and germination enable the students to take up research on advanced aspect which may helpful to design the seed for our requirement.

V. Aim of the course

To impart knowledge on significance, mechanism of dormancy, induction and release of seed dormancy and germination, types and factors influencing germination and their management.

VI. Theory

Unit I

Seed dormancy – definition, concept and theories – significance – evolution; classification and mechanism of dormancy – ecological singnificance.

Unit II

Induction of dormancy during development – hormonal, physiological, molecular and genetic control of dormancy – maternal and paternal contribution; environmental factors influencing dormancy induction and release – seasonal influence – winter and summer annuals – secondary dormancy induction mechanism; artificial induction of dormancy and release; soil seed bank – natural release of dormancy and its mechanism; dormancy breaking – principles and methods.

Unit III

Seed germination – types and phases of germination; imbibition – pattern and water kinetics – events of germination – physical, physiological, biochemical changes -aerobic and anaerobic respiration quiescent.

Unit IV – Physiological and biochemical changes

Enzyme activation – mechanism – factors affecting enzyme activation – breakdown of stored materials – starch, protein and fat – energy generation – mobilization of storage reserves – changes in phenolic compounds.

Unit V – Molecular and genetic mechanisms

Molecular and genetic control of seed germination – auto tropism; factors affecting germination – media – temperature – light – gases; *in-situ* and viviparous germination – causes and mechanism – pattern of seed germination – tri-phasic curve.

VII. Practical

- Seed dormancy – identification of dormancy;
- Estimation of ABA and GA in dormant and non-dormant seeds;
- Study on artificial induction of dormancy;
- Dormancy breaking methods – scarification and stratification;
- Dormancy breaking methods – hormonal and chemical treatments;
- Dormancy breaking methods – after ripening and leaching of inhibitors;
- Dormancy breaking methods – combined treatments;
- Assessing the period of natural release of seed dormancy;
- Seed germination – studying the pattern of imbibition;
- Studying the pattern of seed germination in different media;
- Study on influence of light and temperature on germination and seedling development;
- Estimation of hydrolytic enzyme – α amylase in different species;
- Estimation of hydrolytic enzyme – protease;
- Estimation of hydrolytic enzyme – lipase;
- Estimation of dehydrogenase enzyme and respiratory quotient in seeds;
- Estimation of food reserve composition during seed germination.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignments
- Laboratory experiments
- Group exercises on biochemical estimations

IX. Learning outcome

By learning this course, students will understand the fundamental theories and mechanism underlying in seed dormancy and germination which will be useful for both basic research and development.

X. Suggested Reading

Baskin C and Baskin JM. 2014. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, Cambridge, UK.

Bewley J and Black M. 1994. *Physiology of Development and Germination*. Springer, New York.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development, Germination and Dormancy*. Springer, New York.

Bewley JD and Black M. 1982. *Physiology and Biochemistry of Seeds in Relation to Germination.* Volume 2: Viability, Dormancy and Environmental Control.Springerlink, New York, USA

Benech-Arnold R and Rodolfo S. 2004. *Handbook of Seed Physiology: Applications to agriculture*. CRC Press., Florida, USA.

Black M and Bewley JD. 2000. *Seed Technology and its Biological Basis*. CRC Press. Florida, USA.

Bradbeer JW. 1988. *Seed Dormancy and Germination*. Chapman and Hall, New York, USA.

David R. Murray. 1985. *Seed Physiology*. Volume 2: Germination and Reserve Mobilisation. Academic Press, London, UK.

Heydecker W. 1985. *Seed Ecology*. Pennsylvania State University Press, USA.

Khan AA. 1977. *The Physiology and Biochemistry of Seed Dormancy and Germination*. North – Holland Publishing Company, USA.

Kozlowski TT. 2012. *Seed Biology: Importance, Development and Germination*. (Vol. I). Academic Press Inc., New York.

Maiti RK, Sarkar NC and Singh VP. 2012. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.

Mayer AM and Mayber AP. 1963. *Germination of Seeds*. Pergamon Press, Oxford, New York.

Prakash M. 2011. *Seed Physiology of Crops*. Satish Serial Publishing house. Azadpur. New Delhi.

Roberts EH. 1972. *Viability of seeds*. Springerlink, New York, USA.

XI. Suggested e-books

https://www.springer.com/in/book/9780792373223

https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1756-1051.2000.tb01610.x

https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6

https://books.google.co.in/books/about/Physiology_and_Biochemistry_of_ Seeds_in.html?id=91nsCAAAQBAJ&printsec=frontcover&source=kp_read_ button&redir_esc=y#v=onepage&q&f=false

https://books.google.co.in/books/about/The_Germination_of_Seeds.html? id=aV62AgAAQBAJ&printsec=frontcover&source=kp_ read_button&redir_ esc=y#v=onepage&q&f=false

https://books.google.co.in/books/about/Seed_Dormancy_and_Germination. html?id=18HeBwAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false

XII. Suggested websites

https://agriinfo.in/botany/18/

https:/sproutnet.com/seed-dormancy/

https://www.britannica.com/science/germination

http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html

https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy

I. Course Title : Seed Production Principles and Techniques in Field Crops*

II. Course Code : SST 503

III. Credit Hours : 3 (2+1)

IV. Why this course?

Awareness about the use of quality seed among farmers enhances the seed demand and seed trade. To meet the seed demand, production should be carried out in large areas. Hence, it is essential to learn about the production principles and techniques of quality seed production.

V. Aim of the course

To impart knowledge on principles and practices involved in quality seed production of field crops.

VI. Theory

Unit I

Importance of seed – seed quality concept – factors influencing seed production; generation system of seed multiplication – classes of seed, stages of seed multiplication in varieties and hybrids – seed multiplication ratio (SMR) – seed replacement rate (SRR) – seed renewal period (SRP) – varietal replacement rate (VRR).

Unit II

Genetic and agronomic principles of variety and hybrid seed production; methods and techniques of seed production in varieties and hybrids of important cereals and millets – wheat, oat, rice, maize, sorghum and pearl millet; varietal seed production in small millets – finger millet, fox tail millet, little millet, kodo millet, proso millet and barnyard millet.

Unit III

Methods and techniques of varietal seed production in major pulses – black gram, green gram, cowpea, chickpea, horse gram, soybean and lentil – varietal and hybrid seed production in red gram.

Unit IV

Methods and techniques of seed production in major oil seed crops – groundnut, sesame – varietal and hybrid seed production in sunflower, castor and mustard; varietal seed production in minor oilseed crops (safflower, linseed, niger) – varietal and hybrid seed production in cotton – varietal seed production in jute.

Unit V

Seed production planning for varieties and hybrids of major crops; participatory seed production – seed hubs, seed village concept and community seed bank.

VII. Practical

- Seed selection – quality of seed on field establishment;
- Sowing and nursery management techniques;
- Planting – age of seedling on crop establishment – rice and pearl millet;
- Isolation distance and border rows in hybrid seed production field – space and barrier isolation; modifying isolation based on border rows in maize;
- Planting design for hybrid seed production – rice, maize, pearl millet, cotton, red gram, sunflower;
- Practicing breeding tools for hybrid seed production – detasseling – emasculation and dusting;
- Study on methods of achieving synchronization – rice, bajra, sunflower;
- Practicing supplementary pollination – rice and sunflower;
- Study on foliar nutrition and influence on seed yield;
- Practicing roguing operation – identification of off-types, pollen shedders, shedding tassels, partials, selfed bolls;
- Pre and post harvest sanitation operations – cereals, millets and pulses;
- Estimation of shattering and shattering loss; study on insitu germination and loss;
- Visit to seed production fields;
- Visit to seed industry;
- Seed production planning and economics of seed production – varieties;
- Seed production planning and economics of seed production – hybrids.

VIII. Teaching methods

- Classroom lectures
- Power point presentation
- Student assignment presentation and group tasks
- Field and laboratory experiments
- Field visits

IX. Learning outcome

Successful completion of this course enable student to take up seed production venture in scientific manner to ensure seed quality and profitability.

X. Suggested Reading

Agrawal RL. 2019. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
Hebblethwaite PD. 1980. *Seed Production*. Butterworth Heinemann Ltd., London, UK.
Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi.
Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.
Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.
McDonald MB and Copeland L. 1998. *Seed Production Principles and Practices*. CBS Publishers, New Delhi.
Mondal SS, Saha M and Sengupta K. 2009. *Seed Production of Field Crops*. New India Publishing Agency, New Delhi.
Singhal NC. 2003. *Hybrid Seed Production in Field Crops*. Kalyani Publications, New Delhi.Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.
Singhal NC. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

XI. Suggested e-books

https://www.springer.com/in/book/9780792373223
https://www.springer.com/in/book/9780412075513
https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops
https://www.amazon.in/Production-Field-Crops-Brajesh-Tiwari/dp/9380179405
https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/seed-production-of-agricultural-crops-by-kelly-a-f-227-pages-harlow-longman-1988-price-2500-hard-covers-isbn-0-582-40410-x/8BE3C99DFDC0F02D48E CB53418504D10

XII. Suggested websites

https://agriinfo.in/botany/18/
http://www.fao.org/3/a-e8935e.pdf
http://www.agriquest.info/seed_production.php
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html
http://coin.fao.org/coinstatic/cms/media/16/13666518481740/seed_enterprises_enhacement_and_development_project_in_sierra_leone_mission_1_report_.pdf

I. Course Title : Seed Production: Principles and Techniques in Vegetable Crops*

II. Course Code : SST 504

III. Credit Hours : 3 (2+1)

IV. Why this course?

Seed trade is mainly based on high value low volume seeds. Area under vegetable cultivation is increasing day by day, which demands high area under seed production. The thorough knowledge on vegetable seed production will enable the students to take up seed production venture in low volume high value crops.

V. Aim of the course

To impart knowledge on principles and practices involved in quality seed production of vegetable crops.

VI. Theory

Unit I

Importance and present status of vegetable seed industry – factors influencing vegetable seed production; varietal and hybrid seed production techniques in major solanaceous vegetable crops – tomato, brinjal, chilli; malvaceous vegetable crop – seed production techniques of bhendi.

Unit II

Varietal and hybrid seed production techniques in important cucurbitaceous vegetables – gourds and melons, cole crops – cauliflower, cabbage, knol-khol, root vegetables – carrot, beetroot, turnip, radish and other temperate/ hilly vegetable crops.

Unit III

Varietal seed production techniques in major leguminous vegetables – peas and beans; seed production techniques in leafy vegetables – amaranthus, palak, spinach, and lettuce.

Unit IV

Seed production techniques in tuber crops – potato, sweet potato, colocasia, tapioca and yam, seed-plot technique in potato – true potato seed (TPS) production techniques – seed production techniques in bulb crops – onion, garlic.

Unit V

Vegetative and clonal multiplication – methods, merits and demerits; clonal multiplication – potato, sweet potato, colocasia, tapioca and yam.

VII. Practical

- Identification of vegetable seeds;
- Study on sowing and nursery management;
- Study on transplanting and age of seedling on crop establishment;
- Studying floral biology of solanceous, malvaceous and cucurbitaceous vegetable crops;
- Studying floral biology of other vegetable crops;
- Practicing planting design for hybrid seed production;
- Modification of sex ratio in cucurbits;
- Practicing emasculation and pollination methods;
- Practicing roguing operations – identification of off-types – selfed fruits;
- Harvesting methods – single and multiple harvesting method;
- Practicing seed extraction methods – wet methods – tomato, brinjal, other cucurbitaceous fruits;
- Seed extraction – dry methods – chillies, bhendi, cucurbitaceous;
- Visit to seed production fields;
- Visit to private seed industry;
- Planning and economics of varietal seed production;
- Planning and economics of hybrid seed production.

VIII. Teaching methods

- Classroom lectures with power point
- Student assignment and presentations
- Field and laboratory experiments
- Demonstration
- Hands on training
- group tasks
- Field and industry visits

IX. Learning outcome

Successful completion of this course enable student to gain confidence and to become seed entrepreneur in high value low volume vegetable crops.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
Chadha KL. 1995. *Advances in Horticulture*. Volume 1 to 13. Malhothra Publishing House, New Delhi.
George RAT. 1985. *Vegetable Seed Production*. Lonhman Inc., New York.
Hebblethwaite PD. 1980. *Seed Production*. Butterworth Heinemann Ltd, London, UK.
Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.
Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.
McDonald MB and Copeland L. 1998. *Seed Production: Principles and Practices*. CBS Publishers, New Delhi.
Sen S and Ghosh N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
Singhal NC. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.
Vanangamudi K, Natarajan N, Srimathi P, Natarajan K, Saravanan T, Bhaskaran M, Bharathi A, Natesan P and Malarkodi K. 2006. *Advances in Seed Science and Technology*. Vol. 2. *Quality Seed Production in Vegetables*. Agro bios, Jodhpur.

XI. Suggested e-books

https://www.springer.com/in/book/9780792373223
http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf
http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf
https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&-=1541066209 257&versionId=45008917+251246346

XII. Suggested websites

https://agriinfo.in/botany/18/
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html
http://www.yspuniversity.ac.in/vgc/caft/Compendium2017-18.pdf
https://www.hort.vt.edu/Welbaum/seedproduction/Principles5.html
http://www.agrimoon.com/wp-content/uploads/Seed-Production-of-Vegetable.pdf
http://www.ciks.org/downloads/seeds/4.%20Seed%20Production%20Techniques %20for%20Vegetables.pdf

I. Course Title : Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops
II. Course Code : SST 505
III. Credit Hours : 3 (2+1)

IV. Why this course?

At present seed industry is expanding towards the low volume and high value seeds. Domestication of fruit, plantation and medicinal plants enable the farmers to cultivate commercially. The seed demands in these crops are increasing day by day. Hence, it is essential to learn the techniques of seed production in fruits, flowers and plantation crops.

V. Aim of the course

To impart comprehensive knowledge on seed production techniques in fruits, flowers, spices, plantation and medicinal crops.

VI. Theory

Unit I

Scope for seed production in fruits, flowers, spices, plantation and medicinal crops; factors influencing seed production and quality; propagation methods – seed and clonal propagation; seed and seedling standards; propagation and seed production techniques in major tropical, sub-tropical and temperate fruit crops; seed orchards – seed collection, extraction processing and storage techniques.

Unit II

Seed production techniques in commercially important flower crops – nursery management, clonal propagation, planting, seed crop management, post-harvest seed handling and storage techniques.

Unit III

Seed production techniques in commercially important seed spices and other spices – nursery management, sowing, seed crop management and post-harvest seed handling and storage techniques.

Unit IV

Seed production in commercially important plantation crops – mother tree selection – criteria – nursery management, elite seedling production, planting, plantation management, post-harvest handling and storage techniques.

Unit V

Methods of quality seed production in commercially important medicinal plants – nursery management, sowing, seed crop management, post-harvest handling and storage methods.

VII. Practical

- Study on the floral biology and pollination mechanism;
- Identification of seeds of fruits, flowers, spices, plantation and medicinal crops;
- Selection of mother plants and trees – phenotypic characters and genotypic characters;
- Study on different types of clonal and vegetative propagules;
- Seed and clonal standards of vegetatively propagating crops;
- Germination improvement treatments for seeds and vegetative propagules;
- Study on selection of planting materials and sowing methods;
- Nursery management practices for elite seedling production;
- Seed extraction methods – wet method and dry method;
- Post harvest seed handling – seed grading, upgrading techniques
- Study of seed storage techniques;
- Practicing seed germination enhancement techniques in fruits, spices and plantation crops;

- Practicing seed germination enhancement techniques in flowers and medicinal crops;
- Planning for seed production – economics of seed production in flower crops;
- Visit to mother tree orchard;
- Visit to plantation and orchard.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Group exercise
- Field visit

IX. Learning outcome

Successful completion of this course enables the students to take up elite seed and seedling production on commercial scale.

X. Suggested Reading

Chadha KL. 1995. *Advances in Horticulture*. (Volume 1 to 13). Malhotra Publishing House, New Delhi.

Hartman HT and Kester DE. 2000. *Plant Propagation: Principles and Practices*. Prentice Hall, New Jersey, USA.

Singh SP. 2001. *Seed Production of Commercial Vegetables*. Agrotech, New Delhi.

Vanangamudi K and Natarajan K. 2008. *Advances in Seed Science and Technology. Quality Seed Production in Spices, Plantation, Medicinal and Aromatic crops* (Vol. 5). Agrobios. Jodhpur.

Vanangamudi KM Prabu and Lakshmi S. 2012. *Advances in Seed Science and Technology Vol. 7. Flower Seed Production*. Agrobios, Jodhpur.

XI. Suggested e-books

http://www.worldseed.org/wpcontent/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233836/

https://www.academia.edu/35629702/Hybrid_Seed_Production_and_Flowers

http://www.agrimoon.com/horticulture-icar-ecourse-pdf-books/

https://cbp.icar.gov.in/EBook.aspx

XII. Suggested websites

www.cimap.res.in/english/index.php

www.dmapr.org.in/amprs.kau.in/basic-page/publications

http://ecoursesonline.iasri.res.in/course/view.php?id=153

http://ecoursesonline.iasri.res.in/course/view.php?id=612

http://www.celkau.in/Crops/Plantation%20Crops/Rubber/production.aspx

http://sbc.ucdavis.edu/Courses/Seed_Production/

I. Course Title : Seed Production Techniques in Forage, Pasture and Green Manure Crops

II. Course Code : SST 506

III. Credits Hours : 2 (1+1)

IV. Why this course?

Agriculture and animal husbandry in India is interwoven and livestock is the source of income when crop failed. To feed the livestock population, cultivation and seed production of fodder and forage crops are much important. Likewise green manure crops maintain soil health, which created heavy demand for quality seed.

Hence, study of seed production techniques in these crops will help to produce quality seeds to meet the growing needs.

V. Aim of the course

To impart knowledge on basic principles and methods of quality seed production in forage and green manure crops.

VI. Theory

Unit I

Scope and importance of seed production in forage, pasture and green manure crops – factors influencing seed production – seasonal influence; problems and constraints in seed production – seed set, shattering and seed dormancy; vegetative and clonal propagules and apomictic seed.

Unit II

Quality seed production techniques in major fodder crops – lucerne, hedge lucerne, leucaena, fodder sorghum, fodder maize and oats.

Unit III

Seed and planting material production techniques of major forage grasses – bajra -napier grass, guinea grass, deenanath grass and *Cenchrus* sp.; forage legumes *Stylosanthus*, cowpea and berseem.

Unit IV

Seed production techniques in major green manure crops – *Glyricidia*, *Sesbania* sp., sunnhemp, daincha, jute and *Tephrosia* sp.

Unit V

Post-harvest seed handling – processing, threshing, grading and upgrading; dormancy breaking and germination improvement – quality standards for seed and vegetative propagules.

VII. Practical

- Seed collection and identification of seeds;
- Estimation of seed setting and shattering loss;
- Maturity indices – determination of physiological and harvestable maturity;
- Seed extraction and threshing methods;
- Separation of ill filled seeds – practicing different methods;
- Study of seed and clonal materials – standards;
- Quality of planting material and vegetative propagules on crop establishment;
- Seed quality analysis in forage and fodder crops – tiller wise quality analysis;
- Seed quality analysis in determinate and indeterminate crops;
- Study on effect of ratooning on seed quality;
- Practicing seed quality enhancement techniques;
- Practicing different seed extraction and dormancy breaking treatments;
- Preparation of vegetative propagules and planting;
- Planning for seed production in fodder and green manure crops;
- Economics of seed production in fodder, forage crops and green manure crops;
- Visit to forage and fodder seed production farms.

VIII. Teaching Methods

- Classroom teaching
- Power point presentations
- Students assignment and presentation
- Field and laboratory experiments
- Hands on training
- Demonstration
- Field visit

IX. Learning outcome

After completion of course the students gain confidence to start a seed venture on forage and green manure crops.

X. Suggested Reading

FAO. 2007. *Quality Declared Seed System*. FAO Plant Production and Protection Publication, FAO, Rome.

Farity DT and Hampton JC. 1997. *Forage Seed Production*. Vol. I. *Temperate Species*. CAB International Publications. UK.

Froma J. 1997. *Temperate Forage Legumes*. CAB International Publications. UK.

Gutterridge RG. 1997. *Forage Tree Legumes in Tropical Agriculture*. CAB International Publications, UK.

Masilamani S and Sivasubramanian K. 2016. *Seed Production in Green Manures*. Kalyani Publications, New Delhi.

XI. Suggested e-books

https://www.cabi.org/bookshop/book/9780851992143
https://cgspace.cgiar.org/handle/10568/49375
http://www.fao.org/docrep/009/a0503e/a0503e00.htm
http://www.igfri.res.in/pdf/old_bulletins/tropical_pasture.pdf
https://cgspace.cgiar.org/bitstream/handle/10568/4479/Seed.pdf?sequence= 1&isAllowed=y

XII. Suggested websites

www.igfri.res.in/
https://cgspace.cgiar.org/handle/10568/4479
https://www.euroseeds.eu/grasses-and-clovers
https://www.sare.org/learning-center/green-manures
www.ndri.res.in/ndri/Design/forageres_mag_cen.html
http://orgprints.org/30588/1/Sort%20Out%20Your%20Soil.pdf

I. Course Title : Seed Legislation and Certification*
II. Course Code : SST 507
III. Credit Hours : 3 (2+1)

IV. Why this course?

Awareness on usage of quality seeds among farmers increases the seed demand. To regulate the seed quality and to avoid the spurious seeds in the market, seed legislation and certification procedures should be known by all the stake holders. This course will provide comprehensive knowledge on seed policies, seed law enforcement and seed certification procedures to the learners.

V. Aim of the course

To impart knowledge on seed legislation in relation to seed certification and quality control systems.

VI. Theory

Unit I

Genesis of seed Industry in India; seed quality control – concept and objectives; regulatory mechanisms – Seed Act (1966) – Seed Rules (1968) – statutory bodies – Central Seed Committee – Central Seed Certification Board.

Unit II

Seed Control Order (1983) – New Policy on Seed Development (1988) – Exim Policy – National Seed Policy (2002) – Plant Quarantine Act.

Unit III

Introduction to WTO and IPR – UPOV and its role – OECD seed certification schemes – PPV & FR Act (2001) and Rules (2003) – Seed Bill (2004 and 2011): Seed certification system in SAARC countries, Europe, Canada, Australia and USA.

Unit IV

Seed certification – history and objectives; general and specific crop standards, field and seed standards; seed certification agency – role of certification agency/ department and seed certification officers, phases of seed certification; field inspection – counting procedures – liable for rejection (LFR) – downgrading and partial rejection – reporting.

Unit V

Post-harvest inspection – construction of seed lot number; seed sampling – testing – labeling, sealing and grant of certificate – types and specifications for tags and labels; seed lot validity and revalidation; appellate authority, stop sale order, penalties records and registers to be maintained by seed processing units and seed dealers – verification procedures, role of seed analyst and seed inspector in quality regulation.

VII. Practical

- Preparation of sowing report – varieties – transplanted and direct sown crops and hybrids;
- Verification of sowing report – seed certification procedures;
- Field inspection – estimation of area and isolation distance, stages of inspection for varieties and hybrids – procedures;
- Practicing field counting procedures – methods for row planting, broadcasted – varieties;
- Practicing field counting procedures – direct sown and transplanted crops – varieties;
- Study on field counting procedures – hybrids – planting design, planting ratio and block method and double count;
- Identification of contaminants – genetic and physical contaminants, procedure to remove partials, pollen shedders and shedding tassels;
- Assessing and calculation of field standards for important crops;
- LFR, partial rejection and downgrading – reasons, procedures and preparation of reports;
- Yield estimation – single and multiple harvest crops;
- Post harvest inspection – groundnut, cotton, pulses;
- Inspection and maintenance (licence and renewal) of records in processing unit – float test, preparation of processing report and seed lot number construction;

- Visit to seed certification agency/ department;
- Visit to grow-out test field;
- Visit to seed retail shop – procedures followed by Seed Inspector, verification of records and reporting;
- Procedure to issue tag, specification, bagging, tagging, labelling and sealing.

VIII. Teaching methods

- Classroom lectures
- Guest lectures
- Student assignments and presentations
- Demonstrations
- Field visits

IX. Learning outcome

This course will be useful to develop human resource on seed certification and legislation. Successful completion of this course enables students to become a Seed Certification Officer and Seed Inspector.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
Anon. 2016. *Manual of Seed Certification Procedures*. Directorate of Seed Certification, Coimbatore, Tamil Nadu.
Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers, New Delhi.
Mishra DK, Khare D, Bhale MS and Koutu GK. 2011. *Handbook of Seed Certification*. Agrobios, Jodhpur, Rajasthan.
Neema NP. 1986. *Principles of Seed Certification and Testing*. Allied Publishers, New Delhi
Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India*. Agrobios, Jodhpur, Rajasthan.
Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. *A Handbook of Seed Testing*. Agrobios, Jodhpur, Rajasthan.
Sharma P. 2008. *Seed Legislation*. Gene-tech Book Publishers, New Delhi.
Trivedi PC. 2011. *Seed Technology and Quality Control*. Pointer Publications, Jaipur, Rajasthan.
Tunwar NS and Singh SV. 2003. *Indian Minimum Seed Certification Standards*. Central Seed Certification Board, Ministry of Agriculture, GOI, New Delhi.

XI. Suggested e-books

http://cms.tn.gov.in/sites/default/files/documents/seed-certification-0.pdf
http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN-MINIMUM-SEED-CERTIFICATION-STANDARDS.pdf
https://www.india.gov.in/my-government/documents/e-books
https://books.google.co.in/books/about/Principles_of_Seed_Certification_and_ Tes.html?id=SQWHAAAACAAJ&redir_esc=y
https://dl.sciencesocieties.org/publications/books/tocs/cssaspecialpubl/theroleofseedce

XII. Suggested websites

www.fao.org
www.agri.nic.in
www.agricoop.nic.in
www.gov.mb.ca
http:/agritech.tnau.ac.in
www.betterseed.org
www.oecd.org/india/
http://www.tnagrisnet.tn.gov.in/
https://pir.sa.gov.au/_data/assets/pdf_file/0003/148134/SeedCertification Manual.pdf

I. Course Title : Post Harvest Handling and Storage of Seeds*

II. Course Code : SST 508

III. Credit Hours : 3 (2+1)

IV. Why this course?

Healthy seeds are the demanding enterprise of the recent era for the production of high yield in the next season. The seeds must be well processed and stored for the maintenance of high-yielding crop. During storage, major losses of seeds are caused by various biotic and abiotic factors. There is a need apply proper post harvest handling and storage techniques, which ultimately improve the market value and quality of the seed.

V. Aim of the course

To impart knowledge on principles, techniques and methods of seed processing, treatment and storage.

VI. Theory

Unit I

Seed processing – objectives and principles; processing sequence – threshing, shelling, ginning, extraction methods; drying – principles and methods; seed cleaning, grading, upgrading – methods – machineries and equipment – scalper, pre-cleaner, cleaner cum grader, specific gravity separator, indented cylinder, disc separator, spiral separator, velvet separator, magnetic separator, electronic colour sorter – working principles and functions.

Unit II

Online seed processing – elevators and conveyers – processing plant – specifications, design and layout; mechanical injury – causes and detection – management.

Unit III

Seed treatment – methods – pre and mid storage seed treatments, seed treating formulations and equipments; packaging materials – types – bagging and labeling; seed blending – principle and methods.

Unit IV

Seed storage – purpose and importance – factors affecting storage, optimum condition for storage of different seeds; storage principles – Harrington's thumb rule – concepts and significance of moisture equilibrium – maintenance of safe seed moisture – physical, physiological, biochemical and molecular changes during seed storage – storage behaviour of orthodox and recalcitrant seeds – prediction of viability – viability nomograph.

Unit V

Methods of seed storage – modified atmospheric storage – ultra dry storage – vacuum storage – cryopreservation – germplasm storage – gene banks – NBPGR, IPGRI and National seed storage laboratory; seed storage godown – structure – maintenance – sanitation.

VII. Practical

- Seed extraction – wet and dry methods;
- Seed processing sequence for different crops;
- Design of processing plant – equipments – estimation of processing efficiency;

- Seed drying methods – principle and methods;
- Practicing seed grading – upgrading techniques;
- Delinting methods – assessment of mechanical damage;
- Visit to seed processing unit;
- Seed packaging – effect of packaging materials on seed longevity;
- Prediction of viability during storage – viability nomograph and accelerated ageing test;
- Assessing physical changes during seed storage;
- Assessing physiological changes during seed storage;
- Assessing biochemical changes during seed storage;
- Storage behaviour of recalcitrant seeds;
- Pre-storage seed treatments – protectants – antioxidants – halogens;
- Practicing seed blending methods;
- Seed storage godown – sanitation, fumigation – visit to seed storage godown and cold storage unit.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentation
- Processing experiments
- Demonstration
- Hands on training
- Exposure and field visits

IX. Learning outcome

The students will understand the principles and mechanism involved in seed processing, storage techniques and management practices to arrest the seed deterioration. Students will also acquire skill on seed handling and storage methods on commercial basis.

XI. Suggested Reading

Barton LV. 1961. *Seed Preservation and Longevity*, (Vol. 1). Leonard Hill, London.

Gregg BR, Law AG, Virdi SS and Balis JS. 1970. *Seed Processing*. Avion printers, New Delhi.

Gupta D. 2009. *Seeds: their conservation principles and practices*. Sathish serial publishing house. New Delhi.

Justice OL and Bass LN. 1978. *Principles and Practices of Seed Storage*. Agriculture Hand Book No. 506, Castle House Publication Ltd., Washington.

Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.

Padmavathi S, Prakash M, Ezhil Kumar S, Sathiyanarayanan G and Kamaraj A. 2012. *A Text book of Seed Science and Technology*, New India Publishing Agency, New Delhi.

Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

Singhal NC. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

XI. Suggested e-books

http://dfsc.dk/pdf/Handbook/chapter8_internet.pdf

https://naldc.nal.usda.gov/download/CAT87208646/PDF

https://www.springer.com/in/book/9780792373223

http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf

https://www.kopykitab.com/ebooks/2016/05/6997/sample/sample_6997.pdf

https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&-=1541066209257 &versionId=45008917+251246346

http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf

XII. Suggested websites

http://www.fao.org/3/a-ah803e.pdf
agritech.tnau.ac.in/seed_certification/seedtech_index.html
http://ecoursesonline.iasri.res.in/mod/page/view.php?id=17806
http://www.bcseeds.org/wp-content/uploads/2015/01/Seed-Processing-2015-update.pdf
https://www.carolinafarmstewards.org/wpcontent/uploads/2012/05/Seed Processingand StorageVer_1pt3.pdf

I. Course Title : Seed Quality Testing and Enhancement*

II. Course Code : SST 509

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is the basic input in agriculture and the productivity is mainly depends on field population of plants. By sowing quality seeds, population can be maintained. Hence, it is necessary to know the quality parameters to be analyzed. Through seed treatments, the performance of seed can be improved. Especially to address the drought and climate change the knowledge on seed enhancement techniques is much essential.

V. Aim of the course

To impart knowledge on principles, techniques and methods of seed testing and seed quality enhancement.

VI. Theory

Unit I

Seed testing – history and development; seed testing in India; ISTA and its role in seed testing; seed lot and size, types of seed and size, samples – sampling – intensity and methods, sampling devices, receipt and registration of submitted samples in the laboratory and sub sampling; purity analysis – components and procedure – determination of other distinguishable varieties (ODV) and test weight determination – application of heterogeneity test – method of testing coated and pelleted seeds; seed moisture estimation – principles and methods, application of tolerances.

Unit II

Seed germination test – requirements, media and methods – seedling evaluation, tolerance and reporting results; viability test (TZ test) – principle, procedure and evaluation; vigour tests – concept of seed vigour and vigour test – types of vigour tests – direct and indirect tests – physical, physiological and biochemical tests – principles and methods; seed health test – principles and methods.

Unit III

Genetic purity assessment – laboratory methods – physical, chemical, biochemical and molecular tests – growth chamber and field testing (Grow Out Test) methods; testing of GM seeds; storage of guard sample – referral test; application of tolerance in seed testing; advanced non destructive techniques of seed quality analysis – soft x-ray imaging – hyper spectral imaging, thermal imaging – spectroscopy – e-nose and machine vision techniques.

Unit IV

Seed quality enhancement techniques – history and development; classification – physical, physiological and protective seed treatments – special seed treatments; physical seed treatment – liquid floatation, specific gravity separation, irradiation, electric and electro-magnetic seed treatments – principles and methods – seed pelleting and coating principles, purpose and methods.

Unit V

Physiological seed enhancement treatments – seed infusion, seed priming – principles and methods – physiological, biochemical and molecular mechanisms; pre-germination and fluid drilling techniques; biological seed treatments – microbial inoculation; organic seed treatment – integrated seed treatment – concept and methods of designer seed.

VII. Practical

- Seed testing – sampling and dividing methods;
- Determination of seed test weight and heterogeneity test;
- Physical purity analysis – components, procedure, reporting results;
- Seed moisture estimation – methods and equipments;
- Conduct of seed germination test and seedling evaluation;
- Conduct of quick viability (tetrazolium) test and evaluation;
- Conduct of vigour tests – direct, indirect test and special tests;
- Genetic purity assessment – laboratory and conventional methods – image analysis for seed quality;
- Conducting different seed health tests to identify bacteria, fungi and insects;
- Visit to seed testing laboratory;
- Seed enhancement techniques – practicing physical treatments and water floatation techniques;
- Seed coating and pelleting – uses of adhesives and filler materials;
- Performing seed priming – hydro, halo and bio-priming – solid matrix priming;
- Practicing seed infusion and microbial inoculation treatments;
- Practicing pre-germination technique;
- Studying integrated seed treatment/ designer seed treatment.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentations
- Laboratory experiments
- Demonstration
- Hands on training
- Exposure visits

IX. Learning outcome

Successful completion of this course by the students will be useful to acquire technical skill on seed quality analysis which leads to the development of human resource on seed quality analysis.

X. Suggested Reading

Agrawal PK. 1993. *Hand book of Seed Testing*. Ministry of Agriculture, GOI, New Delhi

Agrawal RL. 1997. *Seed Technology*. Oxford & IBH.

Agrawal PK and Dadlani M. 1992. *Techniques in Seed Science and Technology*. 2nd Ed. South Asian Publications.

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers. New Delhi.
Chalam GV Singh A and Douglas JE. 1967. *Seed Testing Manual*. ICAR and United States Agency for International Development, New Delhi.
Copeland LO and McDonald MB. 2001. *Principles of Seed Science and Technology*. 4th Ed. Kluwer Academic publishers, USA.
International Seed Testing Association. 2018. *Handbook on Seedling Evaluation*, 4th Edition, Published by ISTA, Zurichstr, Switzerland.
International Seed Testing Association. 2019. *International Rules for Seed Testing* 2019. Published by ISTA, Zurichstr, Switzerland.
ISTA. 1999. *Seed Science and Technology*, 27th supplement.
Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. *A Hand book of Seed Testing*. Agrobios. Jodhpur, Rajasthan.
Tridevi PC. 2011. *Seed Technology and Quality Control*. Pointer Publication. Jaipur, Rajasthan.
Vasudevan SN, Doddagowder SR, Rakesh CM and Patil SB. 2013. *Seed Testing and Quality Control*. Agrotech Publications, Udaipur, Rajasthan.

XI. Suggested e-books

http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN MINIMUM SEED CERTIFICATION STANDARDS.pdf.
www.kopykitab.com/Seed-Testing-and-Quality-Control-by-Vasudevan-SN
https://www.jstor.org/stable/10.14321/j.ctt7zt51m
https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13
https://www.researchgate.net/publication/269694458_QUALITY_SEED_ PRODUCTION_ITS_TESTING_AND_CERTIFICATION_STANDARD
https://www.seedtest.org/upload/cms/user/ISTAMethodValidationforSeed Testing-V1.01.pdf
https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational-research-driving-seed-technology/recent-advances-in-seed-enhancements

XII. Suggested websites

http://agritech.tnau.ac.in/seed/Seed_seedtesting.html
https://core.ac.uk/download/pdf/85210907.pdf
https://www.betterseed.org/resources/seed-testing-accreditation-schemes/
http://sbc.ucdavis.edu/About_US/Seed_Biotechnologies/Seed_Enhancement/
https://www.seedtest.org/en/international-rules-for-seed-testing-content-1-1083. html

I. Course Title : Seed Technology of Tree Species
II. Course Code : SST 510
III. Credit Hours : 2 (1+1)

IV. Why this course?

Tree seed production is an important primary niche for carrying forward sustainable agriculture and forest resource management. Knowledge of the seed biology of a tree species is essential to successful seed production and handling of tree crops. The sexual life cycle must be known to plan for genetic improvement, production, collection, conditioning, storage and planting of the seeds for propagation of trees.

V. Aim of the course

To make the students gain knowledge on seed production and handling techniques of various tree species.

VI. Theory

Unit I

Importance of tree seeds – seed quality in plantation establishment – scope of seed production in tree species; seed structure and its significance in natural regeneration of forest species.

Unit II

Reproductive biology – angiosperms and gymnosperms – reproductive age – seasonal influence on flowering – reproductive efficiency; factors influencing seed set – pollination – pollinating agents – self incompatibility – seed dispersal – mode and mechanism of dispersal.

Unit III

Seed stand – selection and delineation – seed production area – seed zone – selection criteria for candidate, plus and elite tree; seed orchards – definition – types – seedling and clonal seed orchard – pollen dilution zone – seed orchard establishment and management; OECD certification programmes for forest reproductive materials and seeds – ISTA certification standards for tree species.

Unit IV

Physiological maturity – maturity indices – determining optimum harvestable maturity; seed collection – methods – factors influencing seed collection – precautions in collection of recalcitrant seeds; seed extraction – methods – wet, dry and cone extraction; drying – critical moisture content – seed processing; dormancy – types of dormancy in tropical, sub tropical and temperate tree seeds – dormancy breaking treatments; recalcitrant seeds – mechanism.

Unit V

Seed production and handling techniques in important tree borne oil seeds (*Madhuca, Pongamia*, *Azadirachta*, *Simaruba*, *Callophyllum*), timber (teak, sandal, pine, cedar, red sanders, shisham), fuel wood (*Acacias*), pulp wood (Bambusa, *Ailanthus*, *Casuarina*, *Melia*, *Eucalyptus*), fodder (*Leucaena, Albizzia*) and ornamental (*Cassia*, *Delonix*) tree species.

VII. Practical

- Study of tree seed structure – internal and external structures;
- Study on phenology of different tree species;
- Selection procedure of candidate and plus trees;
- Assessment of seed set, physiological and harvestable maturity;
- Assessing natural regeneration in different tree species;
- Study on seed dispersal methods and dispersal distance in different species;
- Seed collection techniques in important tree species – seed collection – orthodox and recalcitrant seeds – safety measures during collection;
- Seed extraction methods – wet and dry extractions – fruits, pods, cones, etc.;
- Study on different seed drying methods and precautions;
- Practicing seed grading and upgrading techniques;
- Practicing seed dormancy breaking methods;
- Germination improvement treatments for elite seedling production;
- Study on storage of recalcitrant seed;
- Estimation of critical moisture content for safe storage;
- Visit to seed production area and seed orchard;
- Visit to tree seed processing unit.

VIII. Teaching methods

- Classroom lectures

- Power point presentations
- Student assignments and presentation
- Group exercise
- Laboratory experiments
- Field visit to seed orchard

IX. Learning outcome

Knowledge of the seed biology of a tree species enable to produce good quality seeds, handling and prevent loss of seeds. The knowledge on sexual life cycle enables them to plan for genetic improvement, production, collection, conditioning, storage, and planting of the seeds.

X. Suggested Reading

Dennis AJ, Schepp EN, Green RJ and West cott DA. 2007. *Seed Dispersal*. Agrobios, Jodhpur.

Khanna LS. 1993. *Principles and Practices of Silviculture*. Khanna Bandhu, Dehradun, India.

Lars Schmidt 2000. *Guide to Handling of Tropical and Sub Tropical Forest Seed*. Danida Forest Seed Centre, Denmark.

Negi SS. 1998. *Forest Tree Seed*. International Book Distributors, Dehradun, India.

Ram Prasad and Khandya AK. 1992. *Handling of Forestry Seeds in India*. Associated Publishers, New Delhi.

Sivasubramaniam K, Raja K and Geetha R. 2012. *Recalcitrant Seeds – Causes and Effects*. Sathish Serial Publishing House. Azadpur, New Delhi.

Umarani R and Vanangamudi K. 2004. *An Introduction to Tree Seed Technology*. International Book Distributors, Dehradun.

Vanangamudi K, Natarajan K, Saravanan J, Natarajan N, Umarani R, Bharathi A and Srimathi P. 2007. *Advances in Seed Science and Technology: Forest Tree Seed Production* (Vol. 4). Agrobios, Jodhpur

Willan RL. 1985. *A guide to Forest Seed Handling*. FAO, Rome

Zoebel B and Talbert TT. 1984. *Applied forest tree improvement*. Joh willey and Sons, New Yark.

XI. Suggested e-books

http://www.fao.org/3/a-ah803e.pdf
http://www.fao.org/3/ad232e/AD232E01.htm
https://www.springer.com/gp/book/9783540490289
http://www.fao.org/docrep/006/ad232e/ad232e00.htm
http://envis.nic.in/ifgtb/pdfs/Tree%20Seed%20Management.pdf
https://www.forestry.gov.uk/PDF/FCBU054.pdf/$FILE/FCBU054.pdf
https://www.forestry.gov.uk/PDF/FCBU059.pdf/$FILE/FCBU059.pdf

XII. Suggested websites

www.ista.org.in
ifgtb.icfre.org/index.php
http://www.kfri.res.in/research.asp
http://www.fao.org/3/ad232e/AD232E21.htm
https://www.srs.fs.usda.gov/pubs/gtr/gtr_so107.pdf
http://www.sfri.nic.in/pdf_files/Seed%20Technology.pdf

I. Course Title : Seed Industry and Marketing Management

II. Course Code : SST 511

III. Credit Hours : 2 (1+1)

IV. Why this course?

India has a vibrant seed market. Over the years, the seed industry has evolved side by side with Indian agriculture. Indian seed industry is the fifth largest seed market in the world. This course will provide insights in seed industry development and better management of seed industry and seed marketing.

V. Aim of the course

To empower the students to become seed entrepreneurs by imparting knowledge on seed industry management and marketing strategies.

VI. Theory

Unit I

Introduction to seed industry – genesis, growth and structure of seed industry – mission and objectives – present status of Indian and global seed industry – role of seed industry in Indian agriculture; government initiatives – seed hubs, seed villages and community seed production system.

Unit II

Seed industry – organization set up and functions – public, private, MNC's, seed corporations; structure of small, medium and large seed industries, components of seed industry – public private partnership – custom seed production – risk management – human resource – infrastructure – processing unit – storage go down.

Unit III

Seed production and distribution systems in state and central government; seed supply chain systems – seed production and distribution – planning, organization and coordination, staffing, assembling of resources; cost of seed production – overhead charges.

Unit IV

Seed marketing – definition – importance – role of marketing; type of markets – domestic and global market – problems and perspectives; marketing policies – seed marketing schemes – marketing channels, responsibilities of dealers – marketing mix.

Unit V

Seed demand forecasting – purpose – methods and techniques; indenting and seed dispatch procedures and forms – seed store records – maintenance – missing link in seed supply chain; market intelligence – SWOT analysis; seed cost analysis; seed pricing – policy – components of seed pricing – factors – local market rate (LMR) – fixation of procurement and sale price of seed.

VII. Practical

- Data collection on status of Indian and global seed industry;
- Assessing the factors influencing farmers preference and assessment of seed demand and supply;
- Planning for establishment of small, medium and large seed industry;
- Planning for establishment of seed production and processing unit;
- Economics of seed production – varieties and hybrids;
- Seed pricings and cost analysis;
- Exercise on fixing seed procurement and sale price;
- Study of marketing channels – domestic and international;
- Maintenance of carryover seeds – Assessing risk factors in seed industry and their management;

- Survey and interaction with seed dealers and distributors;
- Visit to state seed corporations;
- Visit to MNCs and expert discussion;
- Case studies and SWOT analysis;
- Visit to modern seed processing unit and advanced seed storage complex;
- Custom seed production, contract farming and procurement – procedures;
- Planning and preparation of project proposal for setup of a seed industry;
- Final practical examination.

VIII. Teaching methods

- Classroom lectures
- Survey
- Student assignment and presentation
- Economic analysis
- Group discussion
- Swot analysis
- Seed industry visit and interaction sessions

IX. Learning outcome

On completion of this course students will gain knowledge and confidence to manage seed industry and able to address the problems in seed industry and seed marketing.

X. Suggested Reading

Acharya SS and Agarwal NL. 2004. *Agricultural Marketing in India*. 4th Ed. Oxford and IBH.
Broadway AC and Broadway A. 2003. *A Text Book of Agri-business Management*.
Kalyani Singh AK and Pandey S. 2005. *Rural Marketing*. New Age Publications.
Kugbei S. 2008. *Seed Economics*. Scientific Publishers, Jodhpur, Rajasthan.
Sharma P. 2008. *Marketing of Seeds*, Green-Tech Book Publishers, New Delhi.
Singh G and Asokan SR. 1991. *Seed Industry in India: A Management Perspective* Oxford & IBH Publishing Co Pvt. Ltd., New Delhi.
Singh S. 2004. *Rural Marketing – Focus on agricultural Inputs*. Vikas Publishing House.

XI. Suggested e-books

https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15
http://www.fao.org/3/V4450E/V4450E00.htm
https://books.google.co.in/books?id=vPVlBos4WkYC
http://download.nos.org/srsec319new/319EL19.pdf
https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf
https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by- Gaur-SC

XII. Suggested websites

www.gov.mb.ca
www.agricoop.nic.in
www.agri.nic.in
https://sathguru.com/seed/
http://www.fao.org/3/V4450E/V4450E03.htm
https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf
https://www.icrisat.org/seed-systems-models-lessons-learned/
https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/

I. Course Title : Seed Health Testing and Management
II. Course Code : SST 512
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seeds are the foundation for crop production and seed health is related to food production in many ways. Healthy seeds, free from seed transmitted pathogens, are a prerequisite for sustainable food production. Seeds are routinely tested to prevent and control plant pests and pathogens that may affect seed quality, seed movement when introduced into new territories. A seed health test is also frequently a phyto-sanitary requirement imposed by national plant protection authorities. This course aids in timely detection and management of seed borne pest and diseases and supply of pest and disease free seeds in market.

V. Aim of the course

To acquaint the students with principle and practices of seed health testing and management of seed borne pathogens and storage insects.

VI. Theory

Unit I

History and economic importance of seed health in seed industry and plant quarantine – important seed borne and seed transmitted pathogens – role of microorganisms in seed quality deterioration – storage and field fungi – effect of storage fungi on seeds – factors influencing storage fungi and management.

Unit II

Transmission of pathogens – mode and mechanism – seed certification standards; mycotoxins – types and its impact on plant, animal and human health; seed health testing methods – direct examination, incubation, serological and molecular methods.

Unit III

Production of disease free seeds in agricultural and horticultural crops; management of seed borne pathogens – plant quarantine – Indian system and networking, post-entry quarantine and international systems – Pest Risk Analysis (PRA); Sanitary and Phytosanitary System (SPS) – certificates; International Seed Health Initiative (ISHI) on seed health standards.

Unit IV

Storage pests – insects, mites, rodents and their development – economic importance; insect infestation – factors influencing, sources and kinds, biochemical changes in stored seeds due to insect infestation; detection methods and estimation of storage losses; types of seed storage structures – domestic and commercial.

Unit V

Fumigation – principles and techniques – type of fumigants; preservatives and seed protectants on seed quality – non-chemical methods for managing seed storage pests – controlled and modified atmospheric storage – trapping devices – IPM for seed storage.

VII. Practical

- Detection of seed borne pathogens – direct examination;
- Detection of seed borne pathogens – incubation methods;
- Detection of seed borne pathogens – serological methods;
- Detection of seed borne pathogens – molecular methods;
- Study on seed transmission of seed borne fungi, bacteria and viruses;
- Identification of storage fungi;
- Management of seed borne pathogens – seed treatment methods;
- Identification of storage insects – internal and external feeders influencing insects;

- Study on the effect of pre harvest spray on field carryover storage pests;
- Estimation of storage losses due to pests;
- Methods of detection of insect infestation;
- Management of storage pests – pesticides, dose determination, preparation of solution and application;
- Management of storage pests – non-chemical management methods;
- Demonstration of controlled atmospheric storage;
- Safe handling and use of fumigants and insecticides;
- Visit to seed storage godowns.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentation
- Laboratory experiments
- Hands on training.

IX. Learning outcome

Successful completion of this course will provide knowledge on production of healthy seeds by timely detection and management of seed borne pathogens and storage pests to meet phyto-sanitary requirements.

X. Suggested Reading

Agarwal VK and Sinclair JB. 1996. *Principles of Seed Pathology*. Edition, CRC Press Inc. Boca Raton, FL.

Athanassiou CG and Arthur FH. 2018. *Recent advances in stored product protection*. Springer-Verlag, Germany

Cotton, RT. 2007. *Insect Pests of Stored grain and Grain products*. Burgess Publ. Co., Minneopolis, Minn., USA

Karuna V. 2007. *Seed Health Testing*. Kalyani Publishers, New Delhi.

Karuna V. 2009. *Fundamentals of Seed Pathology*. Kalyani Publishers, New Delhi.

Neergaard P. 1979. *Seed Pathology*. Vol. 1. The Macmillan Press Ltd.

Ranjeet K. 2017. *Insect Pests of Stored grain – Biology, Behaviour and Management Strategies*. Apple Academic Press, New York, USA.

XI. Suggested e-books

https://link.springer.com/book/10.1007/978-1-349-02842-9

https://www.crcpress.com/Principles-of-Seed-Pathology/Agarwal-Sinclair/p/book/9780429152856

https://books.google.co.in/books/about/Seed_Pathology.html?id=lvVJAAAAYAAJ &redir_esc=y

https://www.taylorfrancis.com/books/9781315365695

https://www.ebooks.com/en-us/610606/insects-of-stored-products/david-rees/

https://www.elsevier.com/books/insects-and-seed-collection-storage-testing-and-certification/kozlowski/978-0-12-395605-7

XII. Suggested websites

www.tnagrisnet.tn.gov.in/

www.storedgrain.com.au/

https://openlibrary.org/subjects/seed_pathology

http://ciat-library.ciat.cgiar.org/articulos_ciat/2015/12620.pdf

www.grainscanada.gc.ca/en/

https://entomology.ca.uky.edu/ef145

http://www.fao.org/3/t1838e/T1838E00.htm#Contents

https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain

Course Title with Credit Load
Ph.D. in Seed Science and Technology (SST)

Course Code	Course Title	Credit Hours
SST 601*	Hybrid Seed Production Technology	3 (2+1)
SST 602	Organic Seed Production	2 (1+1)
SST 603	Physiology and Biochemistry of Seeds	2 (1+1)
SST 604*	Genetic Purity and DUS Testing	3 (2+1)
SST 605	Seed Vigour and Crop Productivity	2 (1+1)
SST 606*	Advances in Seed Science	2 (2+0)
SST 607	Advances in Seed Quality Enhancement	2 (1+1)
SST 608	Germplasm Conservation Techniques	2 (1+1)
SST 609	Seed Ecology	2 (1+1)
SST 610	Seed Planning, Trade and Marketing	2 (1+1)
	Major Courses (Minimum 12 credits from above courses including *marked Courses)	12
	Minor Courses	06
	Supporting Courses	05
SST 691	Seminar I	01
SST 692	Seminar II	01
SST 699	Research	75
	Total Credits	**100**
Comprehensive (Pre-qualifying) Examination (Non-credit of 100 marks) Satisfactory/ Not satisfactory		

*Compulsory Major Courses

Course Contents
Ph.D. in Seed Science and Technology (SST)

I. Course Title : Hybrid Seed Production Technology*
II. Course Code : SST 601
III. Credit Hours : 3 (2+1)

IV. Why this course?

Indian seed industry is dominated by hybrid seeds. Hybrid seed production requires scientific specialized skills and knowledge. Hence, it is necessary to impart knowledge to the students on hybrid seed production techniques and scientific principles involved in hybrid seed production of various crops.

V. Aim of the course

To provide students a comprehensive knowledge and practical exposure on hybrid seed production techniques in agricultural and horticultural crops.

VI. Theory

Unit I

Introduction – history – scope – importance of hybrid development – national and international scenario of seed industry – popular public sector hybrids in various crops. Heterosis – definition – expression – types – utilization of heterosis in hybrid development, hybrid vigour and seed vigour.

Unit II

Types of hybrids – intra-specific, inter-specific hybrids, single, double, three way cross, top cross hybrids – apomixes; generation system of seed multiplication in different types of hybrids. Development and maintenance of inbred lines – male sterile – maintainer lines – fertility restoration – transgenic hybrids – principles and method of development.

Unit III

Breeding tools – genetic mechanism – male sterility – types: CMS, GMS, CGMS, TGMS, PGMS – barnase and barstar system – pistillateness – self incompatibility. Manual creation of male sterility – emasculation and pollination – gametocides – mode of action, mechanism. Synchronization of flowering – problems – methods to achieve synchrony – planting ratio and supplementary pollination methods.

Unit IV

Techniques of hybrid seed production in major agricultural crops – cereals (wheat, rice), millets (maize, sorghum, bajra), pulses (red gram), oilseeds (sunflower, castor, mustard), cotton and forage crops.

Unit V

Hybrid seed production techniques in horticultural crops – tomato, brinjal, chilli, bhendi, onion, bitter gourd, bottle gourd, ridge gourd, cucumber, melon, cabbage, cauliflower, potato, coconut and papaya.

VII. Practical

- Characteristics features of parental lines and their hybrids;
- Floral biology of rice, maize, pearlmillet, sunflower, castor and cotton;
- Study on floral biology of vegetable crops – solanaceous and other vegetables;
- Study on floral biology of cucurbitaceous crops;
- Production and maintenance of A, B and R lines;
- Practicing planting design and border rows – rice, maize, pearlmillet, sunflower and red gram; brinjal and chillies;
- Practicing planting design and border rows in tomato, cotton and cucurbitaceous vegetables;
- Manipulation for synchronization – rice, sunflower, pearlmillet and sorghum;
- Practicing supplementary pollination – rice and sunflower;
- Practicing field inspection in hybrid seed production plot – crops planted in ratio – sunflower, pearlmillet, sorghum, etc.;
- Practicing field inspection in hybrid seed production field – red gram, castor, cotton, cucurbits and tomato;
- Practicing roguing and identification of off-types – pollen shedders – shedding tassel – selfed fruits;
- Visit to hybrid seed production fields;
- Visit to potato seed production plots;
- Determination of cost benefit of hybrid seed production;
- Visit to seed Industry and assessing problems and perspectives in hybrid seed production.

VIII. Teaching methods

- Classroom lectures
- Power point presentation
- Student assignment and presentation
- Demonstration
- Field visits

IX. Learning outcome

By learning this course, students will acquire a comprehensive knowledge and practical skills on hybrid seed production techniques both in agricultural and horticultural crops.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. 3rd Ed. Oxford & IBH Publishers, New Delhi.

Basra A. 1999. *Heterosis and Hybrid Seed Production in Agronomic Crops*. CRC Press., Florida, United States.

Chhabra AK. 2006. *Practical Manual of Floral Biology of Crop Plants*. Department of Plant Breeding, CCSHAU, Hisar.

Dar SH. 2018. *Methods of Hybrid Seed Production in Major Crops*. Educreation Publishing, Chhattisgarh.

Frankel R and Galun E. 1977. *Pollination Mechanisms*, Reproduction and Plant Breeding. Springer Verlag, New York.

Hebblethwaite PD. 1980. Seed Production. Butterworth Heinemann Ltd., London, UK.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

Krishnan M. 2012. *Plant breeding and Hybrid Seed Production*. Domin and Publishers & Distributors, New Delhi, India.

Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices*. Springer Science and Business Media, Boston, United States.
Mondal SS, Saha M and Sengupta K. 2009. *Seed Production of Field Crops*. New India Publishing Agency, New Delhi.
Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.
Singhal NC. 2003. *Hybrid Seed Production*. Kalyani Publishers., New Delhi, India.
Singhal NC. 2003. *Hybrid Seed Production in Field Crops*. Kalyani Publications, New Delhi.
Singhal NC. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
Vanangamudi K, Prabhu M, Kalaivani S, Bhaskaran M and Manonmani V. 2010. *Vegetable Hybrid seed Production and Management*. Agrobios., Jodhpur, India.

XI. Suggested e-books

https://www.springer.com/in/book/9780792373223
https://www.springer.com/in/book/9780412075513
https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops
https://www.kopykitab.com/Vegetable-Hybrid-Seed-Production-And-Management
https://www.researchgate.net/publication/229432295_Hybrid_Seed_Production_ and_Flowers
http://www.worldcat.org/title/seed-production-principles-andractices/oclc
https://libgen.is/search.php?req=Raymond+A++T+George&column=author
https://libgen.is/search.php?req=Raymond%20A%20%20T%20George&column[]= author
https://www.researchgate.net/profile/Gulzar_S_Sanghera/publication/236865752_ Advances_in_Hybrid_Rice_Technology_through_Applications_ of_Novel_Technologies/links/0deec519b46087d815000000.pdf

XII. Suggested websites

www.agriquest.info
www.agriinfo.in
www.seedquest.com
https://agriinfo.in/botany/18/
http://www.fao.org/3/a-e8935e.pdf
http://www.agriquest.info/seed_production.php
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html

I. Course Title : Organic Seed Production
II. Course Code : SST 602
III. Credit Hours : 2 (1+1)

IV. Why this course?

After ascertaining the food security, the present day agriculture is moving towards quality farm produces, hence organic agriculture is getting momentum. The growing demand for organically produced farm produces among the consumers warrants more area under organic agriculture. Hence, organic agriculture needs the seeds which are produced organically and there is great scope for organic seed production.

V. Aim of the course

To make students to understand the concept of organic farming, principles and practices of organic seed production, certification and marketing.

VI. Theory

Unit I

Organic farming – definition, genesis, concepts and principles; importance of organic farming and organic seed; organic seed – strategies, problems and perspectives – organic seed vs conventional seed; organic seed production – factors influencing seed production – soil health – GMO elements of seed.

Unit II

Techniques of organic seed production – selection of land – pre requisite for seed production – conversion period – soil amendments – green manures; multi-varietal seed techniques – organic sources of manures – bulky, concentrated and liquid manures, biofertilizers and biocontrol agents – organic seed treatment.

Unit III

Organic weed management practices – manual and mechanical methods – mulching – thermal weed control; growth promoting substances – *panchakavya*, fish amino acid, etc.; organic plant protection measures – herbal insecticides – IPM strategies; post harvest techniques – drying, processing and grading; organic seed treatment and storage.

Unit IV

Organic certification application – registration – verification of records; organic seed certification – tagging; role of organizations in production and marketing of organic seed – national and international organizations involved – public, private – NGOs – International Federation of Organic Agriculture Movement (IFOAM) – basic standards and EU regulations – organic seed marketing.

Unit V

Crop specific organic seed production and post harvest seed management techniques for major food crops, vegetables and fruit crops – economics of organic seed production and demand for organic seed.

VII. Practical

- Studying the field and seed standards for organic seed production;
- Collection and identification of organic manures and liquids;
- Preparation of organic products for soil application;
- Preparation of *panchakavya*, starter solutions and vermiwash;
- Organic priming of seeds with *panchakavya* and vermiwash;
- Preparation of leaf extracts and starter solutions and preparation of organic products for foliar application;
- Studying the effect of organic nutrients and foliar sprays on seed quality;
- Preparation of organic products for seed treatment and studying the effect on seed quality;
- Assessing the storage behaviour of organically treated seeds;
- Selection of suitable container and dry leaves or shrubs for enhanced storability;
- Organic treatment for management of seed health;
- Production and assessment of bio control agents for effective pest control;
- Economics of organic seed production and assessing demand;
- Visit to organic farm and seed production field;
- Visit to Department of organic certification;
- Visit to organic retail shops.

VIII. Teaching methods

- Classroom lectures
- Group assignments and presentation
- Laboratory and field experiments
- Demonstration
- Field visits

IX. Learning outcome

After completion of this course, students will gain knowledge, skill and confidence to take up organic seed production for sustainable agriculture.

X. Suggested Reading

Bryan Connolly B, Langer J and Lawn CR. 2011. *Organic Seed Production and Saving: The Wisdom of Plant Heritage*. Chelsea Green Publishing, Vermont, USA.

Gehlot D. 2010. *Organic Farming: Components and Management*. Agrobios., Jodhpur, India.

Gehlot D. 2012. *Organic Farming: Standards, Accreditation, certification and Inspection*. Agrobios., Jodhpur, India.

Panda SC. 2012. *Soil Management and Organic farming*, Agrobios., Jodhpur, India.

Panda SC. 2013. *Principles and Practices of organic Farming*. Agrobios., Jodhpur, India.

Suresh N and Deshmukh. 2010. *Organic Farming: Principles, Prospects and Problems*. Agrobios., Jodhpur, India.

White JM. 1995. *Organic Vegetable Production*. UF/IFAS Coop. Ext. Serv., HS720., Florida, United States.

XI. Suggested e-books

https://ufdcimages.uflib.ufl.edu/IR/00/00/33/80/00001/HS22700.pdf
https://www.ifoam.bio/en/organic-landmarks/principles-organic-agriculture
www.apeda.gov.in/apedawebsite/organic/organic.../english_organic_sept05.pd
https://ncof.dacnet.nic.in/Training./Training...in/Cert_and_Inspection_ manual.pdf
https://www.ebooks.com/en-us/96381019/organic-seed-production-and-saving/ bryan-connolly-jocelyn-langer-c-r-lawn/

XII. Suggested website

www.tnocd.net
https://www.sare.org/
https://www.ifoam.bio/
http://www.ncof.dacnet.nic.in
http://edis.ifas.ufl.edu/CV118
www.harrismoran.com/technology/default.htm
https://attra.ncat.org/attra-pub-summaries/?pub=70
http://www.harrismoran.com/technology/default.htm
https://www.academia.edu/4601825/Organic_seed_production
http://www.cals.ncsu.edu/sustainable/peet/IPM/diseases/org_cert.html
https://www.sare.org/Learning-Center/Topic-Rooms/Organic-Production/Organic-Seeds

I. Course Title : Physiology and Biochemistry of Seeds
II. Course Code : SST 603
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is a biological entity and the seed contains all micro and macro nutrients in the form of stored food, toxic compounds and secondary metabolites. Seeds are accumulated with these materials during development and maturation and it gets depleted during deterioration and storage. The developing seed embryo attains capacity to produce a new plant by utilizing these resources. Understanding the mechanism of accumulation of food reserves and pattern of its utilization during germination will enable the students to take up research on seed dormancy, germination and quality enhancement.

V. Aim of the course

To provide insight knowledge on physiological and biochemical events governing seed quality and itsurvival.

VI. Theory

Unit I

Seed development and maturation – role of cell organelles – embryogeny – translocation of assimilates – synthesis of starch, protein, lipid, secondary metabolites and toxic compounds – possible alteration in metabolic pathway.

Unit II

Development of embryo, endosperm and seed coat – translocation of assimilates and food reserves; desiccation tolerance – mechanism, hypothesis, role of LEA proteins; development of hard seeds – mechanisms and factors.

Unit III

Seed dormancy – types – physiology and biochemistry of seed dormancy induction and release – hormonal regulation of seed dormancy – environmental control – genetic inheritance and control of dormancy; physiology of orthodox, recalcitrant and intermediate seeds.

Unit IV

Seed germination – acquisition of viability and capacity of germination during development – genetics of germination acquisition; types of germination – phases of germination – requirements – imbibition – enzyme activation and hormonal regulation – respiration – mitochondrial activity and ATP synthesis – protein and nucleic acid synthesis – metabolism of starch, protein, lipid – physiology of embryo growth and development.

Unit V

Seed deterioration – theories, causes – ultra-structural, cell membrane and functional changes; biochemical changes – enzyme activity, storage reserves and genetic changes; lipid peroxidation – biological effects – free radicals and secondary products.

VII. Practical

- Study on the pattern of seed development and maturation;
- Study on the structural changes during seed maturation;
- Estimation of seed moisture content, fresh and dry weight and acquisition of germination and dormancy;
- Estimation of different hormones during seed development and maturation – GA and ABA;
- Estimation of phenolic compounds during seed maturity;
- Estimation of food reserves accumulation – starch, protein and oil at different stages of maturity;
- Study on the pattern of seed development in recalcitrant seeds;
- Studying the germination behaviour of different type of seeds;
- Study on imbibition pattern and soaking injury in seeds;
- Estimation of enzymes in dormant and non-dormant seeds;
- Estimation of hormones in dormant and non-dormant seeds;
- Studying the effect of light and temperature on dormancy;
- Study on deterioration pattern of orthodox and recalcitrant seeds;

- Estimation of lipid peroxidation product and free fatty acid;
- Studying the cytological and chromosomal changes in deteriorated seeds;
- Estimation of volatile aldehydes during seed storage and deterioration.

VIII. Teaching methods

- Classroom lectures
- Assignments and presentations
- Field and laboratory experiments

IX. Learning outcome

Completion of this course will enable the students to understand the mechanism of seed development, regulation of dormancy, germination and deterioration and help them to understand the mysteries in seed to address the problems in quality seed production and storage.

XI. Suggested Reading

Barton LV. 1961. *Seed Preservation and Longevity*, (Vol. 1). Leonard Hill, London.

Baskin C and Baskin JM. 2014. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, Cambridge, UK.

Bewley JD and Black M. 1982. *Physiology and Biochemistry of Seeds in Relation to Germination* (Vol. I & II). Springer Verlage, Berlin Heldelberg, New York, United States.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development*, Germination and Dormancy. Springer, New York.

Bradbeer JW. 1988. *Seed Dormancy and Germination*. Chapman and Hall, New York, USA.

David R Murray. 1985. *Seed Physiology*. Volume 2: Germination and Reserve Mobilisation. Academic Press, London, UK.

Justice OL and Bass LN. 1978. *Principles and Practices of Seed Storage*. Agriculture Hand Book No. 506, Castle House Publication Ltd., Washington.

Khan AA. 1977. *Physiology and Biochemistry of Seed Dormancy and Germination*. North Holland Co, Amsterdam, New York, United States.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

Mayer AM and Mayber AP. 1989. *Germination of Seeds*. Pergamon Press, Oxford, United kingdom.

Ovcharov KE. 1977. *Physiological Basis of Seed Germination*, Amerind Publishing Co,New Delhi and New York, United States.

Prakash M. 2011. *Seed Physiology of Crops*. Satish Serial Publishing house. Azadpur. New Delhi.

Roberts EH. 1972. *Viability of seeds*. Springerlink, New York, USA.

Vanangamudi K. 2006. *Seed Physiology*. Associated Publishing Company, New Delhi, India.

XI. Suggested e-books

http://agris.fao.org/agris-search/search.do?recordID=US201300553998

http://www.worldcat.org/title/physiological-basis-of-seed-germination-fiziologicheskie-osnovy-vskhozhesti-semyan/oclc/19369598

https://www.springer.com/in/book/9783642686450

https://link.springer.com/chapter/10.1007/978-1-4615-1747-4_2

https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/desiccation-tolerance

https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/embryogenesis

https://www.cell.com/current-biology/comments/S0960-9822(17)30562-6

https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-3040.2012.02542.x

https://dl.sciencesocieties.org/publications/books/pdfs/cssaspecialpubl/physiologyofsee/frontmatter

XII. Suggested websites

http://www.seedbiology.de/dormancy2.asp
http://www.seedbiology.de/dormancy.asp
https://www.ncbi.nlm.nih.gov/pubmed/22620982
https://www.britannica.com/science/germination
http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/
http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html
https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy
https://courses.lumenlearning.com/wm-biology2/chapter/development-seeds-fruit
www.iari.res.in/index.php?option=com_content&view=article&id=449 &Itemid=137

I. Course Title : Genetic Purity and DUS Testing*

II. Course Code : SST 604

III. Credit Hours : 3 (2+1)

IV. Why this course?

Genetic purity of seeds is one of the most important basic quality characters as per Seeds Act 1966. Loss of genetic purity leads to varietal deterioration leads to elimination of variety from seed supply chain. After establishment of PPV and FRA, varietal purity is assessed by using established DUS characters and guidelines. Human resource on methods of genetic purity assessment and DUS characters is much essential to prevent variety deterioration as well as for protection of plant varieties.

V. Aim of the course

To impart knowledge on various methods of genetic purity assessment and DUS testing for protection of plant varieties.

VI. Theory

Unit I

Genetic purity – importance – factors influencing genetic purity; genetic/ cultivar purity test – objectives – principles – methods; laboratory tests – green house and field plot methods, grow – out test, seed and seedling growth tests; chemical and biochemical methods; anthocyanin pigmentation, secondary compounds, phenol, peroxidase and fluorescence tests – chromatography techniques.

Unit II

Electrophoretic analysis of proteins and isozymes; DNA finger printing methods – RAPD, AFLP, SSR, SNP and other markers; computer based machine vision technique and image analysis for varietal identification.

Unit III

Genesis of Plant Variety Protection (PVP); International Union for Protection of New Varieties of Plants (UPOV) and its functions – GATT agreement in relation to plant variety protection; Protection of Plant Varieties and Farmer's Rights (PPV and FR) Act 2001 – objectives, salient features, farmer's rights, breeder's rights, researcher's rights – PPV and FRA Rules 2003.

Unit IV

Criteria for protection of new varieties of plants; Distinctness, Uniformity and Stability (DUS) testing – principles and procedures, guidelines, sample size, test duration, testing option; varieties of common knowledge – extant variety – essentially derived variety – collection of reference samples – grouping of varieties – example varieties; types and categories of characters – recording observations on characteristics – colour characteristics.

Unit V

Assessment of DUS characters of major crops based on morphological, biochemical and molecular markers – rice, maize, wheat, barley, black gram, green gram, red gram, cowpea, rajma, sunflower, groundnut, castor, mustard, tomato, brinjal, onion, potato, chilli, bhendi, cucurbits, cole crops, sugarcane, cotton, flower, fruit and tree species; statistical procedure – computer software for DUS testing; guidelines for registration of germplasm – impact of plant variety protection on seed industry growth.

VII. Practical

- Genetic purity assessment based on seed characters;
- Genetic purity assessment based on seedling growth tests, anthocyanin pigmentation;
- Genetic purity assessment based on secondary compounds, phenol, peroxidase and fluorescence tests;
- Chromatography analysis of secondary compounds;
- Electrophoretic analysis of seed protein and isozymes;
- DNA fingerprinting using PCR techniques;
- DUS testing based on morphological descriptors of plant – rice and millets;
- DUS testing based on morphological descriptors of plant – pulses and oil seeds;
- DUS testing based on morphological descriptors of plant – vegetable crops;
- DUS testing based on morphological descriptors of plant – flower, fruit and tree species;
- Recording observations and interpretation of data;
- Tree method of classification of varieties/ cultivars;
- Chemical and biochemical test applicable for DUS testing;
- Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major agricultural crops;
- Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major horticultural crops;
- Visit to DUS test centers.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Field and laboratory experiments
- Demonstration
- Field visits

IX. Learning outcome

After completion of this course, the students will gain knowledge on the methods of assessing genetic purity and able to distinguish varieties based on DUS characters.

X. Suggested Reading

Anon. 2016. *Manual of Seed Certification Procedures*. Directorate of Seed Certification, Coimbatore, Tamil Nadu.

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers, New Delhi.

Choudhary DR. 2009. *Guidelines for Storage and Maintenance of Registered Plant Varieties in the National Gene Bank*. Published by Protection of Plant Varieties and Farmer's Rights Authority. Ministry of Agriculture, GoI, New Delhi, India.

ISTA. 2010. *Handbook of Variety Testing*. International Seed Testing Association, Switzerland.
Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi, India.
Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.
Mishra DK, Khare D, Bhale, MS and Koutu GK. 2011. *Handbook of Seed Certification*. Agrobios, Jodhpur, Rajasthan.
Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India*. Agrobios, Jodhpur, Rajasthan.
Trivedi PC. 2011. *Seed Technology and Quality Control*. Publications, Jaipur, Rajasthan.

XI. Suggested e-books

https://books.google.co.in/books?isbn=16118603932.
https://books.google.co.in/books?isbn=81894220303.
https://books.google.co.in/books?id=2FbwZwEACAAJ
https://books.google.co.in/books?id=J5bQtgAACAAJ
https:/books.google.co.in/books?isbn=0851997392
https://www.upov.int/edocs/tgdocs/en/tg023.pdf

XII. Suggested websites

www.seedquest.com
www.ucanr.edu
www.sasa.gov.uk
www.ppvfra.org
https://www.upov.int/test_guidelines/en/
http://plantauthority.gov.in/crop-guidelines.htm
https://www.upov.int/resource/en/dus_guidance.html
https://www.upov.int/edocs/tgpdocs/en/tgp_6_section_2.pdf
https://www.upov.int/publications/en/tg_rom/introduction.html

I. Course Title : Seed Vigour and Crop Productivity
II. Course Code : SST 605
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed vigour is an important quality parameter needs to be assessed to estimate the real planting value of seed. Seed vigour is governed by several factors which ultimately decide the crop productivity and yield. Hence, knowledge on the concept of seed vigour and its manifestations, prediction of seed vigour in relation to crop productivity will be useful for better management of seed lots and seed crop.

V. Aim of the course

To impart knowledge on seed vigour, vigour test, impact of seed vigour on seed production, storage and seed management.

VI. Theory

Unit I

Seed vigour – importance, concepts, definitions, vigour *vs* viability, historical development – ISTA vigour committee. Factors influencing seed vigour – genetic, agronomic, biotic and abiotic factors.

Unit II

Seed vigour and senescence – sequence of vigour loss – manifestations of seed vigour – physical, physiological, biochemical and molecular manifestations; vigour in relation to seed dormancy and germination; vigour in relation to value for cultivation and use.

Unit III

Vigour tests – history – definition – characteristics – types – direct and indirect tests – physical test – x-ray radiography, seed size; physiological test – seedling first count, radicle emergence, speed of germination, seedling measurement; stress tests – brick gravel test, cool test, cold test, paper piercing test, ethanol, ammonium chloride and NaCl soak tests, accelerated ageing test, exhaustion test, controlled deterioration test, osmotic stress test.

Unit IV

Chemical and biochemical tests – electrical conductivity test, free sugars and amino acids, tetrazolium chloride test, respiration quotient, GADA test, free fatty acid, DPPH, respiratory and hydrolytic enzymes tests, modern vigour tests – machine vision, Q_2 analyzer – standardization of vigour test.

Unit V

Influence of seed vigour – crop growth, field emergence, productivity and storage; vigour of vegetative propagules; role of seed vigour in field emergence, crop growth, yield and productivity. Seed vigour improvement and management techniques – pre-sowing and pre-storage – mid storage methods to improve seed vigour.

VII. Practical

- Collection and evaluation of germination of seed lots with different vigour status;
- Evaluation of seed vigour by physical vigour test – seed size, colour, weight – turbidity test;
- Evaluation of seed vigour by physiological vigour test – imbibition pattern, speed of emergence, radicle emergence, germination, seedling measurement and computation of various index;
- Conducting different stress tests – brick gravel and paper piercing tests;
- Conducting accelerated ageing and controlled deterioration test;
- Conducting chemical stress test – NH_4Cl, NaCl, mannitol, PEG test;
- Special vigour tests – cool germination test – cold test – anaerobic test;
- Biochemical vigour test – electrical conductivity, free sugars and amino acid test in seed leachate;
- Estimation of dehydrogenase enzyme activity;
- Estimation of free fatty acids in seed lots in varying vigour levels;
- Bio-assay test for seed vigour;
- Estimation of volatile aldehydes in different crop seeds with varying vigour;
- Correlation studies between field emergence and different vigour tests;
- Seed vigour on field establishment, population maintenance and crop growth and productivity;
- Pre-sowing vigour management techniques;
- Pre-storage and mid storage vigour management techniques.

VIII. Teaching methods

- Classroom lectures
- Assignment and presentation
- Slides/ video shows

- Practical exercise
- Hands on training

IX. Learning outcome

This course will enable the students to understand the concept of seed vigour and enhance the analytical skills to predict and assess the vigour accurately so as to adjust the seed lots for its value for cultivation and usage.

X. Suggested Reading

Agrawal PK and Dadlani M. 1992. *Techniques in Seed Science and Technology*. 2nd Ed. South Asian Publications.

Bewley J and Black M. 1994. *Physiology of Development and Germination*. Springerlink, New York.

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Published by Kalyani Publisher., New Delhi, India.

Chalam GV, Singh A and Douglas JE. 1967. *Seed Testing Manual*. ICAR and United States Agency for International Development, New Delhi.

David R Murray. 1985. *Seed Physiology*. Saunders College Publishing/ Har court Brac.

International Seed Testing Association. 2018. *Handbook on Seedling Evaluation*, 4th Edition, Published by ISTA, Zurichstr, Switzerland.

ISTA. 1999. *Seed Science and Technology*, 27th supplement.

Khan AA. 1977. *The Physiology and Biochemistry of Seed Dormancy and Germination*. North–Holland Publishing Company, USA.

Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi, India.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of post harvest seed physiology and technology*. Agrobios., Jodhpur, India.

Mayer AM and Mayber AP. 1963. *Germination of Seeds*. Pergamon Press, Oxford, New York.

Roberts EH. 1972. *Viability of Seeds*. Springerlink, New York.

Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers., New Delhi, India.

Singhal NC. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi, India.

Trivedi PC. 2011. *Seed Technology and Quality Control Pointer Publications*., Jaipur, India.

Vasudevan SN, Doddagowder SR, Rakesh CM and Patil SB. 2013. *Seed Testing and Quality Control*. Agrotech Publications, Udaipur, Rajasthan.

XI. Suggested e-books

https://link.springer.com/chapter/10.1007/978-94-009-2764-3_71
https://link.springer.com/chapter/10.1007/978-1-4684-7747-4_8
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2_7
https://doi.org/10.1079/9780851993959.0073
https://www.researchgate.net/publication/326255175_Seed_Vigour_Testing_ Principland_Methods
https://www.springer.com/in/book/9789400956872
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233836/
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2_8
http://www.worldcat.org/title/techniques-in-seed-science-and-technology/oclc/600 47727
http://wrap.warwick.ac.uk/74767/1/WRAP_0380014-lf-271115-revised_darwin_ review_for_submission_.pdf

XII. Suggested websites

www.ista.org.in
www.cambridge.org
www.tandfonline.com
www.seednet.gov.in
www.seedtest.org
https://academic.oup.com/jxb/article/67/3/567/2893341

http://www.scielo.br/pdf/sa/v72n4/0103-9016-sa-72-4-0363.pdf
https://www.researchgate.net/publication/284279769_Seed_vigour_and_ crop_establishment_Extending_performance_beyond_adaptation
https://www.semanticscholar.org/paper/Seed-vigour-and-crop-establishment%3A -extending-Finch-Savage-Bassel/a5af7beae17bd31058db0f645edd647cbb9e 9c2b

I. Course Title : Advances in Seed Science*
II. Course Code : SST 606
III. Credit Hours : 2 (2+0)

IV. Why this course?

Seed science is the study of seeds from its development to storage. The seed science is interdisciplinary and is closely connected with botany, physiology, biochemistry and genetics. Exposing students to advanced and recent developments in seed science and technology will enable them to take up interdisciplinary advance research.

V. Aim of the course

To impart knowledge on the recent developments in various frontier areas of seed science and their application in seed technology.

VI. Theory

Unit I

Physiological and molecular aspects of seed development – gene expression during seed development – selective elimination of cells – theories and concepts; physiological and molecular regulation of germination and dormancy; desiccation and stress tolerance – gene expression – mechanism – structural changes in membranes of developing seeds; prediction of seed dormancy and seed longevity using mathematical models; climate change effects on pollination, seed formation, development and quality.

Unit II

Recent techniques in seed production of self incompatible, protogyny, protandry and apomictic plant species – Gene Use Restriction Technology (GURT) – terminator and verminator technology – Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) *Cas* – gene editing; seed proteomics – principles, methods, applications in seed science- genetic analysis and QTL mapping of traits related to seed vigour, ageing and longevity – OMICS in related to seed science and technology; somatic embryogenesis – principles and methods of production of synthetic/ somatic seeds – merits and demerits.

Unit III

Modern techniques for identification of varieties and hybrids – principles and procedures; DNA fingerprinting and other molecular techniques and their utilization – GM seeds and their detection techniques; Use of machine vision and image analysis techniques for varietal identification. Application of artificial intelligence (AI) and machine learning (ML) and virtual reality (VR) in seed science.

Unit IV

Recent accomplishments in seed enhancement research – seed coating, pelleting and priming techniques – physiological, molecular and sub-cellular basis of seed priming – detection and identification of seed borne diseases and insect pests through advanced techniques – ELISA and PCR based techniques.

Unit V

International movement of seeds – OECD seed certification schemes – recent developments in seed laws and policies – ethical issues and IPR system related to seed trade and movement.

VII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentations

VIII. Learning outcome

After completion of this course the students will be able to take up research on seed biotechnology.

IX. Suggested Reading

Baskin C and Baskin JM. 2014. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, Cambridge, UK.

Benech-Arnold R and Rodolfo S. 2004. *Handbook of Seed Physiology: Applications to Agriculture*. CRC Press., Florida, United States.

Bewley JD and Black M. 1994. *Seeds: Physiology of Development and Germination*. Springer, New York, USA.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development, Germination and Dormancy*. Springer, New York.

Black M and Bewley JD. 2000. *Seed Technology and its Biological Basis*. CRC Press. Florida, United States.

David R Murray. 1985. *Seed Physiology*. Volume 2: Germination and Reserve Mobilisation. Academic Press, London, UK.

Figeys D. 2005. Industrial Proteomics: Applications for Biotechnology and Pharmaceuticals (No. TP248. 65. P76 I535 2005). United States.

Kozlowski TT. 2012. *Seed Biology: Importance, Development and Germination*. (Vol. I). Academic Press Inc., New York.

Lombardo L. 2014. Genetic Use Restriction Technologies: a review. *Plant biotechnology journal*. **12**(8): 995-1005.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

Nicolas G, Bradford KJ, Come D and Pritchard HW. 2003. *The Biology of Seeds: Recent Research Advances*. Proceedings.

Patterson SD and Aebersold RH. 2003. Proteomics: the first decade and beyond. Nature genetics. **33**(3s): 311.

Rakshit A and Singh HB. 2018. *Advances in Seed Priming*. Springer Nature Singapore Ltd., Singapore.

Redenbaugh K. 1993. *Synseeds: Application of Synthetic Seeds to Crop Improvement*. CRC Press, London, UK.

X. Suggested e-books

https://www.springer.com/gp/book/9783540574484

https://www.synthego.com/resources/crispr-101-ebook

https://link.springer.com/book/10.1007/978-981-13-0032-5

https://www.springer.com/gp/book/9780306447471#aboutBook

https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13

https://www.cambridge.org/core/journals/experimental-agriculture/article/biology-of-seeds-recent-research-advances-edited-by-g-nicolas-k-j-bradford-d-come-and-h-w-pritchard-wallingford-uk-cabi-international-2003-pp-472-9500-isbn-0851996 531/57DACB0A07CFD0246AAD11713540F1E6

https://www.researchgate.net/publication/240592094_Black_M_Bewley_JD_eds_ 2000_Seed_technology_and_its_biological_basis_419_pp_Sheffield_ Sheffield_Academic_Press_89_hardback
https://www.crcpress.com/Handbook-of-Seed-Physiology-Applications-to-Agricu lture/Benech-Arnold-Snchez/p/book/9781560229292
https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6
https://international.neb.com/tools-and-resources/feature-articles/crispr-cas9-and-targeted-genome-editing-a-new-era-in-molecular-biology
https://www.omicsonline.org/scholarly/seed-science-and-technology-journals-articles-ppts-list.php
https://libgen.is/book/index.php?md5=F63727B21E14953F0003168A2452B3FE
https://www.researchgate.net/publication/228621809_Techniques_for_detecting_ genetically_modified_crops_and_products
https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational-research-driving-seed-technology/recent-advances-in-seed-enhancements
https://books.google.co.in/books/about/Advances_in_Seed_Priming.html?id= iBtfDwAAQBAJ&printsec=frontcover&source= kp_read_button&redir_esc= y#v=onepage&q&f=false

XI. Suggested websites

https://www.sbc.ucdavis.edu
https://www.seedbiotech.com
http://www.gmotesting.com/Testing-Options
https://www.ncbi.nlm.nih.gov/pubmed/25185773
https://www.oecd.org/agriculture/seeds/
https://www.addgene.org/crispr/guide/
https://www.yourgenome.org/facts/what-is-crispr-cas9
https://cban.ca/gmos/issues/terminator-technology/
https://www.nature.com/articles/s41598-017-08669-5
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5495694/
https://www.ias.ac.in/article/fulltext/reso/006/05/0039-0047
https://www.cell.com/action/showPdf?pii=S1360-1385%2807%2900038-6
https://www.sciencedirect.com/science/article/pii/S2215017X16301400
https://www.broadinstitute.org/what-broad/areas-focus/project-spotlight/questions-and-answers-about-crispr

I. Course Title : Advances in Seed Quality Enhancement
II. Course Code : SST 607
III. Credit Hours : 2 (1+1)

IV. Why this course?

Quality seed is a vital input for sustainable crop production and food security. Seed enhancement through various techniques can overcome germination constraints by uniform stands, earlier crop development and better yields. Understanding of the principles and mechanisms involved in seed quality improvement would enable to modulate the performance of seed in field.

V. Aim of the course

To impart knowledge on seed quality enhancement techniques and their associated quality changes in seed.

VI. Theory

Unit I

Seed quality – importance and enhancement – principles, concept, significance, strategies; types of seed enhancement – physical, physiological and biological enhancement techniques.

Unit II

Physical seed quality enhancement – concept and principles of grading – upgrading – magnetic, electromagnetic, irradiation, coating, pelleting, colouring; plasma treatment – thermal and cold plasma – treatment; application of nano formulations – concepts – principles – mode of action on improving germination.

Unit III

Physiological methods of seed quality enhancement – seed priming – principles, methods, mode of action – physiological, biochemical and molecular mechanism of priming techniques; seed infusion – principles and methods, mode of action – imparting abiotic stress tolerance – hardening – principles and methods.

Unit IV

Application of biological formulations – bacterial, fungal agents – concepts, formulations and compatibility; methods of application – growth promotion – protection – control over pest and disease infection and mode of action; designer/ smart seed – concept, methods, applicability to different crops.

Unit V

Effect of different treatments on crop establishment and modulation of seedling growth – crop geometry, phenology and yield improvement; storability of primed, coated and pelleted seeds – pre-storage and mid-storage enhancement techniques – hydration-dehydration techniques, moisture equilibrium drying and halogenations – principles, methods and application.

VII. Practical

- Physical seed quality up gradation – specific gravity separator, density grading, floatation technique;
- Practicing seed pelleting – methods of pelleting for different crop species;
- Performing seed coating – polymer, colouring and nano emulsion coating;
- Study on the effect of magnetic and electromagnetic seed treatment on seed germination and vigour;
- Practicing seed priming – hydro, osmo, halo and solid matrix priming methods;
- Nutrient and bio priming and assessing the performance of primed seeds;
- Assessing the storability of primed seed;
- Study on seed hardening on the performance of seed under abiotic stress;
- Preparation of designer/ smart seed for different crops;
- Biological seed treatment – biological formulations, bacteria, fungi, protectants and bio fertilizers;
- Study on the effect of biological seed treatment on seedling growth and disease incidence;
- Estimating the microbial population in biologically treated seeds;
- Assessing the storability and vigour potential of treated seeds;
- Performing mid-storage seed treatment – hydration-dehydration, moisture equilibrium and drying;
- Halogenation of seeds and their effect on seed performances;
- Assessing the performance of treated seeds under field condition.

VIII. Teaching methods

- Classroom lectures
- Student assignments and presentation
- Field and laboratory experiments
- Demonstration

IX. Learning outcome

This course enable the students to understand the mechanism of seed quality improvement, stress tolerance, population maintenance, crop geometry and yield improvement due to various enhancement techniques.

X. Suggested Reading

Bewley JD, Bradford KJ, Hilhorst HWM and Nonogaki H. 2013. *Seeds: Physiology of Development*, *Germination and Dormancy*, Third Edition. Springer, New York, United States.

Doijode SD. 2006. *Seed Quality in Vegetable Crops. In: Handbook of Seed Science and Technology*. Basra AS (Ed.). The Haworth Press, New York, United States. pp. 677–702.

Filatova I, Azharonok V, Lushkevich V, Zhukovsky A, Gadzhieva G, Spasic K, Zivkovic S, Puac N, Lazovic S, and Malovic G. 2013. *Plasma Seeds Treatment as a Promising Technique for Seed Germination Improvement*. 31st International Conference on Phenomena in Ionized Gases, Granada, Spain.

Glick BR. 2012. *Plant Growth-Promoting Bacteria: Mechanisms and Applications*. Hindawi Publishing Corporation, Scientifica.

Halmer P. 2003. 'Methods to improve seed performance.' In: Benech-Arnold RL, Sanchez RA (Eds.). *Seed Physiology, Applications to Agriculture*. Food Product Press, New York, United States.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices*. Springer Science and Business Media., Boston, United States.

Thomas B, Murphy DJ and Murray BG. 2003. *Encyclopedia of Applied Plant Sciences* (3 volume set). Elsevier Science, Netherland.

XI. Suggested e-books

https://www.springer.com/gp/book/9781461446927
https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13
https://www.intechopen.com/recent-advances-in-seed-enhancements
https://link.springer.com/content/pdf/bfm%3A978-981-13-0032-5%2F1.pdf
https://www.researchgate.net/publication/297732007_Advances_in_Seed_ Enhancements
https://www.researchgate.net/publication/309040118_Recent_Advances_in_Seed_ Enhancements
https://www.cambridge.org/core/journals/seed-science-research/article/seed enhancements/ 738B47B10C1C1B12C3D14D42E0B0A6C8
http://www.scientificpub.com/book-details/Seed-Quality-Enhancement-Principles-and-Practices-113.html

XII. Suggested websites

http://seedres.in/
http://agritech.tnau.ac.in/
http://www.bioline.org.br/pdf?cj17015
https://www.seedtest.org/en/home.html
www.niab.com/pages/id/24/Seed_Quality
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4109073/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4746480/
https://content.ces.ncsu.edu/seed-and-seed-quality
http://greenpathindustries.com/plasma-seed-treatment/

I. Course Title : Germplasm Conservation Techniques

II. Course Code : SST 608

III. Credit Hours : 2 (1+1)

IV. Why this course?

Genetic resources are backbone for crop improvement. The tolerance of wild relatives to biotic and abiotic stress is gaining attention of plant breeders for transformation of genes. Hence, the young generation should be exposed to availability of various genetic resources and its conservation techniques for future use.

V. Aim of the course

To impart technical knowledge to students on the current issues and techniques of germplasm conservation for sustainable utilization in agriculture.

VI. Theory

Unit I

Biological diversity in India – importance – need for conservation – concept of natural reserves and gene banks; post-exploration handling of germplasm collections, preservation of seed and plant specimens, importance and use of herbaria; *in-situ* conservation – components – biosphere reserve – natural park; factors influencing conservation; *in-situ* conservation – national programmes – on farm conservation.

Unit II

Ex-situ conservation – components – plant genetic resources conservation in gene banks – national gene banks – gene repositories – seed gene bank – types of collections – base, active and working collections – *perma-frost* seed conservation – guidelines for sending seeds to gene bank; handling of orthodox and recalcitrant seeds for conservation – clonal repositories.

Unit III

Methods of *in-vitro* conservation – short, medium and long term, concept of active and base *in-vitro* genebank; *in-vitro* storage – culture maintenance – problems and perspectives – gene bank maintenance for temperate and tropical fruit crops, spices, tubers, bulbs, medicinal and aromatic plants; conservation of embryos and ovules, meristem, cell/ suspension cultures – protoplast and callus cultures – pollen culture – micro propagation techniques – genetic stability under long term storage.

Unit IV

Cryopreservation – principle and method – handling of orthodox and recalcitrant seeds for cryopreservation – cryoprotectants – desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation and dehydration techniques; application of cryopreservation techniques for agricultural, horticultural and forest crops.

Unit V

Gene bank standards for various crops – monitoring viability of stored seed samples – multiplication and regeneration of stored germplasm materials – National and International organizations – NBPGR and NPGRI – roll and functions; Dooms-day safe seed vault – Biodiversity International – conservation guidelines.

VII. Practical

- Study on *In-situ* conservation methods and case studies;

- Plant exploration, germplasm collection and documenting passport data;
- *Ex-situ* conservation techniques for long term conservation of germplasm collections;
- Preparation and handling of materials, packaging and documentation;
- Preparation of seed album and herbarium specimens for ex-situ conservation;
- Planning and designing of cold storage units and facilities for gene bank;
- Conservation protocols for orthodox seeds;
- Study of conservation protocols for recalcitrant seeds;
- Conservation techniques for vegetative propagules/ clones;
- Cryopreservation techniques – encapsulation, dehydration, freezing, thawing methods;
- Cryopreservation of *in-vitro* cultures – meristem, embryo, cell suspension and pollen cultures;
- Study on freezing and vitrification techniques;
- Conservation technique of forest tree species;
- Study on *in-vitro* cryo-genebanking and database management;
- Visit to national and regional seed gene banks;
- Visit to on-farm conservation sites and Botanical Survey of India.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Practical experiments
- Exposure/ field visits

IX. Learning outcome

This course will enable the students to understand the techniques of germplasm preservation and long term storage of gene pool and seeds.

X. Suggested Reading

Basra AS (Ed.). 1995. *Seed Quality: Basic Mechanisms and Agricultural Implications*. Food Product Press, USA.

Brush SB. 1999. *Genes in the field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

Choudhary DR. 2009. *Guidelines for Storage and Maintenance of Registered Plant Varieties in the National Gene Bank*. Published by Protection of Plant Varieties and Farmer's Rights Authority. Ministry of Agriculture and Farmers Welfare, GoI, New Delhi.

Gupta D. 2009. *Seeds: Their Conservation Principles and Practices*. Sathish Serial Publishing House. New Delhi.

Jarvis DI, Meyer L, Klemick H, Guarino L, Smale M, Brown AHD, Sadiki M and Sthapit B. 2000. *A Training Guide for In-situ Conservation On-farm*. Version 1. International Plant Genetic Resources Institute, Rome, Italy.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur.

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices*. Springer Science and Business Media., Boston, USA.

Meerabi G and Pullaiah T. 2015. *Plant Biodiversity Conservation and Management*, Daya Publishing House, Delhi.

Rao NK, Hanson J, Dulloo ME, Ghosh K, Nowell A and larinde M. 2006. *Manual of Seed Handling in Genebanks*. Bioversity International, Rome.

Vernoy R, Shrestha P and Sthapit B. 2015. *Community Seed Banks: Origins, Evolution and Prospects*, Oxford, Routledge, UK.

XI. Suggested e-books

https://www.springer.com/gp/book/9783319225203
https://www.onlinelibrary.wiley.com/doi/10.1002/9781118316467.ch4
https://www.trove.nla.gov.au/work/10718000?q&versionId=12505038
http://www.libgen.io/book/index.php?md5=E4F14ADA7E2D7F05B1E7CA5C6EF F18E5
http://www.libgen.io/book/index.php?md5=ACEC8DC5834E84F9C13ACB780FA 760BC
http://www.libgen.io/book/index.php?md5=582A419EE2C82B58B98BFD7D856FDB91
http://www.libgen.io/book/index.php?md5=719F94827A8976F06BF2E6DC6FB9C093
http://www.cure.edu.uy/sites/default/files/04Libro%20Advances%2Bin% 2BPlant%202016.pdf
https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/germplasm-conservation
https://www.crcpress.com/Seed-Quality-Basic-Mechanisms-and-Agricultural-Implications/Gough/p/book/9781560228509
https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Establishment_and_management_of_field_genebank_786.pdf

XII. Suggested websites

http://www.nbpgr.ernet.in/
http://www.bioversityinternational.org
http://www.nap.edu/read/2116/chapter/7
http://www.ncbi.nlm.nih.gov/pubmed/18080461
http://www.regjeringen.no/en/topics/food-fisheries-and-agriculture/svalbard-global-seed -vault/id462220/

I. Course Title : Seed Ecology
II. Course Code : SST 609
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is highly influenced by ecological situation in which the seed is produced. Seed also possess several adaptive mechanisms to escape from unfavourable environmental/ ecological situations. Study of underlying mechanisms and ecological significances of the seeds will be useful to the students to carryout research as well as production of quality seeds at different ecological conditions. This course also deals with the ecological strategies acquired by the seed for successful perpetuation.

V. Aim of the course

To study the influence of ecology on seed production, reproductive biology, seed dispersal, longevity and adoptation mechanisms and to study the effect of pollutants on seed production and quality.

VI. Theory

Unit I

Introduction to ecology – seed ecology – importance – genetic effects – geographic adaptation of native and invasive species; ecological factors on seed germination and regeneration; reproductive allocation – reproductive effort; flowering phenology, assessment of resource allocation – positional and azimuth influence on flowering and reproduction; influence of climate change on reproduction, seed formation, germination and dormancy.

Unit II

Seed dispersal – definition – modes of dispersal, dispersal dynamics, aerial seed dispersal, pre and post dispersal hazards, seed predators and ecological significance. Seed polymorphism – types, causes, consequences on seedling adaptation.

Unit III

Soil seed bank – definition – classification – soil seed bank dynamics. Thermodynamic models – population dynamics in soil seed bank – seed longevity and germination models in soil seed bank – weed seed ecology and longevity – long term experiments in buried seeds; ecological significance of seed dormancy and seed polymorphism.

Unit IV

Influence of environment on seed germination – allelopathy, temperature, light, moisture and gaseous environment – eco-physiological role in seed storage.

Unit V

Effect of pollutants – air, water and soil pollutants on seed germination and seedling establishment – factors limiting seedling establishment – problem soils and seed management techniques – climate change and seed production – management strategies to overcome the effect of climate change on seed production and germination.

VII. Practical

- Understanding flowering phenology of different crop species;
- Study of seed dispersal mechanism of different crop species;
- Study on agents and distance of dispersal of different crop species;
- Studies on pre and post dispersal hazards;
- Assessing the natural regeneration in relation to ecology;
- Assessing the problems related to natural regeneration;
- Experiment on naturally buried seeds – dormancy and longevity;
- Studies on effect of environmental factors on seed germination and dormancy;
- Influence of seed polymorphism on germination and dormancy;
- Assessing the allelopathy effect on seed germination in crop species;
- Effect of soil pollutants on seed germination;
- Effect of air pollutants on germination of crop seeds;
- Effect of water pollutants on growth on seed quality;
- Seed management practices for polluted environment and climate change effects;
- Visit to *in-situ* and *ex-situ* conservation sites;
- Visit to biological hotspots.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Practical experiments
- Exposure/ field visits

IX. Learning outcome

This course will make the students to understand the problems in natural regeneration, storage and dormancy and to address these problems.

X. Suggested Reading

Baskin CC and Baskin JM. 1998. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Elsevier, Netherlands.

Fenner M and Ken Thompson. 2005. *The Ecology of Seeds*. Cambridge University Press, London, United Kingdom.

Heydecker W. (Ed.). 1985. *Seed Ecology*. Penn State University Press.
Kozolowski TT. 1972. *Seed Biology* Vol. II, Academic Press., New York and London.
Maiti RK, Sarkar NC and Singh VP. 2006 *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, India.
Sinclair TR and Gardner FP. 1977. *Principles of Ecology in Plant Protection*. CAB International, Wallingford, United Kingdom.

XI. Suggested e-books

https://www.springer.com/gp/book/9780412259302
https://www.cabi.org/bookshop/book/9781845936549
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2000770/
https://www.link.springer.com/chapter/10.1007/978-94-009-4844-0_4
http://www.libgen.io/book/index.php?md5=0CE8B3A7FC6224F8467E8D344B590741
http://www.libgen.io/book/index.php?md5=4AA6FDA278BAA40C1B47BA1EB9E8BC4
http://www.libgen.io/book/index.php?md5=31A06377ADC97C71831D82D4516A4DD7
http://www.libgen.io/book/index.php?md5=97028932B0E1278AE3BE17D231B41F23
http://www.ideal.egranth.ac.in/cgi-bin/koha/opacdetail.pl?biblionumber=116395&shelfbrowse_itemnumber=244623
http://fes.org.in/source-book/ecological-restoration-source-book.pdf?file=ZG93bmxvYWQvd3AxOS5wZGY=?file=ZG93bmxvYWQvd3AxOS5wZGY=
https://www.researchgate.net/profile/Arvind_Singh56/post/I_would_like_to_know_what_is_ the_ecological_restoration_of_a_fo rest_and_why_is_ it_so_important/attachment/59d641aa79197b807799d9af/AS%3A435934916288512%401480946391722/download/1.pdf

XII. Suggested Websites

https://nieindia.org
http://www.uky.edu/hort/Propagation-Seed-Ecology
https://ecology.uni-hohenheim.de
https://www.biologie.uni-regensburg.de/seed ecology
https://researchonline.jcu.edu.au/52954/
http://agris.fao.org/agris-search/search.do?recordID=US201600101233
https://www.oxfordbibliographies.com/view/document/obo-9780199830060/obo-978019983 0060-0086.xml

I. Course Title : Seed Planning, Trade and Marketing
II. Course Code : SST 610
III. Credit Hours : 2 (1+1)

IV. Why this course?

Introduction of high yielding varieties and hybrids in various crops enhanced the International trade on seeds. To meet the international and domestic seed demand, well-structured planning and marketing is essential. This course will expose the students to gain knowledge and skill on planning for a sound seed programme and procedures of trade and to address the trade related issues.

V. Aim of the course

To impart knowledge on planning seed production programmes, national and international movement of seeds and marketing strategies.

VI. Theory

Unit I

Seed industry – genesis, history and growth – structure of seed industry in India – mission and objectives of seed Industry; status and role of seed industry in Indian agriculture.

Unit II

Seed production programmes – characters, types; planning and organizing seed programmes in public and private sectors – small, medium, large and more advanced seed programmes – local, national and international seed programmes; seed demand forecasting – purpose – methods and techniques – factors determining seed demand – seed multiplication ratio, seed replacement rate and variety replacement rate; seed production planning for varieties and hybrids – compact area approach and seed village – contractual seed production – custom seed production – public private partnership – transgenic seeds – demand assessment.

Unit III

New seed policy – genesis – functions; WTO – Indian seed industry – patenting and *suigeneris* system – The Seeds Bill, 2004 and 2011; role and contributions of MNC's in seed trade in India; International trade of seeds – government policies – International organizations involved in seed movement and trade – International Seed Federation (ISF), ISTA – OECD seed schemes – operational guidelines; import and export of seeds – Exim policies – guidelines and salient features; seed production and quality control systems in SAARC Nations and other developed countries; quarantine measures – procedures, guidelines and certificates in international seed movement and trade.

Unit IV

Seed production and distribution system in central and state governments, co-operative and private organisations – seed marketing – definition, concept, importance and type of markets – domestic and global market – problems and perspectives; marketing polices – seed marketing schemes, marketing channels – responsibilities of dealers – marketing mix; handling and management of sales return seed stocks.

Unit V

Seed pricing – local market rate – factors affecting prices and pricing policies – fixation of procurement and sale price of seeds – cost analysis – seed market intelligence – marketing promotional activities; seed supply chain management – missing link – risk and management.

VII. Practical

- Data collection on status of Indian and global seed industry;
- Planning seed programmes for varieties and hybrids;
- Planning for establishment of small and medium seed enterprises;
- Planning for establishment of large scale seed enterprises;
- Planning for custom seed production and contractual seed production;
- Assessment of seed demand – demand forecasting methods;
- Assessment of seed multiplication ratio, seed replacement rate and variety replacement rates for different crops;
- Study on the economics of seed production and marketing;
- Exercise on fixing procurement and sale price of seeds;
- Study of seed marketing channels – survey and interaction with seed dealers and distributors;
- Visit to plant quarantine station and study of quarantine requirements and certificates for domestic and international seed trade;
- Visit to modern seed processing unit, advanced seed storage complex and interactions;
- Visits to state seed corporations;
- Visit to MNCs and expert discussion;

- Case studies and SWOT analysis;
- Planning for establishment of new seed ventures and project preparations;

VIII. Teaching methods

- Classroom lectures
- Students assignment and presentations
- Group discussions
- Field visits and industry visits

IX. Learning outcome

Completion of this course will enable the students to gain knowledge and to start successful seed business.

X. Suggested Reading

Acharya SS and Agarwal NL. 2004. *Agricultural Marketing in India*, 4th Ed. Oxford and IBH.
Agrawal RL. 1996. *Seed Technology*. Oxford, IBH Publishing Co., New Delhi, India.
Broadway AC and Broadway A. 2003. *A Text Book of Agri-business Management*.
Dadheech PK. 1996. *Seed Programming, Management System and Concepts*. Lok Sahitna Kendra, Jodhpur.
Feistrizer P and Fenwickkelly A. 1978. *Improved Seed Production*. FAO, Rome, Italy.
Gurudev Singh and Asokan SR. 1997. *Management of Seed Production Activity*. Oxford and IBH Publishing Co., New Delhi, India.
Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi, India.
Kalyani Singh AK and Pandey S. 2005. *Rural Marketing*. New Age Publications.
Krishnasamy V, Ponnuswamy AS, Balamurugan P, Srimathi P, Natarajan N and Raveendran TS. 2004. *Compendium on Seed Science and Technology*. Directorate of Publications, Tamil Nadu Agricultural University, Coimbatore, India.
Kugbei S. 2008. *Seed Economics*. Scientific Publishers, Jodhpur.
Singh G and Asokan SR. 1992. *Seed Replacement Rate: Some Methodological Issues*. Indian Institute of Management, Ahmedabad, India.
Singh S. 2004. *Rural Marketing – Focus on agricultural Inputs*. Vikas Publishing House.

XI. Suggested e-books

http://www.pondiuni.edu.in/storage/dde/downloads/mbaii_mm.pdf
http://agricoop.nic.in/divisiontype/seeds
https://www.audiencebloom.com/all-in-one-guide-to-planning-and-lauching-content- marketing-strategy/
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15
http://www.fao.org/3/V4450E/V4450E00.htm
https://books.google.co.in/books?id=vPVlBos4WkYC
http://download.nos.org/srsec319new/319EL19.pdf
https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf
https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by- Gaur-SC

XII. Suggested websites

www.gov.mb.ca
www.agricoop.nic.in
www.agri.nic.in
https://sathguru.com/seed/
http://www.fao.org/3/V4450E/V4450E03.htm
https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf
https://www.icrisat.org/seed-systems-models-lessons-learned/
https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Sciences
– Plant Genetic Resources

Preamble

(Plant Genetic Resources)

Plant Genetic Resources (PGR) constitute the basic raw material required essentially for the crop improvement programmes. Agro-biodiversity is the key to success of any programme. The Indian sub-continent is a centre of diversity for several of our crop plants assuming significance globally. Over the last four decades, national and international communities have repeatedly emphasized the use of PGRs for Food and Agriculture (PGRFA). PGR management encompasses assembling and conserving PGRFA, adding value to them through characterization and evaluation, quarantine, supply of pest-free samples, biosecurity. In a latest study by CGIAR genebanks, the scenario has changed due to "highly politicized nature of access and benefit sharing issues at the international, national and local levels". At ICAR level emphasis has been laid on enhanced utilization of Crop Wild Relatives, effective characterisation and documentation, conservation in genebanks, streamlining of germplasm exchange within the purview of national interest, resolution of controversial issues and implementation of multi-lateral system to develop a good vision for agrobiodiversity management.

In view of the current scenario, need for specialised human resource for teaching cutting edge technology with application of basic as well as applied aspects like germplasm assemblage, handling, access to users with benefits, long term genebanking of international standards, biotechnology, pre-breeding for utilizing wild species for future crop improvement, increasing entrepreneurship, etc., would warrant students to have strong knowledge of practical and management skills which will help them to face the competitiveness in public and private sector.

Hence, restructuring of course curricula and delivery system to match with the present situation was felt. In this proposed revision of curriculum in Plant Genetic Resources, the BSMA sub-group organized a series of meetings and electronic media-led consultations to develop a set of courses suitable for M.Sc. and Ph.D. students of the discipline.

Emphasis was laid on basic concepts of Germplasm Exploration and Plant Systematics, Plant Diversity and Conservation, Genetic Enhancement for PGR Utilization, Genomics in PGR management, as well as the innovative developments for M.Sc. and Phenomics and Genomics for PGR Utilization, Plant Taxonomy, Ecogeography and Ecology for Ph.D. courses. The latest state of the art technologies including biotechnology and molecular biology will enable a complete coverage of the subjects. The basic courses have therefore been kept as compulsory courses which need to be taken by all the students irrespective of the subject specialization or stream from which they entered into PG education. The genomic revolution has generated detailed population genetic data. Big data samples of complete genome sequences of many individuals from natural populations of many species have transformed population genetics inferences on samples of loci to population genomics. Molecular analyses of these is essentially to be taught to students. Hence basic concepts of genetics to develop analytical, quantitative and problem-solving skills in classical and molecular genetics for PGR management is incorporated. One of the courses would be to provide knowledge in genomic tools and their application in PGR exploration, collection, conservation and utilization. To provide knowledge in genomic tools and their application in plant genetic resource exploration, collection, conservation and utilization, one course on plant genomics have been framed to develop high-throughput genome-wide-scale technologies, tools and methodologies to elucidate the basics of genetic traits/ genetic diversity in organisms.

In the era of Intellectual Property Rights (IPRs) it is imperative to teach concepts and instruments of, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources which would be done through one course. In addition to conventional hybridization, there is a need for precise tools to decipher the molecular basis of genetic diversity through mapping and sequencing. In one of the courses students would be taught basics of genome structure and organization, generation of molecular markers-basic principles, molecular marker techniques, data handling and analysis of GM. Another course would deal with germplasm data base management using modern tools and softwares. To educate about protecting the economy, environment and plant health from pests and disease including preventing new pests and diseases from arriving, and helping to control outbreaks when they do occur, biosecurity issues for India would be taught.

By intensive discussion with the core faculty, PGR experts and based on the feedback from faculty of ICAR-National Bureau of Plant Genetic Resources, the entire syllabus was restructured with the improvement in existing courses as well addition of new courses. The syllabus was suitably finalized with the view to equip the students to aspire knowledge and skill sets and mould towards entrepreneurship and build themselves to prepare for global competiveness. The BSMA Committee held discussions over four sessions on the topical issues concerning Plant Genetic Resources. The curricula and syllabi were discussed at length in the meetings and workshops. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the committee. The new look and restructured PG programmes in PGR have been designed keeping in view latest international commitments, role of private sector, modern research tools and their applications, supplementary skills required, and to enhance the global competitiveness and employability of our students. Considerable efforts have, therefore gone in for the preparation of this document.

Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses that have been incorporated based on their importance and applied aspects both at national and international level are Genetic Enhancement for PGR Utilization; Genomics in PGR management; Phenomics and Genomics for PGR Utilization; Concepts in Conservation Genetics; Genomic tools and current applications.

Course Title with Credit Load
M.Sc. (Ag.) in Plant Genetic Resources (PGR)

Course Code	Course Title	Credit Hours
PGR 501*	Germplasm Exploration and Plant Systematics	3(2+1)
PGR 502*	Plant Diversity and Conservation	3(2+1)
PGR 503*	Germplasm Characterization and Evaluation	2(1+1)
PGR 504	Genetic Enhancement for PGR Utilization	2(1+1)
PGR 505*	Economic Botany	3(2+1)
PGR 506	Information Management in PGR	2(1+1)
PGR 507*	PGR Exchange and Quarantine	3(2+1)
PGR 508	Genomics in PGR management	2(1+1)
PGR 509	Plant Biosecurity	1(1+0)
PGR 510	Principles of Genetics for PGR Management	2(2+0)
PGR 511	Principles of Plant Breeding for PGR Management	2(1+1)
PGR 512	Concepts in Conservation Genetics	2(1+1)
	Major courses (minimum 20 credits from above courses including *marked Courses)	20
	Minor courses	08
	Supporting courses	06
	Common compulsory courses	05
PGR 591	Seminar	01
PGR 599	Thesis/ Research	30
	Total Credits	**70**

*Compulsory Major Courses

Course Contents
M.Sc. (Ag.) in Plant Genetic Resources (PGR)

I. Course Title : Germplasm Exploration and Plant Systematics*

II. Course Code : PGR 501

III. Credit Hours : 3 (2+1)

IV. Why this course ?

Students need to be educated about the relationships between plants and their evolution, and actual handling of plant specimens during explorations and collections of various germplasm.

V. Aim of the course

The course is designed to make students understand reconstruction of the evolutionary history and classification of plants into taxonomic groups, introduce the students to the theory and practice behind systematic conduct of exploration, ecogeographic survey, sampling strategies, post harvest methods.

VI. Theory

Unit I

History of germplasm exploration, distribution and extent of prevalent genetic diversity; phyto-geographical regions/ ecological zones and associated diversity; Geo-Spatial analysis using GIS (Geographical Information System) tools for mapping eco-geographic distribution of diversity, threatened habitats, remote sensing, use of drones, need for collection missions, Planning and execution, Use of floras, Concept of population and gene pool; gene pool sampling in self- and cross-pollinated and vegetatively propagated species, non-selective, random and selective sampling strategies, coarse and fine grid surveys, planning collection and analyses of eco-geographic data, assessing the threats of genetic erosion.

Unit II

Ethnobotanical aspects of PGR, crop botany, farming systems, collecting wild relatives of crop plants; Post-exploration handling of germplasm collections, preservation of specimens, importance and use of herbaria and preparation of herbarium specimens.

Unit III

Crop Systematics, nomenclature; International code for binomial nomenclature, systems of classification; concept of species and taxa, biosystematics and terminologies for plant description, Classical and modern species concepts, differentiation and evolution of species: speciation, variation within species, phenotypic plasticity.

Unit IV

Taxonomy of higher/ cultivated plants: use of taxonomic literature such as floras, manuals, monographs, indices, catalogues and dictionaries, concept and methods of herbarium and field study, criteria used for classification, identification of plants of economically important families, floristic and monographic works, Modern trends in plant taxonomy – Chemotaxonomy, Numerical taxonomy and Cytotaxonomy; Cronquist system – Angiosperm Phylogeny (AGP) Group classification; molecular systematics – Primary and Secondary metabolites – Semantides; global taxonomic initiatives- barcoding, taxonomic databases.

VII. Practical

- Plant exploration and germplasm collecting, documenting passport data, use of flora and maps, collecting vegetatively propagated species;
- Local field visit for recording of ethnobotanical information/ notes, herbarium collection, report writing on germplasm collecting missions;
- Post exploration handling;
- Collecting wild relatives of crop plants';
- Preparation, maintenance and use of herbarium, Ecogeographical surveys and inventory, Use of GIS in biodiversity mapping and collecting;
- Estimation of genetic diversity in traditional agroecosystems on farm, matrix ranking of farmer selection criteria;
- Classical and modern species concepts and biosystematics, Morphology and anatomy;
- Comparative studies on phytochemistry, Chemotaxonomy;
- Floristic and monographic work; Practical methods for elucidating and proving hypotheses relating to plant speciation, Numerical taxonomy-practice and procedures, Infraspecific categories in relation to population biology, Taxonomic databases and documentation methods in relation to PGR, Taxonomy of crop plants, cultivated species, domesticated species, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation;
- Visit to Biosphere reserves/ renovated degraded ecosystems and Farmer's fields for landraces, visit to NBAGR/ NBPGR Regional stations.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The student will learn to recognize plant families that is commonly cultivated and also learn to identify crop plants and their wild relatives. Exposure to learn the major principles and methods of plant taxonomy (systematics) will help to instill an appreciation of the application of plant taxonomy in the field of plant breeding science and utilise them in everyday life.

X. Suggested Reading

Barrough PA. 1986. *Principles of Geographic Information System for Land Resources Assessment*. Oxford University Press, Oxford, UK.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The Use of Plant Genetic Resources*. Cambridge University Press.

Brown AHD, Clegg MT, Kahler AL and Weir BS. (eds.) 1990. *Plant population genetics, breeding, and genetic resources*. Sinauer Associates, USA.

Chapman and Hall. 1992. *Global biodiversity: Status of the Earth's living resources*. World Conservation Monitoring Centre, London. xx + 594 pp.

Curran PJ 1985. *Principles of Remote Sensing*. Longman Inc., New York.

Davis PH and Heywood VH. 1963. *Principles of Angiosperm Taxonomy*. Oliver & Boyd, UK. 556 p.

Greuter W, Barrie FR, Burdet HM, Chaloner WG, Demoulin V, Hawksworth DL, Jorgenson PM, Nicolson DH, Silva PC, Trehane P and Mcneill J. 1994. *International Code of Botanical Nomenclature*. Regnum Veg. 131, Koeltz. Sci. Books, Konigstein, Germany. 389 p.

Frankel OH and Michaele ES. 1987. *Conservation and evolution*, Cambridge University Press.

Halewood M, Noriega I and Louafi S. 2013. *Crop Genetic Resources as a Global commons: Challenges in International Law and Governance*.

Harlan, J.R. 1992. Crops and Man (Second Edition), American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.

Jackson M, Ford-Lloyd B and Parry M. (editors) 2014. *Plant Genetic Resources and Climate Change*.

Jain SK and Rao RR. 1976. *A Handbook of Field and Herbarium Methods*. Today & Tomorrow's Printers & Publishers, New Delhi, India. 157 p.

Lawrence GHM. 1951. *Taxonomy of Vascular Plants*, Indian ed., 1964. Oxford and IBM Publishing Co., Calcutta, India. 323 p.

Maheshwari JK. 1963. *The Flora of Delhi*. Publications and Information Directorate, CSIR, New Delhi. 447 p.

Meerabi G and Pullaiah T. 2015. *Plant Biodiversity Conservation and Management*. Daya Publishing House, Delhi

Porter CL. 1959. *Taxonomy of Flowering Plants*. W.H. Freeman and Co. Inc., USA. 452 p.

Redden R, Yadav SS, Maxted N, Dullo ME, Guarino L and Smith P. 2015. *Crop Wild Relatives and Climate Change*. Willey-Blackwell.

Zeven AC and De wet JMJ. 1982. *Dictionary of Cultivated Plant and their Regions of Diversity*. Pudoc, Wageningen: Centre for Agricultural Publishing and Documentation.

I. Course Title : Plant Diversity and Conservation*

II. Course Code : PGR 502

III. Credit Hours : 3 (2+1)

IV. Why this course ?

Students need to gain knowledge on biodiversity, especially agrobiodiversity and crop wild relatives germplasm conservation with particular emphasis on genebanks for various species and explants.

V. Aim of the course

The students will grasp the science underpinning biodiversity and agro-biodiversity, concept of PGR, threats to diversity and impact of biotic homogenization for the diversity crisis, concerned legal issues and data recording, various concepts and approaches of plant conservation.

VI. Theory

Unit I

Biodiversity an overview: genetic, species and ecosystem diversity, higher plant diversity, species richness and endemism, biospheres, Gene centres, importance of Indian gene centre. Origin and history of agriculture, conservation and agricultural development, the central role of agro-biodiversity: trends and challenges, centers of crop plant origin and diversity, dynamics of domestication, plant domestication and evolution of crop plants, Crop Wild Relatives, patterns of variation, classification of cultivated plants, concept of gene pool, geographical distribution of crops of Indian origin.

Unit II

Status and trends of agrobiodiversity; Global challenges and conservation of agro-biodiversity-*in-situ, ex-situ,*Impact of climate change on agrobiodiversity, Managing plant genetic resources: Basic science issues; Institutional aspects of managing agrobiodiversity, PGR networks.

Unit III

Agrobiodiversity and livelihoods: Food and nutrition systems, Traditional knowledge, TKDL, Farmers' seed systems and participatory breeding, Valuing PGR and ecosystem services; Value chains of neglected and underutilized (potential crop) species, community biodiversity management.

Unit IV

IPR for innovative entrepreneurship International framework and PGR networks; International treaties and policies in relation to agro-biodiversity conservation, sustainable use and germplasm exchange, CBD, UPOV, ITPGRFA, Nagoya protocol, National policies and legal frame work, Biodiversity Act, PPV and FR Act, Global Plan of action, germplasm registration, IP issues with respect to ITKs and communities, safe guarding biodiversity, case studies, digital sequence information *vs* tangible genetic resources, recent advances in biotechnology and synthetic biology, new forms of life and threats to biodiversity.

Unit V

In situ and *ex situ* conservation: concept of biosphere reserves, gene sanctuaries, on-farm conservation, seed genebanks, Perma-frost conservation, field genebanks, botanical gardens, herbal gardens, *in vitro* repositories and cryo-genebanks; short-, medium- and long-term conservation, concept of base, active and working collections. Importance of seed gene banks; seed structure and function; seed storage behavior, physiological and genetic changes during storage, theories of ageing, viability equations, dormancy. Genebank standards for various crops, ISTA, AOSA, Bioversity International guidelines; monitoring viability of stored samples; strategies for revival and rescue of rare genetic material. Multiplication and regeneration of stored germplasm, Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces.

Unit VI

History and principles of plant tissue culture, Laboratory requirement and general techniques, Tissue culture media, Cellular totipotency, Clonal propagation and clonal multiplication, Somatic embryogenesis, Somaclonal variation, Meristem culture and virus elimination, Cell culture, Anther and pollen culture, Genetic engineering, *In vitro* collecting of plant germplasm, *in vitro* techniques in germplasm exchange, *In vitro* conservation strategies, Concept of *in vitro* active, base genebank and DNA genebank, Introduction to plant cryopreservation, Cryopreservation techniques, Cryopreservation of vegetative propagules and *in vitro* explants, Genetic stability.

Unit VII

Complementary strategies for conservation, scientific basis of *In situ on-farm* conservation; social and cultural context, economic analysis in on-farm conservation, factors influencing farmer variety choice, the value of local crop diversity to markets and to farmers, Community seed genebanks, Institutional frameworks for the implementation of on-farm conservation.

VII. Practical

- Legal issues and FAO code of conduct;
- Seed structure and morphology;
- Seed germination and seedling evaluation;
- Seed viability test, seed sampling and purity analysis, seed dormancy and dormancy breaking treatments, moisture testing methods;
- Vigour testing methods and seed leachate analysis, accelerated aging of seeds and their assessment, seed processing and storage in Gene Bank;
- Preparation of stock solutions, media preparation, preparation of explants and culture initiation in monocots and dicots;
- Meristem isolation and culture establishment, subculture of shoots in monocots and dicots, hardening and field establishment of plantlets;
- Preparation of cryoprotectant solutions and regrowth media, isolation of *in vitro* explants and pre-treatment, cryopreservation of *in vitro* cultures- vitrification based techniques, Encapsulation-dehydration technique, etc.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The students would grasp the science underpinning biodiversity, agricultural biodiversity and conservation imperatives on the global stage. Knowledge on International and National policies and sustainable use of agrobiodiversity would be imbibed by the students.

X. Suggested Reading

Barbara MR, Chin HF and Normah MN. 2013. *Conservation of Tropical Plant Species*, Springer.Frankel OH and Hawks JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press.

Bewley JD and Black M. 1994. *Seeds: Physiology of Development and Germination*. Second Edition. Plenum Press, New York and London. pp. 445.

Benson EE. (ed.). 1999. *Plant Conservation Biotechnology*. Taylor and Fancis Ltd. London.

Bhojwani, Bhojwani SS and Razdan MK. 1983. *Plant Tissue Culture: Theory and Practice.* Elsevier Science Publishing Co.Inc. New York.

Bhojwani SS and Razdan MK. 1983. *Plant Tissue Culture: Theory and Practice*. Elsevier Science Publishing Co.Inc. New York.

Bhojwani SS and Dantu PK. 2013. *Plant Tissue Culture: An introductory text*. Springer.

Bonner FT. 1990. 'Storage of seeds: Potential and limitation of germplasm conservation.' *Forest Ecology and Management*.

Chaudhury R and Malik SK. 2017. *Cryopreservation of Plant Species: Practical Approaches from Handling to Cryobanking*. ICAR-NBPGR, New Delhi. 52 p.

Dodds JH. (eds.) 1991. In vitro *Methods for Conservation of Plant Genetic Resources*. Chapman and Hall, London.

Engels JMM. 1995. In situ *conservation and sustainable use of plant genetic resources for food and agriculture in developing countries*. IPGRI/ DSE.

Engelmann F and Takagi H. (eds). 2000. *Cryopreservation of Tropical Plant Germplasm – Current Research Progress and Application*, IPGRI, Rome/ JIRCAS/Japan.

Ellis RH, Hong TD and Roberts EH. 1985a. *Handbook of Seed Technology for Genebank*. Volume II. Principles and Methodology. International Board for Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985b. *Handbook of Seed Technology for Genebank. Compendium of Specific Germination Information and Test Recommendations*. International Board for Plant Genetic Resources, Rome.

Ford-Lloyd BV, Newburry JH and Callow JA. (eds.) 1998. *Biotechnology and Plant Genetic Resources: Conservation and Use*. CABI, Wellingford.

Guriano L, Ramanatha Rao V and Reid R. 1995. *Collecting plant genetic diversity-Technical Guidelines*. CAB International, Wallingford, UK.

Hong TD and Ellis RH. 1996. A protocol to determine seed storage behaviour. International Plant Genetic Resources Institute IPGRI Technical Bulletin No. 1, Rome.

Jarvis D, Staphit B and Sears L. 2000. *Conserving agricultural biodiversity* in situ: *a scientific basis for sustainable agriculture*. IPGRI, Rome, Italy.

Kartha KK. (ed.). 1995. *Cryopreservation of Plant Cells and Organs*. CRC Press, Boca Rataon, Florida.

Maxted N, Ford-Lloyd BV and Hawkes JG. 1997. *Plant Genetic Conservation: The* In situ *Approach*. Chapman & Hall, London.

McNeely JA. 1988. *Economic and biological diversity: developing and using economic incentives to conserve biological resources*. International Union for Conservation of Nature and Natural Resources, Gland.

Plucknett DL, Smith NJH and Williams JT. 1987. *Genebanks and the World's Food*. Princeton University Press.

Razdan MK and Cocking EC. (eds.) 2000. *Conservation of Plant Genetic Resources* In vitro, Vol. 2: Applications and Limitations. Science Publishers, Inc. USA.

Redden R, Yadav SS, Maxted N, Dulloo ME, Guarino L and Smith P. (eds.) 2015. *Crop wild relatives and climate change*. Wiley-Blackwell. 400 p. ISBN: 978-1-118-85433-4.

e-resource

www.iucnredlist.org

I. Course Title : Germplasm Characterization and Evaluation*

II. Course Code : PGR 503

III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to learn about morphological and quality agronomic traits of accessions as well as their reaction to biotic and abiotic stresses. This will increase the importance of the germplasm.

V. Aim of the course

Students will gain knowledge on germplasm characterisation, evaluation and documentation of information. Recording of morphological and agronomic traits, including quality, as well as those for resilience to biotic and abiotic stresses that will promote utilisation. Exposure to development of web based tools for systematic description for efficient use of germplasm.

VI. Theory

Unit I

Understanding genetic diversity in crop plants; Crop descriptors, descriptor states; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits; Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation, markers and their use in PGR, evaluation of biotic and abiotic stresses, Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.

Unit II

Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces, evaluation and maintenance of wild relatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement.

Unit III

High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping) – evaluation for nutritional traits, resistance traits -Biochemical and molecular markers for characterization.

VII. Practical

- Field layout and experimental designs;
- Recording field data on germplasm evaluation in different agri-horticultural crops;
- Post harvest handling;
- Evaluating quality traits, biochemical and phyto-chemical evaluation of crop germplasm, data processing;
- Documentation, analysis of diversity and cataloguing, data analysis, viability equations, sampling strategies, data documentation, cataloguing, biochemical analyses of samples.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

To educate students about science of managing genetic resources including principles involved in maintaining genetic integrity during regeneration, germplasm characterization and evaluation.

X. Suggested Reading

Brown AHD, Clegg MT, Kahler AL and Weir BS. (eds.). 1990. Plant Population Genetics, Breeding, and Genetic Resources, Sinauer Associates, USA.

Frankel R and Galun E 1977. 'Pollination Mechanisms, Reproduction and Plant Breeding', *Monographs on Theoretical and Applied Genetics*. Springer-Verlag, Berlin, Heidelberg.

Hayward, MD, Bosemak, NO and Romagosa, I. 1993. Plant Breeding: Principles and Practices, Chapman & Hall.

Holden JHN and Williams JT. 1984. *Crop genetic resources: conservation and evaluation*. IBPGR.

Puzone L and Th. Hazekamp. 1996. *Characterization and Documentation of Genetic Resources* Utilizing Multimedia Database. NBPGR, New Delhi.

Rana RS, Sapra RL Agrawal RC and Gambhir R. 1991. *Plant Genetic Resources, Documentation and Information Management*. NBPGR, New Delhi.

Stoskopf NC. 1993. *Plant Breeding: Theory and Practice*. Westview Press.

Sundeep Kumar, *et al.* 2016. *Evaluation of 19,460 wheat accessions conserved in the Indian national genebank to identify new sources of resistance to rust and spot blotch diseases*. PloS One Vol 11, pages 0167702.

Tripathi K, Bhardwaj R, Bhalla S, Kaur V, Bansal R, Yadav R, Gangopadhyay KK, Kumar A and Chaudhury R. 2018. *Plant Genetic Resources Evaluation: Principles and Procedures*.

Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi. vi+50 p.

I. Course Title : Genetic enhancement for PGR Utilization

II. Course Code : PGR 504

III. Credit Hours : 2(1+1)

IV. Why this course ?

Pre-breeding is a vital step in the link between plant genetic resources conservation and its use; Hence, this course is designed to inculcate theoretical and practical know how to understand and use classical and advanced plant breeding methods for planning and execution of prebreeding programmes so that the PGR is put into effective use for food and agriculture.

V. Aim of the course

To teach theoretical and practical know how on CWRs reproductive behavior, acclimatization and adaptation for utilization in prebreeding programmes usig advanced tools.

VI. Theory

Unit I

Concepts of gene pools; Introduction, potential of pre-breeding. Role of crop wild relatives, semi exotics, creating and managing variation, basic concepts to set up a successful pre-breeding programme.

Unit II

Understanding crop adaptation, handling and maintenance of CWRs, synchronization of flowering, overcoming impediments to flowering through photoperiodic adjustments, role of other barriers to flowering, role of amphidiploids, semi exotics and other unadapted germplasm, identifying desirable traits in natural populations, screening for biotic and abiotic stress resistance traits; screening of nutritionally important traits, genetic analysis to understand the inheritance of novel traits.

Unit III

Parental selection for prebreeding, search for superior genotypes, breeding methods for trait transfer; moving the genes – unadapted to adapted, wide hybridization, Incongruity and its management, modern tools for incongruity management, cytogenetical approaches for gene transfer such as alien addition and substitution, segregating populations and their management in wide crosses, purging the undesirable traits, testing and improving the adaptability of wide cross derivatives, cytological studies, florescence microscopy, embryo rescue methods, pollen physiology and storage, pollen storage methods to facilitate wide hybridization, pre- and post-zygotic barriers.

VII. Practical

- Characterization of CWRs by visiting the fields;
- Screening methods for special traits-biotic and abiotic resistance;
- Screening for nutritional traits;
- Crossability studies in CWRs of cereals, legumes, oilseeds, vegetables. Assessment of pre and post-zygotic barriers in wide hybridization crosses;
- Pollen storage studies;

- Special requirements for growing CWRs, inducing flowering by manipulating day length, temperature, chemical spraying, etc.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be conversant with handling of unadapted germplasm, screening methods for special traits-biotic and abiotic resistance, nutritional traits, characterization of CWR, breeding, etc.

X. Suggested Reading

Andey Pereira. 2006. *Plant Reverse Genetics: Methods and Protocols*. Humana Press

Bisht *et al*. 2004. 'Broadening the genetic base of sesame (*Sesamum indicum* L.) through genetic enhancement.' *Plant Genetic Resources* **2**(3): 143-151.

Duvick DN. 1990. 'Genetic enhancement and plant breeding', p. 90-96. In: J Janick and JE Simon (eds.), *Advances in new crops*. Timber Press, Portland.

Dale, JW and von Schantz, M. 2007. From genes to genomes. Concepts and applications of DNA technology. John Wiley & Sons Ltd., Chichester, England.

Goodman, RM. 2004. Encyclopedia of plant and crop science. Marcel Dekker Inc., Switzerland.

Kimber, G and Feldman, M. 1987. Wild Wheat: An introduction. Special report 353, College of Agriculture, University of Missouri-Columbia.

Lynch, M. and Walsh, B. 1998. Genetics and analysis of quantitative traits. Sinauer Associates Inc., MA, USA.

Murphy, D. 2007. Plant breeding and biotechnology: Societal context and the future of agriculture. Cambridge University Press, Cambridge, UK.

Ram JS. 2010. Plant Cytogenetics. CRC Press.

Ramanatha Rao V, Brown AHD, Jackson M. 2001. *Managing Plant Genetic Diversity*. CABI Publication.

Sharma S, Upadhyaya HD, Varshney RK, *et al*. 2013. 'Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes.' *Frontiers in Plant Science* **4**: 309.

Yunbi Xu. 2010. Molecular plant breeding, CABI publishers

e-Resources

https://www.integratedbreedPlaning.net/pre-breeding-effective-use-plant-genetic-resources http://www.croptrust.org/ http://www.bioversityinternational. org/training/training_materials/pre_breeding.htm http://www.grdc.com.au/director/research/prebreeding

I. Course Title : Economic Botany *

II. Course Code : PGR 505

III. Credit Hours : 3(2+1)

IV. Why this course ?

To study the relationship between people and plants including anthropology, botany and use.

V. Aim of the course

The student will learn concept of economic botany and relationship between human and plants including cultivation and economic uses in everyday life.

VI. Theory

Unit I

Introduction to economic botany, Origin of agriculture, domestication and adaptations of cultivated plants, classification into crop groups, reproductive systems and breeding behaviour of crop plants.

Unit II

Origin, evolution, botany, cultivation, use, genetic resource management and utilization of important crops, viz., cereals, pseudo-cereals, millets, legumes, forage and fodder crops, oil yielding plants, fibre yielding plants, under-utilized and under-exploited plants, new and potential crops, processing and use of crop residues.

Unit III

Important taxa in horticulture, floriculture and agro-forestry. Origin, evolution, botany, cultivation, use, genetic resource management and utilization of genetic diversity of important crops, viz., vegetable crops, fruits and nuts, medicinal and aromatic plants, spices and condiments, beverages, fumitory and masticatory plants, rubber yielding plants, wood and timber yielding taxa, cellulose, starch and sugar yielding plants, insecticidal and herbicidal plants, important taxa in agro-forestry, flavouring agents, gums and resins.

VII. Practical

- Botanical microtechniques for the study of structure, development and biochemical status of plant parts;
- Identification of economically important plant parts in different groups of plants-oil yielding plants, cereals, millets, legumes, spices, condiments, woods, timber and industrial crops, medicinal and aromatic plants and fumitory, masticatory plants;
- Structure of economic plant parts-root, stem, leaves, fruits, seeds, recognizing the grains;
- Case studies on adaptations during domestication;
- Histochemical localization of chemical constituents in economically important plant parts e.g. starch-sugars, Proteins-lipids; and studies on sugar, starch, cellulose, fibers, gums, rubber and resins;
- Visit to Museum of economic products in other Institutes, visit to industrial units processing the economic products.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The student will learn concept of economic botany in the field of plant science and utilise them in everyday life.

X. Suggested Reading

Atkinson ET. 1980. *The Economic Botany of the Himalayas*.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*. Cambridge University Press.

Burkill IH. 1951-52. Habits of man and the origins of the cultivated plants of the old World. *Proceeding Linnean Society of London*, 164: 12-42.
Frankel OH and Hawks JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press.
George W. 2014. *Dictionary of Economic Products of India*. Cambridge University Press.
Hanelt P. 2001. *Mansfeld'sencyclopedia of agricultural and horticultural crops*, vol 3. Institute of Plant and Genetics and Crop Plant Research (eds) Springer, Berlin.
Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.
Hill AF. 1952. *Economic Botany: A Textbook of Useful Plants and Plant Products*. Second Edition. New York Toronto London McGraw-hill Book Company, Inc.
Kochhar SL. 2012. *Economic Botany in the Tropics*. Paperback, Fourth edition. Laxmi Publications.
Maiti RK and Singh VP. 2006. *An Introduction to Modern Economic Botany*. Eastern Book Corporation, Delhi.
Mehra KL and Arora RK. 1982. *Plant Genetic Resources of India: their diversity and conservation*. NBPGR, New Delhi.
Morton JF. 1987. *Fruits of warm climates*. Creative Resource Systems. Inc. NC Miami, FL.
Paroda RS and Arora RK (eds.). 1991. *Plant Genetic Resources: Conservation and Management*. NBPGR, New Delhi.
Purseglove W. 1981. *Tropical Crops. Dicotyledons*. The English Language Book Society and Longman.
Purseglove W. 1981. *Tropical Crops. Monocotyledons*. The English Language Book Society and Longman.
Schery RW. 2001. *Plants for Man*.
Simpson BB and Ogorzaly M. 2013. *Plants in Our World: Economic Botany*, McGraw-Hill Education, New York, NY.
Simpson BB, Molly Ogorzaly, Simpson Beryl. 2001. *Economic Botany: Plants in Our World*. Mcgraw-hill Science/ engineering/ math.
Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. Mc MIllan Press.
Wealth of India: Raw material series, CSIR, India

I. Course Title : Information Management in PGR
II. Course Code : PGR 506
III. Credit Hours : 2 (1+1)

IV. Why this course ?

Vast amount of information is generated in various disciplines and it needs to be documented in proper way.

V. Aim of the course

To train students in germplasm data base management using modern tools and softwares.

VI. Theory

Unit I

Documentation of germplasm collections, principles of documentation of information in genebanks, concept of data base creation and management; Relational Database Management Systems; Web based PGR networks.

Unit II

Statistical techniques in management of germplasm, developing core collection, estimating sample size during plant explorations, impact of sampling on population structure.

Unit III

Sequential sampling for viability estimation, introduction of binomial, normal and negative cumulative normal, use of Probit scales, viability equations and nomograms, estimation of sample size for storage and viability testing. Germplasm documentation; basics of computer and operating systems, database management system- PGR Portal, Cryodatabase, *In vitro* genebank database, use of statistical softwares, pictorial and graphical representation of data; Introduction to communication network.

Unit IV

Introduction to database management and DBMS, Introduction to Perl and Bioperl. Collection and storage of sequences, NCBI- providing access to biomedical and genomic information.

VII. Practical

- Experimental designs and data analysis;
- Viability equations, sampling strategies, data documentation;
- Cataloguing;
- PGR portal, Cryodatabase management;
- Writing programmes in Perl for bioinformatics applications.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations
- Hands-on-learning on computer

IX. Learning Outcome

Students would be well versed with database management system and use of statistical softwares.

X. Suggested Reading

Agrawal RC, Archak S and Tyagi RK. 2012. *An overview of biodiversity information with special reference to PGR*. Computer and Electronics in Agriculture 84: 92-99.

Archak S and Agrawal RC. 2013. *PGR informatics at the NBPGR: Status, challenges and future*. In A road map for implementing the MLS of ABS in India (Eds Halewood, M, Brahmi, P.Mathur, PN and Bansal, KC). Bioversity International, Rome and NBPGR, New Delhi.

Painting KA, Perry MC, Denning RA and Ayad WG. 1993. *Guide Book for Genetic Resources Documentation*. IPGRI, Rome, Italy.

Puzone L and Th. Hazekamp. 1996. Characterization and Documentation of Genetic Resources Utilizing Multimedia Database.

Rana RS, Sapra RL, Agrawal RC and Gambhir R. 1991. *Plant Genetic Resources*. Documentation and Information Management, NBPGR, New Delhi.

I. Course Title : PGR Exchange and Quarantine *

II. Course Code : PGR 507

III. Credit Hours : 3(2+1)

IV. Why this course ?

In view of updated rules and regulations for access of germplasm and its safe movement following international phytosanitary measures, these issues need to be taught in detail.

V. Aim of the course

To impart knowledge onsafe exchange of germplasm nationally and internationally alongwith the quarantine related issues which are either legislative or technical.

VI. Theory

Unit I

History, principles, objectives and importance of plant introduction, pre-requisite and conventions for exchange of PGR, national and international legislations and policies.

Unit II

Principles, objectives and relevance of plant quarantine, regulations and plant quarantine set up in India, pest risk analysis, pest and pathogen information database; quarantine in relation to integrated pest management, symptoms of pest damage, economic significance of seed-borne pests (insects, mites, nematodes, fungi, bacteria, viruses, phytoplasma, viroids, weeds, etc.), detection and identification of pests including use of recent techniques like ELISA, PCR, etc.

Unit III

Salvaging techniques for infested/ infected germplasm, post-entry quarantine operation, seed treatment and other prophylactic treatments and facilities, domestic quarantine; seed certification; international linkages in plant quarantine, weaknesses and future thrust. Symptoms of pest damage, pests of quarantine significance for India, sampling of bulk material for quarantine, Plant Quarantine/ biosecurity system in other countries, case histories of alien invasive species.

Unit IV

Genetically Modified Organisms (GMOs) or Genetically Engineered Plants (GEPs), Concepts of biosafety, risk analysis and consequences of spread of GE crops on the environment; Treaties and multilateral agreements governing trans-boundary movement of GEPs or GMOs, Indian regulatory system for biosafety.

VII. Practical

- Inventory of IQ/ EQ samples;
- Joint inspection for pest detection;
- Detection of pests of quarantine significance (Conventional, Electron microscopy, ELISA and molecular techniques);
- Primer designing;
- Pest risk analyses, quarantine in relation to integrated pest management; salvaging of infested/ infected germplasm;
- Seed treatment and other prophylactic treatments and facilities; domestic quarantine; seed-health certification.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations
- Hands-on-learning on computer

IX. Learning Outcome

Knowledge gain on current national and international regulations related to germplasm exchange and plant quarantine, detection techniques for pests, salvaging methods, sampling techniques, biosafety of transgenics, etc.

X. Suggested Reading

Albrechsten SE. 2006. *Testing methods for seed-transmitted viruses: principles and protocols.* UK: CAB International, Wallingford. 268 p.

Bhalla S, Chalam VC, Tyagi V, Lal A, Agarwal PC and Bisht IS. 2014. Teaching Manual on Germplasm Exchange and Plant Quarantine. ICAR-NBPGR, New Delhi, India p. 340+ viii.

Bhalla S, Chalam VC, Lal A, and Khetarpal RK. 2009. *Practical Manual on Plant Quarantine.* National Bureau of Plant Genetic Resources, New Delhi, India. 204p+viii.

Bhalla S, Chalam VC, Singh B, Gupta K and Dubey SC. 2018. Biosecuring Plant Genetic Resources in India: Role of Plant Quarantine. ICAR-NBPGR, New Delhi vi+216 p.

Chalam VC, Dubey SC, Murali Krishna C, Bhalla S and Singh K (eds.). 2018. *Transboundary Movement of Living Modified Organisms: Strengthening Capacities of Enforcement Agencies.* ICAR-National Bureau of Plant Genetic Resources and Ministry of Environment, Forest and Climate Change, New Delhi, India. vi+159 p. ISBN 978-81-937111-2-5

Gupta K and Dubey SC. 2017. 'Biosecurity policies influencing international exchange of PGR.' *Indian Journal of Plant Genetics Resources* **30**: 258-266.

Khetarpal RK, Lal A, Varaprasad KS, Agarwal PC, Bhalla S, Chalam VC and Gupta K. 2006. Quarantine for Safe Exchange of Plant Genetic Resources. In: *Hundred Years of Plant Genetic Resources Management in India* (eds. AK Singh, Kalyani Srinivasan, Sanjeev Saxena and BS Dhillon), National Bureau of Plant Genetic Resources, New Delhi, pp 108-139.

Richardson MJ. 1990. An Annotated list of seed-borne diseases (Fourth Edition). International Seed Testing Association, P.O. Box 412. CH 8046 Zurich, Switzerland.

I. Course Title : Genomics in PGR management

II. Course Code : PGR 508

III. Credit Hours : 2 (1+1)

IV. Why this course ?

In addition to conventional hybridization, there is a need for precise tools to decipher the molecular basis of genetic diversity through mapping and sequencing.

V. Aim of the course

Students would be taught basics of genome structure and organization, generation of molecular markers-basic principles, molecular marker techniques, data handling and analysis of GM.

VI. Theory

Unit I

Structure and function of DNA, genome organization, tools and techniques for genetic manipulation, Introduction to genetic markers, classification and comparison of markers, basis for DNA polymorphism and principles of generating molecular markers- RFLP, PCR, sequencing, next generation sequencing techniques, molecular marker techniques eg. RAPD, ISSR, AFLP, etc.; STMS, SNPs markers, GBS, GWAS, data handling and statistical analysis.

Unit II

Overview of molecular marker applications and recent advances, genetic diversity analysis using molecular markers, DNA Fingerprinting and cultivar identification.

Unit III

Introduction to transgenics, development of genetically modified crops, monitoring strategies and methods for detecting transgenics, Genome Editing.

VII. Practical

- DNA isolation and purification, DNA quantification;
- RAPD, ISSR, STMS, SCAR, SRAP;
- Data Analysis.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge on current state-of-the-art technological developments of genomics era, current challenges being faced and handled.

X. Suggested Reading

BD Singh and Singh AK (Eds). 2015. *Marker-assisted Plant Breeding: Principles and Practices*. Springer.

Henry RJ. (Editor). 2001. *Plant Genotyping: The DNA Fingerprinting of Plants,* CABI Publishing.

Henry R (ed.) 2013. Molecular Markers in Plants. Wiley and Blackwell Publication, Iowa USA, 196 p.

Lewin B. 2008. Genes IX. Jones and Bartlett.

Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity– Plants and Animals*. Chapman and Hall, London.

Tuberosa R, Graner A and Frison E (eds.). 2014. Genomics of Plant Genetic Resources, Volume 1. Managing, Sequencing and Mining Genetic Resources. Springer Science, New York, 825 p.

Varshney RK and Tuberosa R (eds.) 2007. Genomics-Assisted Crop Improvement Vol 2: Genomics Applications in Crops. Springer Dordrecht, The Netherlands, 509 p.

I. Course Title : Plant Biosecurity

II. Course Code : PGR 509

III. Credit Hours : 1(1+0)

IV. Why this course ?

Safe transboundary movement of germplasm to biosecureindia against the ravages of exotic pests is important and hence need to understand the basics.

V. Aim of the course

To educate about protecting the economy, environment and plant health from pests and disease including preventing new pests and diseases from arriving, and helping to control outbreaks when they do occur.

VI. Theory

Unit I

History of biosecurity, concept of biosecurity, components of biosecurity, Quarantine, Invasive Alien Species, biowarfare, emerging/ resurgence of insects, pests and diseases.

Unit II

National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures/ World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, Issues related to release of genetically modified crops.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge gain on current national and international regulations related to plant biosecurity

I. Course Title : Principles of Genetics for PGR Management

II. Course Code : PGR 510

III. Credit Hours : 2(2+0)

IV. Why this course ?

Students need to understand all the basic principles of genetics to be able to exploit the PGR

V. Aim of the course

To understand basic concepts of genetics and to develop analytical, quantitative and problem-solving skills in classical and molecular genetics for PGR management.

VI. Theory

Unit I

History and role of genetics in crop improvement, polyploidy, mutation, genetic diversity in PGR, genetic principles of diversity and its distribution, evolution of crop plants through ploidy manipulation.

Unit II

Cytology-euploidy, haploid, diploid, polyploids, chimeras, role of polyploids in crop breeding, evolutionary advantages of autopolyploids vs allopolyploids, Role of aneuploids in basic and applied aspects of crop breeding, apomixis, haploids and their uses, modes of reproduction, male sterility, CMS, heterosis and hybrid development.

Unit III

Methods of studying polymorphism, Overview of molecular marker applications and recent advances, genetics of mitochondria and chloroplast, extra chromosomal inheritance, eugenics, epigenetics, basics of genome structure and organization, generation of molecular markers-RFLP, PCR, sequencing; principles, merits and demerits of RAPD, ISSR, SSR, SCAR, SCOT, SRAP, AFLP, SNP.

Unit IV

Population-Mendelian Population, random mating population, frequencies of genes and genotypes, causes of change, Hardy-Weinberg equilibrium.

VIII. Teaching methods

- Lectures,
- Power point presentations,
- assignments, quiz,
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge and skill gain on current basic and advanced methodologies in genetics

X. Suggested Reading

Griffin HG and Griffin AM. 1994. *PCR Technology: Current Innovations*. CRC Press, London.
Hancock JF. 2004. *Plant Evolution and Origin of crop species*, 2nd edition. CABI.
Henry RJ (Editor). 2001. *Plant Genotyping: The DNA Fingerprinting of Plants*. Publisher: CABI Publishing.
Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity – Plants and Animals*. Chapman and Hall, London.
Miller AJ. 2007. *Crop Plants: Evolution*. John Wiley and Sons.

I. Course Title : Principles of Plant Breeding for PGR Management

II. Course Code : PGR 511

III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to understand all the basic principles of plant breeding to be able to exploit the PGR.

V. Aim of the course

To impart theoretical knowledge and practical skills about plant breeding objectives in PGR management especially for germplasm maintenance, regeneration and pre-breeding.

VI. Theory

Unit I

Objectives of plant breeding, genetic basis of breeding self- and cross – pollinated crops, nature of variability, components of variation, genotype-environment interaction, general and specific combining ability, self-incompatibility and male sterility in crop plants and their commercial exploitation.

Unit II

Principles of breeding for biotic and abiotic stresses, Breeding self pollinated and cross pollinated crops, pure line theory; pure line selection and mass selection methods, line breeding, pedigree, bulk, backcross, single seed descent and multiline method. Breeding methods in asexually/ clonally propagated crops, clonal selection.

Concept of plant ideotype and its role in crop improvement. Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights, DUS testing.

Unit III

Molecular breeding-molecular markers, fundamental concepts in the development of molecular markers, types (isozymes, RFLP, RAPD AFLP), mapping populations (RILs, NILs, DH, Backross), their merits and demerits, markers assisted selection, linkage disequilibrium and the concept of marker-trait association-case studies, marker assisted pre-breeding programmes.

VII. Practical

- Floral biology in self and cross pollinated species, selfing and crossing techniques;
- Selection methods in segregating populations and evaluation of breeding material.
- Analysis of variance (ANOVA);
- Estimation of heritability and genetic advance, maintenance of experimental records;
- Learning techniques in hybrid seed production using male-sterility in field crops.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge gain on plant breeding principles and applications

X. Suggested Reading

Allard RW. 1981. *Principles of Plant Breeding*. John Wiley & Sons.
Chopra VL. 2001. *Breeding Field Crops*. Oxford & IBH.
Chopra VL. 2004. *Plant Breeding*. Oxford & IBH.
Poehlman JM and Borthakur DN. 1972. *Breeding Asian Field Crops*. Oxford & IBH.
Roy D. 2003. *Plant Breeding, Analysis and Exploitation of Variation*. Narosa Publ. House.
Sharma JR. 2001. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill.
Simmonds NW. 1990. *Principles of Crop Improvement*. English Language Book Society.
Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.

I. Course Title : Concepts in Conservation Genetics
II. Course Code : PGR 512
III. Credit Hours : 2(1+1)

IV. Why this course ?

To provide knowledge in genomic tools and their application in plant genetic resource (PGR) exploration, collection, conservation and utilization.

V. Aim of the course

Conservation genetics focuses on processes within small and fragmented populations and on practical approaches to minimize deleterious effects on them. This course will introduce students to the relatively young discipline of conservation genetics with the basic understanding on genetic and epigenetic principles. Emphasis will be placed on general principles rather than specific experimental procedure. A basic knowledge of Mendelian genetics and simple statistics is a prerequisite for registering this course.

VI. Theory

Unit I

Genetic material, cell division, chromosomes, nucleic acids, biological significance of DNA, Mendelian principles I and II, calculation of genetic ratios, Chi-Square method, dominance, Gene Interaction, multiple alleles, sex determination, extranuclear inheritance, quantitative inheritance, linkage and recombination, genetic map, environmental effects – external and internal, phenocopies, concordance, discordance, epigenetics, environmental epigenetics, DNA methylation, histone modification, gene environment vs epigene environment, epigenetic inheritance.

Unit II

Modern Synthesis Theory – Endangered and extinct species – causes of extinctions – Structure and content of conservation genetics – genetics and extinctions – Genetic versus demographic and environmental factors in conservation biology – Limitations of Genetics in Conservation Biology.

Unit III

Hardy Weinberg Principle, proportions – deviations from Hardy–Weinberg equilibrium, Inbreeding – Assortative and dissassortive mating, extensions of Hardy –Weinberg equilibrium, evolutions in large population, natural selection and adaptation, directional, stabilizing and disruptive selection, mutation, migration and their interaction, evolution in small population, genetic drift, inbreeding, inbreeding depression, outbreeding, outbreeding depression, population fragmentation, gene flow.

Unit IV

Genetically viable populations, reproductive fitness, population viability analysis, recovery of endangered species/ threatened population, legal issues related to endangered species and their protection, minimum viable population, recovery of endangered species, legal issues related to endangered species and their protection.

VII. Practical

- Deriving Hardy Weinberg equilibrium, problems on Hardy Weinberg equilibrium, calculation of gene frequencies, autosomal loci with two alleles, estimation of gene frequencies, autosomal loci with multiple alleles, estimation of gene frequencies;
- Sex linked loci, estimation of inbreeding co-efficient – problems in epigenetics, genetic variability of threatened populations, hybridization and introgression analysis;
- Plant forensics, storage of plant genetic samples for time-series analyses.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Complete understanding of conservation genetics for PGR handling

X. Suggested Reading

Allendorf. FW. 2007. *Conservation and the genetics of populations*. Blackwell Publishing Ltd, Australia.

Frankham R, Ballou JD and Briscoe DA. 2004. *A primer of Conservation Genetics*. Cambridge University Press

Frankham R, Ballou JD and Briscoe DA. 2009. *An Introduction to Conservation Genetics*, 2nd edition. 2009. Cambridge University Press: Cambridge, UK.

Höglund J. 2009. *Evolutionary Conservation Genetics*. Oxford University Press, USA.

Strickberger MW. 1996. *Genetics*, Prentice Hall of India Pvt Limited.

Tollefsbol T. 2017. Handbook of Epigenetics, Elsevier.

e-Resources

http://www.scu.edu.au/research/cpcg/

http://genetics.forestry.ubc.ca/cfcg/

Course Title with Credit Load
Ph.D. in Plant Genetic Resources (PGR)

Course Code	Course Title	Credit Hours
PGR 601*	Recent Advances in Germplasm Conservation	2(1+1)
PGR 602*	Phenomics and Genomics for PGR Utilization	2(1+1)
PGR 603*	Economic Botany and Crop Diversification	2(1+1)
PGR 604	PGR Policies and Regulatory Mechanisms	1(1+0)
PGR 605	Molecular Population Genetics in PGR Management	3(2+1)
PGR 606	Plant Taxonomy, Ecogeography and Ecology	2(1+1)
PGR 607	*In-situ on farm* conservation	2(1+1)
PGR 608	Genomic tools and current applications	3(2+1)
PGR 609*	Intellectual Property Rights and Regulatory Mechanisms (e-course)	1(1+0)
	Major courses (Minimum 12 credits from above courses including *marked Courses)	12
	Minor courses	06
	Supporting courses	05
PGR 691	Seminar I	01
PGR 692	Seminar II	01
PGR 699	Thesis/ Research	75
	Total Credit Hours	**100**
	Comprehensive (Pre-qualifying) Examination (Non-credit of 100 marks) Satisfactory/ Not satisfactory	

*Compulsory major courses

Course Contents
Ph.D. in Plant Genetic Resources (PGR)

I. Course Title : Recent Advances in Germplasm Conservation*
II. Course Code : PGR 601
III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to understand all the recent and current issues and procedures for germplasm conservation

V. Aim of the course

To provide knowledge on advances in seed physiology, biology and banking to lead to retention of high seed quality during conservation and all aspects of conservation science and technology.

VI. Theory

Unit I

Seed development and maturation; Seed storage behavior: physiological and molecular basis of desiccation sensitivity; Dormancy, seed germination- mobilization of reserves and their control processes; Viability and vigour-principle and testing procedures; Seed testing for inadvertent introduction of transgenes.

Unit II

Seed storage for long-term conservation and factors affecting seed longevity; seed processing for short, medium and long-term storage, artificial aging and controlled deterioration test; ultra-desiccation techniques for germplasm conservation, richness index, ecological correlates of *ex-situ* seed longevity, permafrost conservation, maintenance of Seed Genebank, status of global seedgene banks.

Unit III

In-vitro techniques in PGR management, *In-vitro* methods of clonal propagation, *In-vitro* collecting and germplasm exchange, Meristem culture and virus elimination, somaclonal variation, application of somatic embryogenesis in PGR, Methods of *in-vitro* conservation- short, medium-term and long term, Concept of active and base *in-vitro* genebank, Status of World cryo- and cryo-gene banks, embryo rescue technique, history and principles of cryopreservation, cryoprotectants- role and applicability, freezing injury and factors affecting cryoprotection, methods of cryopreservation-conventional and vitrification based techniques, varied applications of cryopreservation, handling difficult-to store non-orthodox seeds, embryonic axes, pollen and dormant buds, Management of *in-vitro*, cryo and DNA genebank- Practical considerations, Monitoring genetic stability of *in-vitro* conserved and cryopreserved germplasm, database management for *in-vitro* and cryopreserved germplasm

VII. Practical

- Seed morphology and structure;

- Desiccation rates and freezing to low and ultra low temperatures, seed storage behavior determination in sample seeds, seed viability and vigour tests;
- Seed longevity and accelerated ageing test in different types of seeds, handling hard seededness and physiological immaturity;
- Post harvest handling methods of difficult-to-store seeds, dormant buds, and pollen, ultra-desiccation of seeds, biochemical tests of seed deterioration;
- Preparation of stock solutions, culture media, cryoprotectant solutions and regrowth media, Isolation of explants and *in vitro* culturing in growth retarding media for slow growth conservation, meristem isolation in dicots and monocots;
- Pretreatments, preculturing, cryoprotectant treatments varying temperature and durations, cold hardening- plants and explants, cryopreservation techniques- encapsulation-dehydration, vitrification, encapsulation-vitrificaion, droplet freezing, thawing- slow and fast, recovery and regrowth- media, light conditions;
- *In vitro*-cryo-genebanking and database management, morphological and molecular markers for assessing genetic stability-demonstration.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Advanced conservation techniques including biotechnological tools would be learnt by students.

X. Suggested Reading

Barbara MR, Chin HF and Normah MN. 2013. Conservation of Tropical Plant Species. Springer.

Bewley JD and Black M. 1994. *Seeds Physiology of Development and Germination*, Second Edition. Plenum Press, New York and London.

Chaudhury R and Malik SK. 2017. *Cryopreservation of Plant Species: Practical Approaches from Handling to Cryobanking*. ICAR-NBPGR, New Delhi. 52 p.

Chaudhury R, Pandey R, Malik SK, Bhag Mal (eds). 2003. *In vitro* Conservation and Cryopreservation of Tropical Fruit Species. IPGRI Office for South Asia, New Delhi, India/ NBPGR, New Delhi, India, 293 pp.

Cromarty A. 1984. Techniques of drying seeds, pp 88-125. *Seed Management Techniques for Genebank* (JB Dicke, S Linington and JT Williams, eds). International Board on Plant Genetic Resources, Rome.

Cromarty A, Ellis RH and Robert EH. 1982. *The Design of Seed Storage Facilities for Genetic Conservation*, Revised 1985. International Board on Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985a. Handbook of Seed Technology for Genebank Volume II. Principles and Methodology. International Board for Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985b. Handbook of Seed Technology for Genebank Compendium of Specific Germination Information and Test Recommendations. International Board for Plant Genetic Resources, Rome.

Ellis RH. 1988. The viability equation, seed viability monographs, and practical advice on seed storage. *Seed Science and Technology* **16**: 29-50.

Hong TD and Ellis RH. 1996. A protocol to determine seed storage behaviour. International Plant Genetic Resources Institute IPGRI Technical Bulletin No. 1, Rome.

Mandal BB, Chaudhury R, Engelmann F, Bhag Mal, Tao KL and Dhillon BS (editors). 2003. Conservation Biotechnology of Plant Germplasm. NBPGR, New Delhi, India/ IPGRI, Rome, Italy, 293 pp.

Reed BM. 2008. Cryopreservation—Practical Considerations. In: Reed B.M. (eds) Plant Cryopreservation: A Practical Guide. Springer, New York, NY

Roberts EH. 1972. *Viability of Seeds*. Chapman and Hall, London.

I. Course Title : Phenomics and Genomics for PGR Utilization*

II. Course Code : PGR 602

III. Credit Hours : 2(1+1)

IV. Why this course ?

Utilisation of conserved germplasm all over World has been poor and needs emphasis for increasing the resilience and productivity of agricultural production systems. Students need to understand all the advanced techniques in phenotyping and genotyping to be able to exploit the PGR.

V. Aim of the course

To impart theoretical and practical knowledge on recent advances in crop germplasm evaluation and use. To teach current advances in genomic technologies in use for breeding, phylogenetic analyses, understanding genetic value, facilitating germplasm selection in genebanks, and develop practical skills in phenotyping and genotyping.

VI. Theory

Unit I

Advances in phenotyping to overcome limitations in use of germplasm collections; advanced methodology of germplasm evaluation and predictive methods for identification of useful germplasm, phenomics facility, quantitative imaging techniques using remote sensing. Experimental designs, analyses of evaluation data and database management.

Unit II

Evaluation of crop germplasm for agronomic traits: Evaluation against biotic/ abiotic stresses; quality attributes and other value addition traits. Management and utilization of crop germplasm, germplasm registration, Core and minicore collections; Germplasm enhancement/ pre-breeding and use of wild relatives in crop improvement, embryo rescue method, pollen physiology and storage, integration of big data into breeding programs, harmonising agro-biodiversity conservation and agricultural development, New crops of the future, biofortified crops.

Unit III

Uses and applications of molecular markers in PGR – analysis of genetic diversity, identification of gaps in collection, molecular cytology, Establishment of core and mini-core collections using molecular markers, Identification of desirable genes and alleles, germplasm characterisation, trait mapping, genome sequencing, High throughput genotyping – GBS, association mapping studies: GWAS, molecular tagging of QTLs, FIGS.

VII. Practical

- Management and utilization of crop germplasm: Exercise for developing core set;
- Validation using molecular markers;
- Evaluation of crop germplasm for value addition;
- Evaluation of crop germplasm against biotic/ abiotic stresses;

- Evaluation of germplasm for quality traits;
- Biochemical/ Molecular characterisation of germplasm.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be exposed to latest methodologies for characterizing the germplasm for maximum utilization

X. Suggested Reading

Brown AHD, Clegg MT, Kahler AL and Weir BS (eds.). 1990. *Plant population genetics, breeding, and genetic resources*, Sinauer Associates, USA.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*. Cambridge University Press.

Frankel OH and Hawks JG. 1975. *Crop genetic resources for today and tomorrow*. Cambridge University Press.

Frankel OH and Michaele ES. 1987. *Conservation and evolution*. Cambridge University Press.

Frankel R and Galun E. 1977. *Pollination mechanisms, reproduction and plant breeding*.

Genetic Data Analysis II: methods for Discrete Population Genetic Data. Sinauer Associates, Massachusetts, USA.

Griffin HG and Griffin AM. 1994. *PCR Technology: Current Innovations*. CRC Press, London.

Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.

Hayward MD, Bosemak NO and Romagosa I. 1993. *Plant Breeding: Principles and Practices*. Chapman & Hall.

Holden JHN and Williams JT. 1984. *Crop genetic resources: conservation and evaluation*, IBPGR.

Hillis, D and Moritz C. 1990. Molecular Systematics. Sinauer Associates, USA.

IPGRI. 1997. Regeneration of accessions in seed collections: a decision guide: Handbook for genebanks No. 5. Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity – Plants and Animals*. Chapman and Hall, London.

Lynch M and Walsh B. 1998. *Genetics and analysis of quantitative traits*. Sinauer Associates, Massachusetts, USA.

Peterson WW, Marie-Noelle N and Robert JH. 2018. Role of genomics in promoting the utilization of plant genetic resources in genebanks. *Briefings in Functional Genomics* **17**(3): 198–206.

Stoskopf NC. 1993. *Plant Breeding: theory and practice*. Westview Press.Tanksley SD and Orton TJ. 1983. *Isozymes in Plant Genetics and Breeding*, Part A and B. Elsevier Science Publication, Amsterdam.

Varshney RK, Mahendar T, Aggarwal RK, *et al*. 2007. Genic Molecular Markers in Plants: Development and Applications. In: Varshney RK, Tuberosa R. (eds). *Genomics-Assisted Crop Improvement*. Dordrecht: Springer Netherlands, 13–29.

I. Course Title : Economic Botany and Crop diversification*

II. Course Code : PGR 603

III. Credit Hours : 2(1+1)

IV. Why this course ?

Deeper understanding of origin and cultivation of all major crop plants and potential crops is essential for students.

V. Aim of the course

To apprise students about economic uses of plants including in fields such as Ethnopharma-cology as well as potential/ new commercial crops.

VI. Theory

Unit I

Structure, development and chemical constituents of plant parts- cereals, pulses and oilseeds, vegetables, fruits, nuts.

Unit II

Origin, history, evolution, domestication, botany, genetic resources activities, cultivation, production and utilization of various crops- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants.

Unit III

Economic uses and commercial importance of crop plants- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants, fodder and forage crops. Current topics on potential crops, biofortified crops, lost and neglected crops, revival of lesser known crops, the marketing of potential crops.

Unit IV

Importance of plants with respect to society and environment- Social and religious significance of plants in environmental amelioration. Case studies of massive economic gains due to use of lesser known crops/ genes in history of agriculture.

VII. Practical

- Structure, development and chemical constituents of plant parts-cereals;
- Structure, development and chemical constituents of plant parts-pulses and oilseeds;
- Structure, development and chemical constituents of plant parts-vegetables, fruits, nuts;
- Structure, development and chemical constituents of plant parts-ornamental plants, underutilized plants.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be prepared for understanding all crops including underutilized crops and their economic potential

X. Suggested Reading

Beryl Brintnall Simpson. 2013. *Plants in Our World: Economic Botany*. McGraw-Hill Education, 2014, New York, NY.

Beryl Brintnall Simpson, Molly Ogorzaly, Simpson Beryl. 2001. Economic Botany: Plants in Our World. Mcgraw-hill Science/ engineering/ math.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*, Cambridge University Press.

Burkill IH 1951-52 Habits of man and the origins of the cultivated plants of the old World. *Proceeding Linnean Society of London*, 164: 12-42.

Commercial products of India. Watt, Sir George.
Economic Botany. By Hill, Albert R
Frankel OH and Hawks JG. 1975. *Crop genetic resources for Today and Tomorrow*. Cambridge University Press.
George Watt (2014) Dictionary of Economic Products of India. Cambridge University Press. Wealth of India CSIR
Hanelt P. 2001. Institute of Plant and Genetics and Crop Plant Research (eds) *Mansfeld's encyclopedia of agricultural and horticultural crops*, vol 3. Springer, Berlin.
Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA
Hill Albert F. 1952. *Economic Botany: A Textbook of Useful Plants and Plant Products*, Second Edition. New York Toronto London McGraw-hill Book Company, Inc.
Kochhar SL. 2012. *Economic Botany in the Tropics*, Paperback, Fourth edition. Laxmi Publications.
Maiti RK and Singh VP. 2006. *An Introduction to Modern Economic Botany*. Eastern Book Corporation, Delhi.
Mehra KL and Arora RK. 1982. *Plant genetic resources of India: their diversity and conservation*. NBPGR, New Delhi.
Morton JF 1987. *Fruits of warm climates* Creative Resource Systems. Inc. N.C., Miami, FL.
Paroda RS and Arora RK (eds.). 1991. *Plant genetic resources: conservation and management*. NBPGR, New Delhi
Purseglove W. 1981. *Tropical Crops. Dicotyledons*. The English Language Book Society and Longman.
Purseglove W. 1981. *Tropical Crops. Monocotyledons*. The English Language Book Society and Longman.
Sturtevant's notes on edible plants. Hedrick UP.
Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. Mc MIllan Press.

I. Course Title : PGR Policies and Regulatory Mechanisms

II. Course Code : PGR 604

III. Credit Hours : 1(1+0)

IV. Why this course ?

Biodiversity is regarded as a treasure under national sovereignty and hence regulatory mechanisms and PGR policies need to be understood

V. Aim of the course

To educate students about concepts and instruments of intellectual property rights, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources.

VI. Theory

Unit I

Concept of intellectual property, need for IP protection, Dimensions and nature of IPR, conflicting community interest with private right. Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information, GI registration. Process of obtaining an IPR, World Intellectual Property Organization, Patent Cooperation Treaty (PCT).

Unit II

Plant breeder's rights, protection of plant varieties, UPOV; registration of plant varieties and essentially derived varieties, duration and effect of registration; traditional knowledge systems, farmer's rights, folklore, code of conduct, access and benefit sharing; compulsory license; plant varieties protection appellate tribunal.

Unit III

International instruments concerning agro-biodiversity, Convention on Biological Diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms, geographical appellations. Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement.

Unit IV

Multilateral agreement on trade in goods – relevance to agriculture, Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures (SPS), international plant protection convention, agreement on Technical Barriers to Trade (TBT). Plant quarantine, biosafety related issues.

Unit V

National legislations related to biodiversity conservation and IPR protection.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be able to understand the intricacies of PGR policies and do patent search.

X. Suggested Reading

Anonymous. *Providing Protection For Plant Genetic Resources: Patents, Sui Generis Systems and Biopartnerships*. Kluwer Academic Press, ISBN: 9041188754; Distributer: Landmark Ltd.

Kate KT and Laird SA. 1999. *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*. Earthscan, London.

Michael M. *et al.* 2005. *Valuation and Conservation of Biodiversity: Interdisciplinary Perspectives on the Convention on Biological Diversity*. Springer.

Srivastava SK. 2016. *Commercial Use of Biodiversity: Resolving the Access and Benefit Sharing Issues*. SAGE Publications, India, Pvt. Ltd.

e-resources

http://www.icar.org.in/files/reports/other-reports/icar-ipmttcguide.pdf
http://www.wto.org
http://www.geographicindications.com
http://www.cbd.int www.patentoffice.nic.in
http://www.uspto.gov
http://www.wipo.int
http://www.nif.org.in
http://www.fao.org/Legal/treaties/Treaty-e.htm
http://www.plantauthority.gov.in
http://www.nbaindia.org

I. Course Title : Molecular Population Genetics in PGR Management

II. Course Code : PGR 605

III. Credit Hours : 3(2+1)

IV. Why this course ?

The genomic revolution has generated detailed population genetic data. Big data samples of complete genome sequences of many individuals from natural populations of many species have transformed population genetics inferences on samples of loci to population genomics: the analysis of genome-wide patterns of DNA variation within and between species. Molecular analyses of this is essentially to be taught to students.

V. Aim of the Course

Students would be provided insights into organization and structure of genetic variation in plant populations and practical skills in molecular diversity analyses.

VI. Theory

Unit I

The genetic structure of populations – Genetic transmission in populations, the Hardy-Weinberg principle and estimating allele frequencies, testing of departures from Hardy-Weinberg proportions, inbreeding and self-fertilization, analyzing the genetic structure of populations: Bayesian F-statistics, Nei'sGst, Weir & Cockerham's, the Wahlund Effect and Wright's F-statistics.

Unit II

Natural selection, genetic drift, mutations – The genetics of natural selection, estimating viability, Selection at one locus with many alleles, fertility selection and sexual selection, Selection component analysis, genetic drift- mutation, migration and genetic drift, selection and genetic drift; the coalescent.

Unit III

Quantitative genetics – introduction to quantitative genetics, resemblance among relatives, partitioning variance, evolution of quantitative traits, simultaneous evolution of several quantitative traits, mapping quantitative trait loci, introduction to linkage disequilibrium and association analysis.

Unit IV

Molecular evolution – introduction to molecular population genetics, the neutral theory of molecular evolution, patterns of nucleotide and amino acid substitutions, detecting selection on nucleotide polymorphisms; patterns of selection on nucleotide polymorphisms, Tajima's D, Fay's and Wu's H, and Zeng et al's E, introduction to population genomics and challenges.

Unit V

Evolution in multigene families, phylogeography, analysis of molecular variance (AMOVA), nested clade analysis, basics of cladistic analysis.

VII. Practical

- Calculating gene and genotypic frequencies;
- Testing of HWE;
- Estimation of allele frequencies under forces of selection, mutation and migration;
- Calculation of inbreeding coefficient;

- Estimation of linkage disequilibrium;
- Quantifying genetic variation at the molecular level, analysis of molecular variance;
- Hypothesis testing in molecular evolution, estimation of evolutionary parameters.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students will be well versed with basics of variations and molecular diversity analyses

X. Suggested Reading

Cutter AD. 2019. *A Primer of Molecular Population Genetic*. Oxford University Press.

Hartl DL and Clark AG. 2006. *Principles of Population Genetics*, 4th Ed. Sinauer Associates, Sunderland, MA.

Matthew B. Hamilton. 2009. *Population Genetics*, 1st Ed. Wiley-Blackwell.

Matthew W. Hahn. 2018. *Molecular Population Genetics*, Oxford University Press.

Casillas S and Barbadilla A. 2017. *Molecular Population, Genetics* **205**: 1003–1035.

I. Course Title : Plant Taxonomy, Ecogeography and Ecology

II. Course Code : PGR 606

III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to understand all the recent advances in plant taxonomy for understanding crop evolution and future prospects with respect to variable ecologies.

V. Aim of the course

To educate students about interdisciplinary scientific study of the distributions, abundance and relations of organisms and their interactions with the environment, and the study of ecosystems. To provide information on ecogeographic surveys, sampling strategies and legal issues involved in germplasm collecting. To teach taxonomic databases and documentation systems.

VI. Theory

Unit I

Origin and diversity of life, speciation, biosystematics, basic elements of plant ecology, ecological components, population ecology- populations and life history, growth and limits. Community ecology- species interactions, role of interactions and structure.

Unit II

Ecosystems- concept of ecosystems, ecological balance, vegetation dynamics, productivity and nutrient cycling. Conservation ecology, seed ecology, nature conservation and environmental management, ecosystem restoration, biogeography and evolution. Biodiversity functioning- genetic adaptations, population irruptions/ crisis in nature, community change and ecosystem regulation. Biodiversity conservation-geographical patterns in biodiversity, habitat fragmentation and conservation areas. Biodiversity management and exploitation-biodiversity resources and their harvesting, impact of physical and biotic factors on sustainability- case studies, impact of biotic and climatic factors on biomes and biodiversity- pollution and over-exploitation.

Unit III

Genetic diversity of PGR, genetic principles of diversity and its distribution. Indicators of diversity, assessing the threats of genetic erosion; eco-geographic surveys: planning, collection and analysis of eco-geographic data, outputs of eco-geographic surveys.

Unit IV

Differentiation and evolution of species and biosystematics, Modern evidences: morphology and anatomy; embryology and palynology; Modern evidences: Biogeography and Cytotaxonomy; Modern evidences: Comparative studies on phytochemistry, Chemo-taxonomy; Molecular taxonomy; Hybrids, domesticated species, wild-cultivated continuum.

Unit V

Sampling strategies theory and practice, strategies for wild species; Germplasm collecting: legal issues and the FAO code of conduct, participatory approaches to collecting including indigenous knowledge, Traditional knowledge systems. Taxonomic databases and documentation systems.

VII. Practical

- Concepts and methods for computing biodiversity, Alpha and beta models, calculation of species richness and endemism;
- Field visits to protected areas- biospheres/ national parks, understanding various ecosystems;
- Geospatial analysis and use of GIS;
- Identification and learning the use of CWRs of various families, survey of local biodiversity (field study), ecological status of various species (field study);
- Population and community patters- case studies on local flora;
- Identification of alien species and their impact assessment, study of protected areas, restoration of threatened and native species, bioresources and their harvesting, classical and modern species concepts and biosystematics, morphology and anatomy;
- Comparative studies on phytochemistry, chemotaxonomy, floristic and monographic work;
- Practical methods for elucidating and proving hypotheses relating to plant speciation, Numerical taxonomy-practice and procedures; biosystematic studies and their role in improving plant taxonomies, infraspecific categories in relation to population biology, taxonomic databases, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Complete understanding of taxonomic principles for PGR handling

X. Suggested Reading

Ananthakrishanan. 1989. *Bioresource ecology*, Oxford & IBH Pub. Co. (New Delhi).

Brummitt RK and Powell CE. 1992. *Authors of Plant Names*. Royal Botanic Gardens, Kew, London, UK. 732 p.

Hermann R. 1980. *Ecology: a text book*. Springer.

Heywood VH. 1973. *Taxonomy and Ecology*. Academic Press London.

Hollingsworth PM, Bateman RM and Gornall RJ (eds.). 1999. *Molecular Systematics and Plant Evolution*. Taylor and Francis, London and New York. 485 p.

Iriondo *et al*. 2008. *Conserving Plant Genetic Diversity in Protected Areas: Population management of CWR*. CAB International, Wallingford, UK.

Kumar HD. 1992. *Modern concepts of ecology*. Vikas Publishing House (New Delhi),

Meffe and Carroll 1997. *Principles of Conservation Biology*, 2nd edition. Publisher: Sinauer Associates.

Paroda RS and Arora RK (eds.) 1991. *Plant genetic resources: conservation and management*. NBPGR, New Delhi.

Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. McMIllan Press.

Trehane P, Bricknell CD, Baum BR, Hetterscheid WLA, Leslie AC, McNeill J, Spongberg SA and Vrugtman F. 1995. *The International Code of Nomenclature for Cultivated Plants Regnum Veg*. 133. Quarterjack Publishing, Wimborne, UK. 175 p.

Vavilov NI 1887-1943. Origin and Geography of Cultivated Plants. English ed.: Translated by Love, D. 1992. Camb. University Press, Cambridge, UK. 498 p.

Watt G 1889-1896. *A Dictionary of Economic Products of India*. 7 vols., Repr. 1972. Calcutta, India.

Woodbury AM. 1954. *Principle of general ecology*. Blakiston, New York.

I. Course Title : *In situ On-farm* conservation

II. Course Code : PGR 607

III. Credit Hours : 2(1+1)

IV. Why this course ?

One of the alternatives to agrobiodiversity conservation which is dynamic in nature needs understanding

V. Aim of the course

To impart knowledge about *in-situ* and/ *On-farm* conservation of crop diversity and type of information required for such an approach.

VI. Theory

Unit I

Conservation strategies (*in-situ*, *Ex-situ* community conservation), *In situ* conservation of wild species in nature reserves, *In situ* conservation of crop diversity on-farm.

Unit II

Phytogeographic surveys and inventory, estimation of genetic diversity, population biology, concept of minimum viable population, population viability and population genetics theory, designation of gene management zones (GMZs)/ gene sanctuaries, management and monitoring of GMZs, threat of genetic erosion, conservation agency priorities, biologically important species, National action plan for agrobiodiversity, Delhi Declaration on Agrobiodiversity.

Unit III

Social, cultural and economic factors influencing crop genetic diversity, Agro-ecosystem factors: natural and farmer-managed, agromorphological characters, farmer selection and maintenance, the genetics structure of crop landraces and the challenge to conserve them *in situ* on-farms, seed systems: formal vs informal.

Unit IV

Institutional frameworks for the implementation of on-farm conservation, identification of target crops, site selection, community sensitization, participatory plant breeding, sampling, structuring, documentation and presenting information for action plans, increasing crop genetic diversity's competitiveness for farmers, improvising the material and farmers 'access to genetic materials, increasing consumer demand, the role of policy, deciding on an appropriate initiative, evaluating benefit-enhancement options, role of Geographical Indications (GI) in agri-horticultural crops.

VII. Practical

- Floristic surveys and inventory (wild species in nature reserves and crop species in traditional agro-ecosystems), questionnaire preparation;
- Visit to commercial units processing native crops, and to on farm fields and to community seed banks in villages;
- The genetic structure of crop landraces and the challenge to conserve them *in situ* on-farm at selected sites.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students will understand the current status of this method

X. Suggested Reading

Brush SB 1999. *Genes in the field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

Jarvis D I, Meyer L, Klemick, H, Guarino, L, Smale M, Brown, AHD, Sadiki, M and Sthapit B. 2000. A Training Guide for *In situ* Conservation On-farm. Version 1. International Plant Genetic Resources Institute, Rome, Italy.Maxted N, Dulloo ME, Ford-Lloyd BV (eds.). 2016. Enhancing Crop Genepool Use: Capturing Wild Relative and Landrace Diversity for Crop Improvement. CAB International, Wallingford, UK.

Jarvis D, Hodgkin T, Brown AHD, Tuxill JD, Loìpez Noriega I, Smale M, Shtapit B, Samper S. 2016. Crop Genetic Diversity in the Field and on the Farm. Principles and Applications in Research Practices. Yale Agrarian Studies Series. Bioversity International, Maccarese/ Swiss Agency for Development and Cooperation (SDC), Bern/ Yale University Press, New Haven.

Maxted N, Dulloo ME, Ford-Lloyd BV, Frese L, Iriondo JM, Pinheiro de Carvalho MAA (eds.). 2012. Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces. CAB International, Wallingford.

Maxted N, Guarino L, Myer L, Chiwona EA. 2002. Towards a methodology for on-farm conservation of plant genetic resources. *Genetic Resources and Crop Evolution* **49**: 31-46.

Vernoy, R, Shrestha P and Sthapit B. 2015. *Community Seed Banks: Origins, Evolution and Prospects*. Oxford, Routledge.

I. Course Title : Genomic Tools and Current Applications

II. Course Code : PGR 608

III. Credit Hours : 3(2+1)

IV. Why this course ?

Plant genomics aims to develop high-throughput genome-wide-scale technologies, tools and methodologies to elucidate the basics of genetic traits/ genetic diversity in organisms

V. Aim of the course

To provide knowledge in genomic tools and their application in plant genetic resource exploration, collection, conservation and utilization.

VI. Theory

Unit I

Genomics: Basic concept, structural, comparative and functional genomics, genomic tools, TILLING, EcoTILLING, Genome duplication and ploidy variation, application of genomic tools in PGR valuation, conservation and utilization.

Unit II

DNA barcoding: Basic concept, methodologies, utility of DNA barcoding in species delineation, plant exploration and collection, conservation and utilizing species in widening gene pool of major crops.

Unit III

DNA markers: Types, application in assessment of diversity in germplasm, DNA fingerprinting and genetic identity analysis, allele mining, development and validation of core sets, genetic association studies and genomic selection in germplasm collections.

VII. Practical

- Gene based screening of trait-specific germplasm using linked molecular markers;
- Amplification and sequencing of DNA barcoding loci for species identification in crops;
- Allele mining in trait-specific germplasm for quality traits in crops;
- DNA fingerprinting for identity analysis in crops, molecular markers for designation and validation of germplasm core-sets.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge on current state-of-the-art technological developments of genomics era, current challenges and handling methods

X. Suggested Reading

Fleury D, Jefferies S, Kuchel H and Langridge P. 2010. Review Paper: Genetic and genomic tools to improve drought tolerance in wheat. *Journal of Experimental Botany* **61**: 3211–3222.

Gupta PK, Kulwal PL and Jaiswal V. 2014. Association Mapping in Crop Plants: Opportunities and Challenges: *Advances in Genetics* **85**: 109-147.
Henry R (ed.) 2013. *Molecular Markers in Plants*. Wiley and Blackwell Publication, Iowa USA, 196 p.
Pérez-de-Castro AM, Vilanova S, Cañizares J, *et al*. 2012. Application of genomic tools in plant breeding. *Current Genomics* **13**: 179-195.
Primrose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics: Part III Genome Analysis, Genomics, and Beyond.* 7th Edition, Blackwell, Malden, USA, pp. 323-481.
Sucher NA, Hennell JR and Carles MC (eds.) 2012. *Plant DNA Fingerprinting and Barcoding: Methods and Protocols*. Humana Press, Springer Science, New York, 201 p.
Tuberosa R, Graner A and Frison E (eds.) 2014. *Genomics of Plant Genetic Resources, Volume 1. Managing, Sequencing and Mining Genetic Resources*. Springer Science, New York, 825 p.
Varshney RK and Tuberosa R (eds.) 2007. *Genomics-Assisted Crop Improvement Vol 2: Genomics Applications in Crops*. Springer Dordrecht, The Netherlands, 509 p.

I. Course Title : Intellectual Property Rights and Regulatory Mechanisms*

II. Course Code : PGR 609

III. Credit Hours : 1(1+0)

IV. Why this course ?

Biodiversity conservation and its judicious utilization are important in sustainable plant breeding programs. Breeders' and farmers' rights are important in scenario of globalization of agriculture so knowledge of IPRs is essential for a plant breeder to protect his varieties.

V. Aim of the course

To educate students about concepts and instruments of intellectual property rights, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources.

VI. Theory

Unit I

Concept of intellectual property, need for IP protection, Dimensions and nature of IPR, conflicting community interest with private right. Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information, GI registration. Process of obtaining an IPR, World Intellectual Property Organization, Patent Cooperation Treaty (PCT).

Unit II

Plant breeder's rights, protection of plant varieties, UPOV; registration of plant varieties and essentially derived varieties, duration and effect of registration; traditional knowledge systems, farmer's rights, folklore, code of conduct, access and benefit sharing; compulsory license; plant varieties protection appellate tribunal; finance, accounts and audit; infringement, offenses, penalties and procedure.

Unit III

International instruments concerning agro-biodiversity, Agenda 21, Convention on Biological Diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms, geographical appellations.

Unit IV

Multilateral agreement on trade in goods – relevance to agriculture, Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures (SPS Agreement), international plant protection convention, agreement on technical barriers to trade (TBT); Plant quarantine, biosafety related issues.

Unit V

National legislations related to biodiversity conservation and IPR protection, Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks

IX. Learning Outcome

All current aspects on IPRs, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation would be understood.

X. Suggested Reading

Kate KT and Laird SA. 2002. *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*. Earthscan.

Markussen M *et al*. 2005 Valuation and Conservation of Biodiversity: Interdisciplinary Perspectives on the Convention on Biological Diversity, Springer.

Marin PLC. 2002. *Providing Protection For Plant Genetic Resources: Patents, Sui Generis Systems And Biopartnerships*. Publisher: Kluwer Law International, ISBN: 9041188754; Distributer: Landmark Ltd.

e-Resources

http://www.icar.org.in/files/reports/other-reports/icar-ipmttcguide.pdf
http://www.wto.org;
http://www.geographicindications.com;
http://www.cbd.int;
http://www.patentoffice.nic.in;
http://www.uspto.gov;
http://www.wipo.int;
http://www.nif.org.in;
http://plantauthority.gov.in
http://nbaindia.org

ANNEXURE I

List of BSMA Committee Members for Plant Science

(Genetics and Plant Breeding/ Seed Science and Technology/ Plant Genetics Resources)

Name	Address	Specialization
Dr Z.S. Solanki Former Vice-Chancellor	Agriculture University, Kota (Rajasthan) Present Address: 2/8 Suswani Mata Colony Mandore, Jodhpur-342 304, Rajasthan zssolanki@gmail.com Mob.: 09481029482	Chairman
Dr Bhabendra Baisakh Professor & Head	Department of Genetics and Plant Breeding Orissa University of Agriculture and Technology Bhubaneswar-751 003 bhaba4@gmail.com Mob.: 09437195452	Convener
Dr S.R. Maloo Former Director (Research) & Dean	Agriculture College Maharana Pratap University of Agriculture and Technology, Udaipur Present Address: 47, Anand Nagar Ayad Bridge University Road Udaipur-313 001 shivratan.maloo@yahoo.com Mob.: 09414169710	Genetics & Plant Breeding
Dr J.P. Sharma Professor	Department of Plant Breeding and Genetics-cum-Director Research, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009 jpsdr2015@gmail.com Mob.: 09419134737	Genetics & Plant Breeding
Dr S. Sundareswar Professor	Department of Seed Science & Technology Tamilnadu Agricultural University Coimbatore-641 003 sundarseeds@gmail.com Mob.: 09442020149	Seed Science & Technology
Rekha Chaudhary Professor	National Bureau of Plant Genetic Resources New Delhi-110 012 Rekha.chaudhary@gmail.com rscientist58@gmail.com Mob.: 09871101592	Plant Genetics Resources

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 1

Plant Protection

– Entomology
– Plant Pathology
– Nematology

Contents

Acknowledgements

BSMA Committee for Plant Protection thanks Dr Arvind Kumar, Chairman, National Core Group and Vice-Chancellor, Rani Laxmi Bai Central Agricultural University, Jhansi for his mentorship and guidance throughout. Dr K.M. Bujarbaruah, Dr M.S. Nataraj, Dr N.C. Patel, Dr Pradeep Kumar Bisen, respectively, Vice-Chancellors of Assam Agricultural University, University of Agricultural Sciences, Bengaluru, Anand Agricultural University and Jawaharlal Nehru Krishi Vishwa Vidyala, Jabalpur reserve our gratitude and appreciation for having hosted our meetings and workshops involving all the stake- holders in higher agricultural education. The Committee is also indebted to Dr N.S. Rathore, the erstwhile DDG (Education) and Dr G. Venkateshwarlu, ADG (EQR), ICAR for providing input and all the administrative support.

Dr A.K. Bhowmick
Convener

Dr S. Lingaraju
Chairman

Preamble

(Plant Protection)

The BSMA Committee on Plant Protection meticulously deliberated upon the issues to ameliorate the overall agricultural education programme, and plant protection in particular. The curricula and syllabi of the three disciplines, viz., Entomology, Plant Pathology and Nematology, were discussed in the meetings and workshops convened by the BSMA Committee on Plant Protection. The opinions and suggestions invited from institutions, eminent scientists, and other stakeholders (private entrepreneurs, governmental and non-governmental organizations) were reviewed by the Committee. The modified post-graduate programme in Plant Protection has been designed to meet out the demands of private sector, advanced research and applications, supplementary practical skills required, and to enhance national and global competence and employability of our students.

The Master's and Doctoral programmes retain the fundamental aspects, e.g. morphology, taxonomy, physiology, biology/ bionomics and ecology (analogous to learning the basic *ragas* in Indian classical music to excel in music) besides covering the applied aspects of beneficial biota, be they insects, nematodes, fungi or bacteria), their commercial utilization, pest/ pathogen spectrum of specific crops and their management. Various current issues and latest approaches in the subject of Entomology, Plant Pathology and Nematology have been given a new thrust. Aiming at improving the theoretical and practical knowledge of the postgraduate students in their respective subjects the number of Masters courses have been increased from 20 (in the previous dispensation) to 23 in Entomology; and from 14 to 15 in Nematology with considerable credit load on the practical aspects. At the doctoral level, impetus has been given to research work. Certain courses have been merged if the syllabi in them were found overlapping.

- *Entomology*. Some of the salient features of the revised curriculum at the Master's level include: emphasis on molecular approaches and nanotechnology in entomology; molecular systematics; understanding host plant resistance and breeding for pest resistant crop cultivars; ecological engineering/ farmscaping for pest management in conventional and organic farming systems; besides an independent course on integrated management of pest/ disease situations (insects, mites, diseases and nematodes) in protected cultivation; independent, advanced training in edible and therapeutic insects; medical and veterinary entomology; sericulture, apiculture and lac culture to encourage location-specific self-employment *vis-à-vis* enhancing farm income; detailed study on post-harvest losses due to insects, mites and vertebrate pests, and their management; an elaborate exposure to plant quarantine, bio-safety and bio-security in view of the rising invasive insect pest infestations and repercussions of climate change. These aspects have been included in the Master's curriculum itself keeping in view of the invasive, exotic pest infestation records as also with a view to cover the details of Indian Biodiversity Act. The course on Commercial Entomology has been split into three separate courses (Apiculture, Sericulture and Lac Culture) to give wider scope for location-specific self employment, as envisaged in the National Educational Policy and towards enhancement of farmer's income. At the Doctoral level, the coverage of different courses, both theoretical and practical, has been reduced with a view to enable the scholars concentrate on their research work towards achieving significant transferable technologies.

- *Plant Pathology*. Two Master's programme courses have been done away with, viz., Mushroom Production Technology and Insect Vectors of Plant Viruses and other Pathogens. The erstwhile nomenclature of the (masters and doctoral) courses on Bacteria is changed to 'Plant Pathogenic Prokaryotes' and 'Advances in Plant Pathogenic Prokaryotes', respectively. Since the exploitation of Botanicals for the pathogens' suppression and the disease management is gaining ground, the aspects pertaining to them find a place in a course. A course on Plant Nematology is made a compulsory course at master's level.
- *Nematology*. The contents of each course have been considerably refurbished in line with the developments. Considering the growing realization that plant nematodes are a major biotic constraints in the cultivation of crops raised under protected cultivation regimes, a new course on IPM in Protected Cultivation has been formulated: the same has been cross-listed with Entomology and Plant Pathology.

The reader of this note can see that this preamble is meant to give a bird's view about our BSMA Committee's recommendations *vis-a-vis* the three disciplines of Entomology, Plant Pathology and Nematology. The 'Courses at a Glance' provided in the beginning of each discipline will instantly tell the changes from the previous dispensation of 2009 (the first BSMA effort). There is no gainsaying the fact that the syllabi of each course may be consulted for a larger use.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Protection
– Entomology

Preamble
(Entomology)

Plant improvement has a long history for its growth and development. Plant breeding became established as a science in the twentieth century following the rediscovery of Mendel's laws of inheritance. Nearly 50% of global increase in food production is attributed to plant breeding. Since genetic improvement in an inherent feature, products of plant breeding can have wide global impact as exemplified by the Green Revolution for wheat and rice varieties of 1960s or transgenic crops of recent decades. Therefore developing sufficient human resources in Genetics and Plant Breeding with advanced knowledge and technical skill will further elevate the agricultural sector to attain a new peak in increasing food production matching the requirement of population.

Present agriculture research and international market demand the need for specialised human resource for teaching cutting edge technology with application of biotechnology, nanotechnology, artificial intelligence in crop improvement, increasing entrepreneurship etc, would warrant students to have strong knowledge of practical and management skills which will help them to face the competitiveness in public and private sector.

Hence, restructuring of course curricula and delivery system to match with the present situation is the need of the time. In this proposed revision of curriculum in Genetics and Plant Breeding, the BSMA sub-group organized a series of meetings and electronic media-led consultations to develop a set of courses suitable for M.Sc. and Ph.D. students of the discipline.

The meetings were focussed on the basic principles as well as the innovative developments in Genetics and Plant Breeding, as the platform building status of Plant Sciences. Built on this platform with the latest state of the art technologies including biotechnology and molecular biology will enable a complete coverage of the subjects. The basic courses have therefore been kept as compulsory courses which need to be taken by all the students irrespective of the subject specialization or stream from which they entered into PG education.

The BSMA Committee had thread bare discussions over four sessions on the topical issues concerning Genetics and Plant Breeding, Seed Science and Technology and Plant Genetic Resources. The curricula and syllabi of all these disciplines were discussed at length in the meetings and workshops. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the committee. The new look and restructured PG programmes in Genetics and Plant Breeding have been designed in considerations based on demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and to enhance the global competitiveness and employability of our students. Considerable efforts have, therefore gone in for the preparation of this document.

Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and social need both at national and international level areMolecular Breeding and Bioinformatics, Breeding for Quality and Special Traits, Seed Production and Certification, Breeding Vegetable Crops, Breeding Fruit Crops, Breeding Ornamental Crops for M.Sc. and IPR and Regulatory Mechanism (e-course) as well as Population Genetics for Ph.D. programme.

Course Title with Credit Load
M.Sc. (Ag) in Plant Protection - Entomology

Course Code	Course Title	Credit Hours
ENT 501*	Insect Morphology	3 (2+1)
ENT 502*	Insect Anatomy and Physiology	3 (2+1)
ENT 503*	Insect Taxonomy	3 (1+2)
ENT 504*	Insect Ecology	3 (2+1)
ENT 505*	Biological Control of Insect Pests and Weeds	3 (2+1)
ENT 506*	Toxicology of Insecticides	3 (2+1)
ENT 507	Host Plant Resistance	2 (1+1)
ENT 508*	Concepts of Integrated Pest Management	2 (2+0)
ENT 509*	Pests of Field Crops	3 (2+1)
ENT 510*	Pests of Horticultural and Plantation Crops	3 (2+1)
ENT 511*	Post Harvest Entomology	2 (1+1)
ENT 512	Insect Vectors of Plant Pathogens	2 (1+1)
ENT 513	Principles of Acarology	2 (1+1)
ENT 514	Vertebrate Pest Management	2 (1+1)
ENT 515	Techniques in Plant Protection	1 (0+1)
ENT 516	Apiculture	3 (2+1)
ENT 517	Sericulture	3 (2+1)
ENT 518	Lac Culture	3 (2+1)
ENT 519	Molecular Approaches in Entomology	3 (2+1)
ENT 520	Plant Quarantine, Biosafety and Biosecurity	2 (2+0)
ENT 521	Edible and Therapeutic Insects	2 (1+1)
ENT 522	Medical and Veterinary Entomology	2 (1+1)
ENT 523	Forest Entomology	2 (1+1)
ENT 591	Master's Seminar	1 (0+1)
ENT 599	Master's Research	30 (0+30)

*Compulsory Major Courses

Course Contents
M.Sc. (Ag) in Plant Protection-Entomology

I. Course Title : Insect Morphology
II. Course Code : ENT 501
III. Credit Hours : 3 (2+1)

IV. Aim of the course

To acquaint the students with the external morphology of the insect's body and the functioning of various body parts.

V. Theory

Unit I

External Morphology: Insect body wall structure, cuticular outgrowths, colouration and special integumentary structures in insects, body tagmata, sclerites and segmentation.

Head- Origin, structure and modification; mouthparts, antennae, their types and functioning; tentorium and neck sclerites.

Thorax- Areas and sutures of tergum, sternum and pleuron, pterothorax; wings: structure and modifications, venation, wing coupling apparatus and mechanism of flight; legs: structure and modifications.

Abdomen- Segmentation and appendages; genitalia and their modifications; embryonic and post-embryonic development.

Unit II

Insect sense organs (mechano-, photo- and chemo- receptors); organogenensis at pupal stage; insect defense; chaetotaxy; morphological traits in relation to forensic entomology.

Unit III

Types of immature stages in insect orders, morphology of egg, nymph/ larva and pupa, identification of different immature stages of crop pests and stored product insects. Comparative study of life history strategies in hemi-metabola and holometabola, immature stages as ecological and evolutionary adaptations, significance of immature stages for pest management.

VI. Practical

- Preparation of permanent mounts of different body parts and their appendages of taxonomic importance including male and female genitalia;
- Dissection of genitalia. Types of immature stages in insects; their collection, rearing and preservation;
- Identification of immature insects to orders and families, in endopterygote orders, viz., Diptera, Lepidoptera, Hymenoptera and Coleoptera using key;

VII. Learning outcome

- Students are expected to have a complete understanding of the comparative morphology of the external features of insects that can be utilized in taxonomy, ecology and applied entomology.

VIII. Suggested Reading

Chapman RF. 1998. *The Insects: Structure and Function*. Cambridge Univ. Press, Cambridge.

Chu HF. 1992. *How to Know Immature Insects*. William Brown Publication, Iowa.

Duntson PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publishers, New Delhi.

Evans JW. 2004. *Outlines of Agricultural Entomology*. Asiatic Publ., New Delhi.

Gillott C. 1995. *Entomology*, 2nd Ed. Plenum Press, New York, London.

Gullan PJ and Cranston PS. 2000. *The Insects, An Outline of Entomology*, 2nd Ed. Blackwell Science, UK.

Peterson A. 1962. *Larvae of Insects*. Ohio University Press, Ohio.

Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Chapman and Hall, London.

Snodgross RE. 1993. *Principles of Insect Morphology*. Cornell Univ. Press, Ithaca.

Tembhore DB. 2000. *Modern Entomology*, Himalaya Publishing House, Mumbai.

Stehr FW. 1998. *Immature Insects*. Vols. I, II. Kendall Hunt Publication, Iowa.

I. Course Title : Insect Anatomy and Physiology

II. Course Code : ENT 502

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge about the anatomy and physiology of insect body systems; nutritional physiology; and their applications in entomology.

V. Theory

Unit I

Scope and importance of insect physiology; physiology of integument, moulting, chemistry of cuticle, biosysthesis of chitin; growth, hormonal control, metamorphosis and diapause; pheromone secretion, transmission, perception and reception.

Unit II

Physiology and mechanism of digestion, circulation, respiration, excretion, reproduction, secretion (exocrine and endocrine glands) and nerve impulse transmission in insects.

Unit III

Importance of insect nutrition- role of vitamins, proteins, amino acids, carbohydrates, lipids, minerals and other food constituents; extra and intra-cellular microorganisms and their role in physiology; artificial diets.

VI. Practical

- Latest analytical techniques for analysis of free amino acids of haemolymph;
- Determination of chitin in insect cuticle;
- Examination and count of insect haemocytes; preparation and evaluation of various diets;
- Consumption, utilization and digestion of natural and artificial diets.

VII. Learning outcome

- Students are expected to have a thorough understanding of insect growth and development, physiology of exoskeleton, endoskeleton and different organ systems;

action and role of hormones, pheromones, physiology of nutrition and its application.

VIII. Suggested Reading

Chapman RF. 1998. *Insects: Structure and Function*. ELBS Ed., London.

Duntson PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publishers, New Delhi.

Gullan PJ and Cranston PS. 2000. *The Insects*: *An Outline of Entomology*, 2nd Ed. Blackwell Science, UK.

Kerkut GA and Gilbert LI. 1985. *Comprehensive Insect Physiology, Biochemistry and Pharmacology*. Vols. I-XIII. Pergamon Press, New York.

Patnaik BD. 2002. *Physiology of Insects*. Dominant Publishers, New Delhi.

Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Vol. 1. *Structure, Physiology and Development*. Chapman and Hall, New York.

Simpson SJ. 2007. *Advances in Insect Physiology*, Vol. 33, Academic Press (Elsevier), London, UK.

Wigglesworth VB. 1984. *Insect Physiology*. 8th Ed. Chapman and Hall, New York.

I. Course Title : Insect Taxonomy

II. Course Code : ENT 503

III. Credit Hours : 3 (1 + 2)

IV. Aim of the course

To sensitize the students on the theory and practice of classifying organisms (with special reference to animals) and the rules governing the same. To introduce the students to the classification of insects up to the level of families with hands-on experience in identifying the families of insects with an emphasis on the practical aspects.

V. Theory

Unit I

History of insect classification; principles of systematics and its importance. Identification, purpose, methods character matrix, taxonomic keys. Descriptions-subjects of descriptions, characters, nature of characters, analogy *v/s* homology, parallel *v/s* convergent evolution, intraspecific variation in characters, polythetic and polymorphic taxa, sexual dimorphism. Brief evolutionary history of insects-introduction to phylogeny of insects and Classification of Superclass Hexapoda – Classes – Ellipura (Collembola, Protura), Diplura and Insecta- and the Orders contained. International Code of Zoological Nomenclature, Phylocode, its brief explanation and uses. Process of speciation and interbreeding allopatric species. Molecular systemnatics, DNA barcoding, karyological and biochemical approaches in taxonomy. Insect labeling protocols and procedures.

Unit II

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them. Collembola, Protura, Diplura. Class Insecta: Subclass Apterygota – Archaeognatha, Thysanura. Subclass: Pterygota, Division Palaeoptera – Odonata and Ephemeroptera. Division: Neoptera: Subdivision: Orthopteroid and Blattoid Orders (=Oligoneoptera: Plecoptera, Blattodea, Isoptera, Mantodea, Grylloblattodea, Dermaptera, Orthoptera, Phasmatodea, Mantophasmatodea, Embioptera, Zoraptera), Subdivision: Hemipteroid Orders (=Paraneoptera): Psocoptera, Phthiraptera, Thysanoptera and Hemiptera.

Unit III

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them (Continued). Division Neoptera – Subdivision Endopterygota, Section Neuropteroid- Coleopteroid Orders: Strepsiptera, Megaloptera, Raphidioptera, Neuroptera and Coleoptera, Section Panorpoid Orders Mecoptera, Siphonaptera, Diptera, Trichoptera, Lepidoptera, and Section Hymenopteroid Orders: Hymenoptera.

VI. Practical

- Study of Orders of insects and their identification using taxonomic keys;
- Keying out families of insects of different major Orders: Odonata, Orthoptera, Blattodea, Mantodea, Isoptera, Hemiptera, Thysanoptera, Phthiraptera, Neuroptera, Coleoptera, Diptera, Lepidoptera and Hymenoptera;
- Field visits to collect insects of different orders.

VII. Learning outcome

- Students are expected to know the evolution of arthropods, especially insects and other hexapods, and their hierarchical classification
- Acquire working skills for collecting, mounting, and preserving insects
- Understand the basic concepts of taxonomic hierarchy, identification, taxonomic characters, variations, taxonomic keys and preparation of taxonomic papers
- Identify insects of economic importance up to family levels, taking up the insect orders of agriculture and veterinary importance

VIII. Suggested Reading

CSIRO 1990. *The Insects of Australia: A Text Book for Students and Researchers*. 2nd Ed. Vols. I and II, CSIRO. Cornell Univ. Press, Ithaca.

Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.

Gullan PJ and Cranston PS. 2010. *The Insects: An outline of Entomology*. 4th Ed. Wiley-Blackwell Publications, West Sussex, UK.

Mayr E. 1971. *Principles of Systematic Zoology*. Tata McGraw Hill, New Delhi.

Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Chapman and Hall, London.

Ross HH.1974. *Biological Systematics*. Addison Wesley Publ. Company.

Triplehorn CA and Johnson NF. 1998. *Borror and DeLong's Introduction to the Study of Insects*. 7th Ed. Thomson/ Brooks/ Cole, USA/ Australia.

I. Course Title : Insect Ecology

II. Course Code : ENT 504

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To teach the concepts of ecology, basic principles of distribution and abundance of organisms and their causes. Study life tables, constructing life tables, organization of communities, diversity indices. Train students in sampling methodology, calculation of diversity indices, relating insect population fluctuations to biotic and/ or abiotic causes.

V. Theory

Unit I

History and definition. Basic Concepts. Organisation of the Biological world. Plato's

Natural Balance *vs* Ecological Dynamics as the modern view. Abundance and diversity of insects, Estimates and Causal factors. Study of abundance and distribution and relation between the two. Basic principles of abiotic factors and their generalised action on insects. Implications for abundance and distribution of organisms including insects- Law of the Minimum, Law of Tolerance, and biocoenosis, Systems approach to ecology.

Unit II

Basic concepts of abundance- Model *vs* Real world. Population growth basic models – Exponential *vs* Logistic models. Discrete *vs* Continuous growth models. Concepts of Carrying capacity, Environmental Resistance and Optimal yield. Vital Statistics-Life Tables and their application to insect biology. Survivorship curves. Case studies of insect life tables. Population dynamics- Factors affecting abundance-Environmental factors, dispersal and migration, Seasonality in insects. Classification and mechanisms of achieving different seasonality- Diapause (Quiescence) – aestivation, hibernation.

Unit III

Biotic factors- Food as a limiting factor for distribution and abundance, Nutritional Ecology. Food chain- web and ecological succession. Interspecific interactions- Basic factors governing the interspecific interactions- Classification of interspecific interactions – The argument of cost-benefit ratios. Competition- Lotka-Volterra model, Concept of niche ecological homologues, competitive exclusion. Evolution of mimicry, colouration, concept of predator satiation; evolution of life history strategies.

Unit IV

Community ecology- Concept of guild, Organisation of communities- Hutchinson Ratio, May's *d/w*, Relation between the two and their association with Dyar's Law and Przibram's law. Relative distribution of organisms, Concept of diversity- the Wallacian view. Assessment of diversity. Diversity- stability debate, relevance to pest management. Pest management as applied ecology. Climate change and insect pest/ natural enemy population; ecological engineering.

VI. Practical

- Types of distributions of organisms;
- Methods of sampling insects, estimation of densities of insects and understanding the distribution parameters- Measures of central tendencies, Poisson Distribution, Negative Binomial Distribution;
- Determination of optimal sample size. Learning to fit basic population growth models and testing the goodness of fit;
- Fitting Holling's Disc equation;
- Assessment of prey-predator densities from natural systems and understanding the correlation between the two;
- Assessing and describing niche of some insects of a single guild;
- Calculation of niche breadth, activity breadth and diagrammatic representation of niches of organisms;
- Calculation of diversity indices- Shannon's, Simpson's and Avalanche Index and understanding their associations and parameters that affect their values;
- Problem solving in ecology. Field visits to understand different ecosystems and to study insect occurrence in these systems.

VII. Learning outcome

- The students are expected to be well versed with the basic concepts of ecology, ecological succession, population ecology, community ecology, nutritional ecology and different insect-ecosystem interactions
- Quantification of insect diversity and abundance, life table analyses, predator-prey and host-parasitoid relations, functional and numerical responses, niche breadth and overlap

VIII. Suggested Reading

Begon M, Townsend CR and Harper JL. 2006. *Ecology: From Individuals to Ecosystems*. 4th Ed. Blackwell Publishing, USA/ UK/ Australia.

Chapman JL and Reiss MJ. 2006. *Ecology: Principles and Applications*. 2nd Ed. Cambridge Univ. Press, Cambridge.

Fowler J, Cohen L and Jarvis P. 1998. Practical Statistics for Field Biology. 2nd Ed. John Wiley & Sons, Chichester, West Sussex PO19 8SQ, England.

Gotelli NJ and Ellison AM. 2004. *A Primer of Ecological Statistics*. Sinauer Associates, Inc., Sunderland, MA.

Gotelli NJ. 2001. *A Primer of Ecology*. 3rd Ed. Sinauer Associates, Inc., Sunderland, MA

Gupta RK. 2004. *Advances in Insect Biodiversity*. Agrobios, Jodhpur.

Krebs CJ. 1998. *Ecological Methodology*. 2nd Ed. Benjamin-Cummings Publ. Co., New York.

Krebs CJ. 2001. *Ecology: The Experimental Analysis of Distribution and Abundance*. 5th Ed. Benjamin-Cummings Publ. Co., New York.

Magurran AE. 1988. *Ecological Diversity and its Measurement*. Princeton Univ. Press, Princeton.

Price PW. 1997. *Insect Ecology*. 3rd Ed. John Wiley, New York.

Real LA and Brown JH. (Eds). 1991. *Foundations of Ecology: Classic Papers with Commentaries*. University of Chicago Press, Chicago.

Schowalter Timothy D. 2011. *Insect Ecology – An Ecosystem Approach*. 3rd Ed. Academic Press, London, UK/ CA, USA.

Southwood TRE and Henderson PA. 2000. *Ecological Methods*. 3rd Ed. Methuen and Co. Ltd., London.

Speight MR, Hunta MD and Watt AD. 2006. *Ecology of Insects: Concepts and Application*. Elsevier Science Publ., The Netherlands.

Townsend Colin R, Begon Michael and Harper John L. 2008. *Essentials of Ecology*. 3rd Ed. Blackwell Publishing, USA/ UK/ Australia.

Wilson EO, William H and Bossert WH. 1971. *A Primer of Population Biology*. Harvard University, USA.

Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold, London.

I. Course Title : Biological Control of Insect Pests And Weeds

II. Course Code : ENT 505

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To train the students with theory and practice of biological control, mass production techniques and field evaluation of various biological control agents like parasitoids, predators and various entomopathogenic microorganisms.

V. Theory

Unit I

History, principles and scope of biological control; important groups of parasitoids, predators and pathogens; principles of classical biological control- importation, augmentation and conservation. History of insect pathology, infection of insects by bacteria, fungi, viruses, protozoa, rickettsiae, spiroplasma and nematodes.

Unit II

Biology, adaptation, host seeking behaviour of predatory and parasitic groups of insects. Role of insect pathogenic nematodes, viruses, bacteria, fungi, protozoa, etc., their mode of action. Biological control of weeds using insects. Epizootiology, symptomatology and etiology of diseases caused by the above and the factors controlling these. Defense mechanisms in insects against pathogens.

Unit III

Mass production of quality bio-control agents- techniques, formulations, economics, field release/ application and evaluation. Development of insectaries, their maintenance.

Unit IV

Successful biological control projects, analysis, trends and future possibilities of biological control. Importation of natural enemies- Quarantine regulations, biotechnology in biological control. Semiochemicals in biological control.

VI. Practical

- Identification of common natural enemies of crop pests (parasitoids, predators, microbes) and weed killers;
- Visits to bio-control laboratories to learn rearing and mass production of egg, egg-larval, larval, larval-pupal and pupal parasitoids, common predators, microbes and their laboratory hosts, phytophagous natural enemies of weeds;
- Field collection of parasitoids and predators. Hands-on training in culturing, identification of common insect pathogens. Quality control and registration standards for biocontrol agents.

VII. Learning outcome

- Students are expected to have a good understanding of the role of natural enemies in managing pest populations below those causing economic damage
- Learn the techniques for mass production of quality bio-agents and their optimal use in IPM

VIII. Suggested Reading

Burges HD and Hussey NW. (Eds). 1971. *Microbial Control of Insects and Mites*. Academic Press, London.

De Bach P. 1964. *Biological Control of Insect Pests and Weeds*. Chapman and Hall, New York.

Dhaliwal GS and Arora R. 2001. *Integrated Pest Management: Concepts and Approaches*. Kalyani Publishers, New Delhi.

Gerson H and Smiley RL. 1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*. Chapman and Hall, New York.

Huffaker CB and Messenger PS. 1976. *Theory and Practices of Biological Control*. Academic Press, London.

Ignacimuthu SS and Jayaraj S. 2003. *Biological Control of Insect Pests*. Phoenix Publ., New Delhi.

Saxena AB. 2003. *Biological Control of Insect Pests*. Anmol Publ., New Delhi.

Van Driesche and Bellows TS. Jr. 1996. *Biological Control*. Chapman and Hall, New York.

I. Course Title : Toxicology of Insecticides

II. Course Code : ENT 506

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To orient the students with structure and mode of action of important insecticides belonging to different groups, development of resistance to insecticides by insects, environmental pollution caused by toxic insecticides and their toxicological aspects.

V. Theory

Unit I

Definition and scope of insecticide toxicology; history of chemical control; pesticide use and pesticide industry in India.

Unit II

Classification of insecticides and acaricides based on mode of entry, mode of action and chemical nature; categorization of insecticides on the basis of toxicity – criteria for bees, beneficial insects and other insects in general; structure and mode of action of organochlorines, organophosphates, carbamates, pyrethroids, tertiary amines, neonicotinoids, oxadiazines, phenyl pyrozoles, insect growth regulators, microbials, botanicals, new promising compounds/ new insecticide molecules; nanopesticides; drawbacks of insecticide abuse.

Unit III

Principles of toxicology; evaluation of insecticide toxicity; joint action of insecticides-synergism, potentiation and antagonism; factors affecting toxicity of insecticides; insecticide compatibility, selectivity and phytotoxicity. bioassay definition, objectives, criteria, factors, problems and solutions.

Unit IV

Insecticide metabolism; insect-pest resistance to insecticides; mechanisms and types of resistance; insecticide resistance management and pest resurgence.

Unit V

Insecticide residues, their significance and environmental implications; procedures of insecticide residue analysis. Insecticide Act, registration procedures, label claim, and quality control of insecticides; safe use of insecticides; diagnosis and treatment of insecticide poisoning.

VI. Practical

- Insecticide formulations and mixtures;
- Laboratory and field evaluation of bio-efficacy of insecticides;
- Bioassay techniques;
- Probit analysis;
- Evaluation of insecticide toxicity;
- Toxicity to beneficial insects;
- Pesticide appliances;
- Working out doses and concentrations of pesticides;
- Procedures of residue analysis.

VII. Learning outcome

- Students are expected understand the concept of toxicity, bio-efficacy, insecticide formulations, modes of action of insecticides, estimation of insecticide residues and have significant know-how about the functioning of various types of spray equipments.

VIII. Suggested Reading

Chattopadhyay SB. 1985. *Principles and Procedures of Plant Protection*. Oxford and IBH, New Delhi.

Dodia DA, Petel IS and Petal GM. 2008. *Botanical Pesticides for Pest Management*. Scientific Publisher (India), Jodhpur.
Dovener RA, Mueninghoff JC and Volgar GC. 2002. Pesticides formulation and delivery systems: meeting the challenges of the current crop protection industry. ASTM, USA
Gupta HCL.1999. *Insecticides: Toxicology and Uses*. Agrotech Publ., Udaipur.
Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action*. Narosa Publ. House, New Delhi.
Ishaaya I and Degheele D. 1998. *Insecticides with Novel Modes of Action: Mechanism and Application*. Norosa Publishing House, New Delhi.
Krieger RI. 2001. *Handbook of Pesticide Toxicology*. Vol-II. Academic Press. Orlando Florida.
Mathews GA. 2002. *Pesticide Application Methods*. 4th Ed. Intercept. UK.
Matsumura F. 1985. *Toxicology of Insecticides*. Plenum Press, New York.
Otto D and Weber B. 1991. *Insecticides: Mechanism of Action and Resistance*. Intercept Ltd., UK.
Pedigo LP and Marlin ER. 2009. *Entomology and Pest Management*, 6th Edition, Pearson Education Inc., Upper Saddle River, New Jersey 07458, U.S.A.
Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998. *Insecticides in Agriculture and Environment*. Narosa Publ. House, New Delhi.
Prakash A and Rao J. 1997. *Botanical Pesticides in Agriculture*. Lewis Publication, New York.
Roy NK. 2006. *Chemistry of Pesticides*. Asia Printograph Shahdara Delhi.

I. Course Title : Host Plant Resistance
II. Course Code : 507
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To orient the students with host plant resistance.

V. Theory

Unit I

History and importance of resistance; principles, classification, components, types and mechanisms of resistance.

Unit II

Insect-host plant relationships; theories and basis of host plant selection in phytophagous insects.

Unit III

Chemical ecology, tritrophic relations, volatiles and secondary plant substances; basis of resistance. Induced resistance – acquired and induced systemic resistance.

Unit IV

Factors affecting plant resistance including biotypes and measures to combat them.

Unit V

Screening techniques; breeding for insect resistance in crop plants; exploitation of wild plant species; gene transfer, successful examples of resistant crop varieties in India and world.

Unit VI

Role of biotechnology in plant resistance to insects.

VI. Practical

- Screening techniques for measuring resistance;

- Measurement of plant characters and working out their correlations with plant resistance;
- Testing of resistance in important crops;
- Bioassay of plant extracts of susceptible/ resistant varieties;
- Demonstration of antibiosis, tolerance and antixenosis.

VII. Learning outcome

- Students are expected to acquire a thorough knowledge of the types and basis of mechanisms involved in host plant resistance, screening techniques to measure resistance and insect resistance breeding.

VIII. Suggested Reading

Dhaliwal GS and Singh R. (Eds). 2004. *Host Plant Resistance to Insects -Concepts and Applications*. Panima Publ., New Delhi.

Maxwell FG and Jennings PR. (Eds). 1980. *Breeding Plants Resistant to Insects*. John Wiley and Sons, New York.

Painter RH. 1951. *Insect Resistance in Crop Plants*. MacMillan, London.

Panda N and Khush GS. 1995. *Plant Resistance to Insects*. CABI, London.

Smith CM. 2005. *Plant Resistance to Arthropods – Molecular and Conventional Approaches*. Springer, Berlin.

I. Course Title : Concepts of Integrated Pest Management

II. Course Code : ENT 508

III. Credit Hours : 2 (2+0)

IV. Aim of the course

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM. Train students in computation of ETL and implementing IPM programmes.

V. Theory

Unit I

History, origin, definition and evolution of various terminologies. Importance of resistance, principles, classification, components, types and mechanisms of resistance. National and international level crop protection organizations; insecticide regulatory bodies; synthetic insecticide, bio-pesticide and pheromone registration procedures; label claim of pesticides – the pros and cons.

Unit II

Concept and philosophy, ecological principles, economic threshold concept and economic consideration. Insect-host plant relationships; theories and basis of host plant selection in phytophagous insects.

Unit III

Tools of pest management and their integration- legislative, quarantine regulations, cultural, physical and mechanical methods; semiochemicals, biotechnological and bio-rational approaches in IPM. Pest survey and surveillance, forecasting, types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost-benefit ratios and partial budgeting; case studies of successful IPM programmes. ITK-s in IPM, area-wide IPM and IPM for organic farming; components of ecological engineering with successful examples.

Unit IV

Characterization of agro-ecosystems; sampling methods and factors affecting sampling; population estimation methods; crop loss assessment direct losses, indirect losses, potential losses, avoidable losses, unavoidable losses; global and Indian scenario of crop losses. Computation of EIL and ETL; crop modeling; designing and implementing IPM system. Screening techniques; breeding for insect resistance in crop plants; exploitation of wild plant species; gene transfer, successful examples of resistant crop varieties in India and world.

VI. Learning outcome

- Students are expected to have significant knowledge of IPM concepts, estimation of losses due to insect pests, computation of ETL, EIL and should be able take management decisions.

VII. Suggested Reading

Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches*. Kalyani Publishers, New Delhi.

Horowitz AR and Ishaaya I. 2004. *Insect Pest Management: Field and Protected Crops*. Springer, New Delhi.

Ignacimuthu SS and Jayaraj S. 2007. *Biotechnology and Insect Pest Management*. Elite Publ., New Delhi.

Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management*. Prentice Hall, New Delhi.

Pedigo RL. 2002. *Entomology and Pest Management*. 4th Ed. Prentice Hall, New Delhi.

Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York.

I. Course Title : Pests of Field Crops

II. Course Code : ENT 509

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To familiarize the students about nature of damage and seasonal incidence of pestiferous insects that cause loss to major field crops and their effective management by different methods.

V. Theory

Systematic position, identification, distribution, host-range, bionomics, nature and extent of damage, seasonal abundance and management of insect and mite pests and vectors. Insect pest scenario in relation to climate change.

Unit I

Polyphagous pests: grasshoppers, locusts, termites, white grubs, hairy caterpillars, and non-insect pests (mites, birds, rodents, snails, slugs, etc.). Insect pests of cereals and millets and their management.

Unit II

Insect pests of pulses, tobacco, oilseeds and their management.

Unit III

Insect pests of fibre crops, forage crops, sugarcane and their management.

VI. Practical

- Field visits, collection and identification of important pests and their natural enemies;
- Detection and estimation of infestation and losses in different crops;
- Study of life history of important insect pests.

VII. Learning outcome

- Students are expected to acquire knowledge of insect pests of field crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

David, BV and Ramamurthy, VV. 2001. *Elements of Economic Entomology*. Popular Book Depot, Chennai.
Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi.
Dunston AP. 2007. *The Insects: Beneficial and Harmful Aspects*. Kalyani Publishers, New Delhi
Evans JW. 2005. *Insect Pests and their Control*. Asiatic Publ., New Delhi.
Nair MRGK. 1986. *Insect and Mites of Crops in India.* ICAR, New Delhi.
Prakash I and Mathur RP. 1987. *Management of Rodent Pests.* ICAR, New Delhi.
Saxena RC and Srivastava RC. 2007. *Entomology at a Glance.* Agrotech Publ. Academy, Udaipur.

I. Course Title : Pests of Horticultural and Plantation Crops
II. Course Code : ENT 510
III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge on major pests of horticultural and plantation crops regarding the extent and nature of loss, seasonal history, their integrated management.

V. Theory

Systematic position, identification, distribution, host range, bionomics and seasonal abundance, nature and extent of damage and management of insect pests of various crops.

Unit I

Fruit Crops- mango, guava, banana, jack, papaya, pomegranate, litchi, grapes, *ber*, fig, citrus, *aonla*, pineapple, apple, peach and other temperate fruits.

Unit II

Vegetable crops- tomato, potato, radish, carrot, beetroot, cole crops, French beans, chow-chow, brinjal, okra, all gourds, drumstick, leafy vegetables, etc.

Unit III

Plantation crop- coffee, tea, rubber, coconut, arecanut, cashew, cocoa, etc.; Spices and Condiments- pepper, cardamom, clove, nutmeg, chillies, turmeric, ginger, beetlevine, etc.

Unit IV

Ornamental, medicinal and aromatic plants and pests in polyhouses/ protected cultivation.

VI. Practical

- Collection and identification of important pests and their natural enemies on different crops;
- Study of life history of important insect pests and non-insect pests.

VII. Learning outcome

- Students are expected to acquire knowledge of insect pests of horticultural, medicinal and plantation crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

Atwal AS and Dhaliwal GS. 2002. *Agricultural Pests of South Asia and theirManagement*. Kalyani Publishers, New Delhi.

Butani DK and Jotwani MG. 1984. *Insects and Vegetables*. Periodical Expert Book Agency, New Delhi.

Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essential of Agricultural Entomology*. Kalyani Publishers, New Delhi.

Srivastava RP. 1997. *Mango Insect Pest Management*. International Book Distr., Dehra Dun.

Verma LR, Verma AK and Goutham DC. 2004. *Pest Management in Horticulture Crops: Principles and Practices*. Asiatech Publ., New Delhi.

I. Course Title : Post Harvest Entomology

II. Course Code : ENT 511

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To focus on requirement and importance of grain and grain storage, to understand the role of stored grain pests and to acquaint with various stored grain pest management techniques for avoiding losses in storage.

V. Theory

Unit I

Introduction, history of storage entomology, concepts of storage entomology and significance of insect pests. Post-harvest losses *in toto vis-à-vis* total production of food grains in India. Scientific and socio-economic factors responsible for grain losses. Concept of seed vault.

Unit II

Important pests namely insects, mites, rodents, birds and microorganisms associated with stored grain and field conditions including agricultural products; traditional storage structures; association of stored grain insects with fungi and mites, their systematic position, identification, distribution, host range, biology, nature and extent of damage, role of field and cross infestations and natural enemies, type of losses in stored grains and their effect on quality including biochemical changes.

Unit III

Ecology of insect pests of stored commodities/ grains with special emphasis on role of moisture, temperature and humidity in safe storage of food grains and commodities. Stored grain deterioration process, physical and biochemical changes and consequences. Grain storage- types of storage structures i.e., traditional, improved and modern storage structures in current usage. Ideal seeds and commodities' storage conditions.

Unit IV

Important rodent pests associated with stored grains and their non-chemical and chemical control including fumigation of rat burrows. Role of bird pests and their management. Control of infestation by insect pests, mites and microorganisms. Preventive measures- Hygiene/ sanitation, disinfestations of stores/ receptacles, legal methods. Curative measures- Non-chemical control measures- ecological, mechanical, physical, cultural, biological and engineering. Chemical control-prophylactic and curative- Characteristics of pesticides, their use and precautions in their handling with special emphasis on fumigants. Insecticide resistance in stored product pests and its management; recent advances (MAS, PPP, HS) in storage pest management; integrated approaches to stored grain pest management.

VI. Practical

- Collection, identification and familiarization with the stored grains/ seed insect pests and nature of damage caused by them;
- Detection of hidden insect infestation in stored food grains;
- Estimation of uric acid content in infested produce; estimation of losses in stored food grains;
- Determination of moisture content in stored food grains;
- Familiarization of storage structures, demonstration of preventive and curative measures including fumigation techniques;
- Treatment of packing materials and their effect on seed quality;
- Field visits to save grain campaign, central warehouse and FCI warehouses and institutions engaged in research or practice of grain storage like CFTRI, Mysore; IGSMRI, Hapur, etc. (only where logistically feasible).

VII. Learning outcome

- Students are expected to acquire knowledge of pestiferous insects, mites, rats and birds affecting stored produce, their nature of damage, life history traits and effective management.
- Detection of insect infestation and familiarization with different storage structures.
- Learning preventive and curative measures to manage infestation in storage houses.

VIII. Suggesting Reading

Hall DW. 1970. *Handling and Storage of Food Grains in Tropical and Subtropical Areas.* FAO. Agricultural Development Paper No. 90 and FAO, Plant Production and Protection Series No. 19, FAO, Rome.

Jayas DV, White NDG and Muir WE. 1995. *Stored Grain Ecosystem*. Marcel Dekker, New York.

Khader V. 2004. *Textbook on Food Storage and Preservation*. Kalyani Publishers, New Delhi.

Khare BP. 1994. *Stored Grain Pests and Their Management*. Kalyani Publishers, New Delhi.

Subramanyam B and Hagstrum DW. 1995. *Interrelated Management of Insects in Stored Products*. Marcel Dekker, New York.

I. Course Title : Insect Vectors of Plant Pathogens

II. Course Code : ENT 512

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To teach the students about the different groups of insects that act as vectors of plant pathogens, vector-plant pathogen interaction, and management of vectors for controlling diseases.

V. Theory

Unit I

History of developments in the area of insects as vectors of plant pathogens. Important insect vectors and their characteristics; mouth parts and feeding processes of important insect vectors. Efficiency of transmission.

Unit II

Transmission of plant viruses and fungal pathogens. Relation between viruses and their vectors.

Unit III

Transmission of plant viruses by aphids, whiteflies, mealy bugs and thrips.

Unit IV

Transmission of mycoplasma and bacteria by leaf hoppers and plant hoppers.

Unit V

Transmission of plant viruses by psyllids, beetles and mites. Epidemiology and management of insect transmitted diseases through vector management.

VI. Practical

- Identification of common vectors of plant pathogens- aphids, leafhoppers, whiteflies, thrips, beetles, nematodes;
- Culturing and handling of vectors; demonstration of virus transmission through vectors- aphids, leafhoppers and whiteflies;
- Vector rearing and maintenance;
- Estimating vector transmission efficiency, studying vector-virus host interaction.

VII. Learning outcome

- Students are expected to be well versed with insect vectors of plant pathogens, acquire knowledge on disease transmission and vector management techniques.

VIII. Suggested Reading

Basu AN. 1995. *Bemisia tabaci* (Gennadius) – *Crop Pest and Principal Whitefly Vector of Plant Viruses*. Oxford and IBH, New Delhi.

Harris KF and Maramarosh K. (Eds.). 1980. *Vectors of Plant Pathogens*. Academic Press, London.

Maramorosch K and Harris KF. (Eds.). 1979. *Leafhopper Vectors and Plant Disease Agents*. Academic Press, London.

Youdeovei A and Service MW. 1983. *Pest and Vector Management in the Tropics*. English Language Books Series, Longman, London.

I. Course Title : Principles of Acarology

II. Course Code : ENT 513

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquaint the students with external morphology of different groups of mites, train in identification of commonly occurring families of plant associated mites, provide information about important mite pests of crops and their management.

V. Theory

Unit I

History of Acarology; importance of mites as a group; habitat, collection and preservation of mites. Soil arthropods and their classification, habitats and their identification.

Unit II

Introduction to morphology and biology of mites and ticks. Broad classification-major orders and important families of Acari including diagnostic characteristics. Estimation of populations; sampling and extraction methods for soil arthropods.

Unit III

Economic importance, seasonal occurrence, nature of damage, host range of mite pests of different crops, mite pests in polyhouses, mite pests of stored products and honeybees. Management of mites using acaricides, phytoseiid predators, fungal pathogens, etc. Culturing of phytophagous, parasitic and predatory mites. Mode of action of acaricides, resistance of mites and ticks to acaricides, its management.

VI. Practical

- Collection of mites from plants, soil and animals;
- Extraction of mites from soil, plants and stored products;
- Preparation of mounting media and slide mounts;
- External morphology of mites;
- Identification of mites up to family level using keys;
- Studying different rearing techniques for mites.

VII. Learning outcome

- Students are expected to identify mites up to family level.
- Acquire knowledge of mite pests of cultivated crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

Anderson JM and Ingram JSI. 1993. *Tropical Soil Biology and Fertility: A Handbook of Methods.* CABI, London.

Chhillar BS, Gulati R and Bhatnagar P. 2007. *Agricultural Acarology*. Daya Publ. House, New Delhi.

Dindal DL. 1990. *Soil Biology Guide*. A Wiley-InterScience Publ., John Wiley and Sons, New York.

Gerson U and Smiley RL. 1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*. Chapman and Hall, NewYork.

Gupta SK. 1985. *Handbook of Plant Mites of India.* Zoological Survey of India, Calcutta.

Gwilyn O and Evans GO. 1998. *Principles of Acarology*. CABI, London.

Jeppson LR, Keifer HH and Baker EW. 1975. *Mites Injurious to Economic Plants*. University of California Press, Berkeley.

Krantz GW. 1970. *A Manual of Acarology*. Oregon State Univ. Book Stores, Corvallis, Oregon.

Pankhurst C, Dube B and Gupta, V. 1997. *Biological Indicators of Soil Health.* CSIRO, Australia.

Qiang Zhiang Z. 2003. *Mites of Green Houses- Identification, Biology and Control*. CABI, London.

Sadana GL. 1997. *False Spider Mites Infesting Crops in India.* Kalyani Publishers House, New Delhi.

Walter DE and Proctor HC. 1999. *Mites- Ecology, Evolution and Behaviou*r. CABI, London.

Veeresh GK and Rajagopal D. 1988. *Applied Soil Biology and Ecology*. Oxford and IBH Publ., New Delhi.

I. Course Title : Vertebrate Pest Management

II. Course Code : ENT 514

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To impart knowledge on vertebrate pests like birds, rodents, mammals and others of different crops, their biology, damage they cause and management strategies.

V. Theory

Unit I

Introduction to vertebrate pests of different crops; biology of vertebrate pests such as rodents, birds and other mammals.

Unit II

Bio-ecology of birds of agricultural importance, patterns of pest damage and assessment, roosting and nesting systems in birds; management of pestiferous birds; conservation of predatory birds.

Unit III

Bio-ecology of rodents of agricultural importance, patterns of pest damage and assessment, burrowing pattern and habitat of rodents; management of pestiferous rodents.

Unit IV

Bio-ecology of higher vertebrates of agricultural importance, patterns of damage and assessment, their habitat; management of pestiferous vertebrates.

Unit V

Management strategies- physical (trapping, acoustics and visual), chemical (poisons, repellents, fumigants and anticoagulants), biological (predators, parasites), cropping practices, alteration of habitats, diversion baiting and other eco-friendly methods – Operational practices- baiting, equipments and educative programmes.

VI. Practical

- Identification of important rodents, birds and other vertebrate pests of agriculture, food preference and hoarding;
- Social behaviour, damage assessment, field survey, population estimation, management strategies: preventive and curative methods.

VII. Learning outcome

- Students are expected to be well versed with vertebrate pest diversity, their nature of damage, life history traits, behaviour and effective management.

VIII. Suggested Reading

Ali S. 1965. *The Book of Indian Birds*. The Bombay Natural History Society, Bombay.

Fitzwater WD and Prakash I. 1989. *Handbook of Vertebrate Pest Control*. ICAR, New Delhi.

Prakash I and Ghosh PK. 1997. *Rodents in Indian Agriculture*. Vol. I. State of Art Scientific Publ., Jodhpur.

Prakash I and Ghosh RP. 1987. *Management of Rodent Pests*. ICAR, New Delhi.

Prater SH. 1971. *The Book of Indian Animals*. The Bombay Natural History Society, Bombay.

Rahman A. 2020. *Protective and Productive Entomology* Narendra Publishing House, New Delhi

I. Course Title : Techniques in Plant Protection

II. Course Code : ENT 515

III. Credit Hours : 1 (0+1)

IV. Aim of the course

To acquaint the students with appropriate use of plant protection equipments and techniques related to microscopy, computation, pest forecasting, etc.

V. Practical

- Pest control equipments, principles, operation, maintenance, selection, and

application of pesticides;
- Release of bio-control agents;
- Seed dressing, soaking, root-dip treatment, dusting, spraying, and pesticide application through irrigation water;
- Application of drones in plant protection;
- Soil sterilization, solarization, deep ploughing, flooding, techniques to check the spread of pests through seed, bulbs, corms, cuttings and cut flowers;
- Uses of light, transmission and scanning electron microscopy;
- Protein isolation from the pest and host plant and its quantification using spectrophotometer and molecular weight determination using SDS/ PAGE;
- Use of tissue culture techniques in plant protection;
- Computer application for predicting/ forecasting pest attack and identification.

VI. Learning outcome

- Students are expected to have a good knowledge of different plant protection equipments and techniques related to pest forecasting.

VII. Suggested Reading

Alford DV. 1999. *A Textbook of Agricultural Entomology*. Blackwell Science, London.
Crampton JM and Eggleston P. 1992. *Insect Molecular Science*. Academic Press, London.

I. Course Title : Apiculture

II. Course Code : ENT 516

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge about the honey bees, and their behaviour and activities; bee husbandry, bee multiplication, bee enemies and diseases and their management; hive products, apitherapy; and managed bee pollination of crops

V. Theory

Unit I

Historical development of apiculture at global level and in India; Classification of bees; global distribution of genus *Apis* and races; Morphology and anatomy of honey bee; Honey bee biology, ecology, adaptations; Honey bee behaviour – nest founding, comb construction, brood care, defense, other in-house and foraging activities; Bee pheromones; Honey bee communication.

Unit II

Commercial beekeeping as an enterprise; Design and use of bee hives; Apicultural equipment; Seasonal bee husbandry; Honey bee nutrition and artificial diets; Absconding, swarming, drifting – causes and management; Curbing drone rearing; Laying worker menace – causes, signs and management.

Unit III

Bee genetics; Principles and procedures of bee breeding; Screening of honey bee colonies; Techniques in mass queen bee rearing; Mating nuclei and their establishment; Selective mating; Queen bee management; Bee packages.

Unit IV

Ectoparasitic and endoparasitic bee mites – biology, ecology, nature and symptoms of damage, management tactics; Wax moths, wasps and ants – biology, ecology, nature and symptoms of damage, management tactics; Predatory birds, their damage potential and management tactics; Pesticide poisoning to honey bees, signs and protection; Protocols in evaluation of pesticide toxicity to honey bees.

Unit V

Honey – composition, properties, crystallization, post-harvest handling and processing; Honey quality standards and assessment; Apicultural diversification – potential and profitability; Production/ collection of bee pollen, propolis, royal jelly, bee venom and bees wax and their post-harvest handling; Apitherapy; Value addition of hive products; Development of apiculture project.

Unit VI

Non-*Apis* pollinators, their augmentation and conservation; Role of bee pollinators in augmenting crop productivity; Managed bee pollination of crops.

VI. Practical

- Morphological characteristics of honey bee;
- Mouthparts; digestive, respiratory and reproductive adaptations in different castes of honey bees;
- Recording of colony performance;
- Seasonal bee husbandry practices;
- Swarming, queenlessness, swarming, laying workers menaces, etc. and their remedies;
- Innovative techniques in mass queen bee rearing; selection and breeding of honey bees;
- Instrumental insemination; formulation of artificial diets and their feeding;
- Production technologies for various hive products;
- Bee enemies and diseases and their management;
- Recording pollination efficiency;
- Application of various models for determining pollination requirement of crop;
- Developing a beekeeping project.

VII. Learning outcome

- Students are expected to have a comprehensive knowledge of bee biology, physiology and bee keeping/ apiculture.
- With practical training it is expected that students develop entrepreneurial skills for apiculture.

VIII. Suggested Reading

Abrol DP and Sharma D. 2009. *Honey Bee Mites and Their Management.* Kalyani Publishers, New Delhi, India.

Abrol DP. 2009. *Honey bee Diseases and Their Management.* Kalyani Publishers, New Delhi, India.

Abrol DP. 2010. *Beekeeping: A Compressive Guide to Bees and Beekeeping.* Scientific Publishers, India.

Abrol DP. 2010. *Bees and Beekeeping in India.* Kalyani Publishers, New Delhi, India.

Abrol DP. 2012. *Pollination Biology: Biodiversity Conservation and Agricultural Production.* Springer.

Atwal AS. 2001. *World of Honey Bees.* Kalyani Publishers, New Delhi- Ludhiana, India.

Atwal AS. 2000. *Essentials of Beekeeping and Pollination.* Kalyani Publishers, New Delhi-Ludhiana, India.

Bailey L and Ball BV. 1991. *Honey Bee Pathology*. Academic Press, London.
Crane Eva and Walker Penelope. 1983. *The Impact of Pest Management on Bees and Pollination*. Tropical Development and Research and Institute, London.
Free JB. 1987. *Pheromones of Social Bees*. Chapman and Hall, London.
Gatoria GS, Gupta JK, Thakur RK and Singh Jaspal. 2011. *Mass Multiplication of Honey Bee Colonies*. ICAR, New Delhi, India.
Grahm Joe M. 1992. *Hive and the Honey Bee*. Dadant & Sons, Hamilton, Illinois, USA.
Grout RA. 1975. *Hive and the Honey Bee*. Dadant & Sons, Hamilton, Illinois, USA.
Holm E. 1995. *Queen Rearing Genetics and Breeding of Honey Bees*. Gedved, Denmark.
Laidlaw HH Jr and Eckert JE. 1962. *Queen Rearing*. Berkeley, University of California Press.
Laidlaw HH. 1979. *Contemporary Queen Rearing*. Dadant & Sons, Hamilton, Illinois, USA.
Mishra RC. 2002. *Perspectives in Indian Apiculture*. Agro-Botanica, Jodhpur, India.
Mishra RC. 1995. *Honey Bees and their Management in India*. I.C.A.R., New Delhi, India.
Morse AA. 1978. *Honey Bee Pests, Predators and Diseases*. Cornell University Press, Ithaca and London.
Rahman, A. 2017. *Apiculture in India*, ICAR, New Delhi
Ribbands CR. 1953. *The Behaviour and Social Life of Honey Bees*. Bee Research Association Ltd., London, UK.
Rinderer TE. 1986. *Bee Genetics and Breeding*. Academic Press, Orlando.
Sardar Singh. 1962. *Beekeeping in India*. I.C.A.R., New Delhi, India (Reprint: 1982).
Seeley TD. 1985. *Honey Bee Ecology*. Princeton University Press, 216 pp.
Snodgrass RE. 1925. *Anatomy and Physiology of the Honey Bee*. Mc Graw Hill Book Co., New York & London.
Snodgrass RE. 1956. *Anatomy of the Honey Bee*. Comstock Publishing Associates, Cornell Univ. Press, Ithaca, New York.

I. Course Title : Sericulture
II. Course Code : ENT 517
III. Credit Hours : 3 (2+1)

IV. Aim of the Course

To familiarize the students with entrepreneurial opportunities in entomology, sericulture in particular, and providing information on silk worm rearing, production and management.

V. Theory

Unit I

History of Sericulture, importance, organizations involved in sericulture activities, silkworm types, distribution, area and silk production.

Unit II

Mulberry species, ecological requirements, cultivation, improved varieties, propagation methods, sapling production, planting and pruning techniques; pest and diseases, management strategies; intercropping, water and weed management. Food plants of eri silkworm, castor cultivation, intercultural operations, nutrient and water management; method of harvest; host plants of Tasar, nursery and cultivation, selection of seed, soaking and heap making, pruning techniques. Food plants of Muga silkworm, Som and Soalu propagation methods; nursery techniques; intercultural operations and weed management.

Unit III

Silkworm origin – classification based on voltinism, moultinism, geographical distribution and genetic nature – pure races –multivoltine and bivoltine races – cross breeds – bivoltine hybrids –Races and hybrids of mulberry, eri, tasar and muga silkworm- Morphology and biology of silkworm, sex limited characters; anatomy of digestive and excretory systems of larva; structure and function of silk glands.

Unit IV

Rearing house, types, disinfection, room and bed disinfectants; egg incubation methods, Chawki rearing, feeding, cleaning and spacing; rearing of late age worms, feeding, cleaning, spacing and moulting care; mountages, cocoon harvesting and marketing; pests and diseases of silkworms and their management.

Unit V

Post cocoon technology, stifling, cocoon cooking, brushing, reeling, re-reeling, bleaching, degumming, dyeing, printing and weaving, different reeling machines; value addition in sericulture; economics of sericulture.

VI. Practical

- Morphology of mulberry plants;
- Identification of popular mulberry genotypes;
- Nursery bed and main field preparation;
- Planting methods;
- Identification of nutrient deficiency symptoms;
- Identification of weeds;
- Pruning and harvesting methods;
- Identification of pests and diseases of mulberry–*Terminalia arjuna, Terminalia tomentosa,* Som and Soalu- Nursery and pruning techniques – Intercultural operations;
- Morphology of silkworm – Identification of races – Dissection of mouth parts and silk glands – Disinfection techniques – rearing facilities – silkworm rearing – feeding, cleaning and spacing – Identification of pests and diseases of mulberry silkworm – hyperparasitoids and mass multiplication techniques – silkworm egg production technology –Tasar, Eri and muga silkworms – rearing methods–pests and diseases of non-mulberry silkworms – Visit to grainage, cocoon market and silk reeling centre – Economics of silkworm rearing.

VII. Learning outcome

- Students taking up sericulture are expected to have a thorough knowledge of silkworm morphology, races, biology, and all the practices of rearing for silk production.
- They should be well versed with the pests and diseases of silkworm and their management.
- With practical training it is expected that students develop entrepreneurial skills for sericulture or link up with industries to sell cocoons for silk production or guide farmers engaged in silk worm rearing/ sericulture.

VIII. Suggested Reading

Dandin SB and K Giridhar. 2014. Hand book of Sericulture Technologies. Central Silk Board, Bangalore, 423p.

Govindaiah G, VP, Sharma DD, Rajadurai S and Nishita V Naik. 2005. A text book on mulberry crop protection. Central Silk Board, Bangalore.450 p.

Jolly MS, Sen SK, Sonwalkar TN and Prasad GK. 1980. Non–mulberry Silks. FAO Agicultural Services Bulletin 29. Food and Agriculture Organization of the United Nations, Rome, 178 p.

Mahadevappa D, Halliyal VG, Shankar DG and Ravindra Bhandiwad. 2000. Mulberry Silk Reeling Technology. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi. 234 p.

Mohanty PK. 2003. Tropical wild cocoons of India. Daya Publications, Tri Nagar, New Delhi, 197 p.

Nataraju B, Sathyaprasad K, Manjunath D and Kumar A. 2005. Silkworm crop protection. CSB, Bangalore. 412 pp.

Rangaswami G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly MS. 1976. Food Plants of non-mulberry silkworms. In: *Mulberry cultivation*. FAO Agricultural Services Bulletin. Vol.1, Chapter-13. Rome, Italy. 96 p.

Tribhuvan Singh and Saratchandra B. 2004. Principles and Techniques of silkworm seed production. Discovery publishing House, New Delhi, 360 pp.

IX. E-resources

www.silkwormgenomics.org; www.silkboard.com; ww.silkgermplasm.com; www.csrtimys.res.in

I. Course Title : Lac Culture

II. Course Code : ENT 518

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To familiarize the students with entrepreneurial opportunities in entomology with an emphasis on lac culture in particular. To provide information on lac insect rearing, production and management.

V. Theory

Unit I

History of lac production; importance, potential of lac production in India; organizations involved in lac production activities; strains of lac insects and lac crops – distribution, area and production of different strains of lac.

Unit II

Steps and operation of lac production; lac host plant species, ecological requirements, their cultivation; seasons of host plants, harvest time of host plants, rearing seasons; grouping of host trees, pruning methods, timing; lac host plant pests and diseases; management strategies.

Unit III

Basic morphology and taxonomy of lac insect, strains of lac insect and their characteristics; composition of lac; biology of lac insect, species diversity and distribution.

Unit IV

Introduction, lac insect-host plant interaction; selection of brood lac, local practices, improved alternatives, coupe system; propagation of lac insects: natural self inoculation, artificial inoculation; inoculation process and duration; removal of phunki, harvesting of lac, immature harvesting, mature harvesting and time of harvesting. Predators and parasitoids of lac insect, hyperparasites, diseases and their management.

Unit V

Lac production stages; factors affecting yield and quality of shellac. Pure stock of host plants (kusum, palas, ber, pigeonpea, semialata); alternative method; technology of brood preserving. Host-specific technologies – cultivation on specific host plants; integration of lac cultivation with agro-forestry and horticulture; socio-economic potential of lac; export-import of lac/ lac products; marketing of lac and its products. Lac processing and value addition; entrepreneurship development.

VI. Practical

- Lac host cultivation and lac production practices;
- Equipments for lac production;
- Conventional and advanced methods;
- Coupe system of lac production;
- Cultivation of suitable host plants;
- Pruning of host trees;
- Herbarium of host plants;
- Strains of lac insects;
- Brood lac selection and treatment for pest management;
- Slide preparation of adult and immature stages;
- Inoculation of host tree;
- Identification of natural enemies of lac insect and their management;
- Molecular characterization of lac insect where possible;
- Harvesting;
- Process of manufacture of seed lac, shell lac from stick lac;
- Grading of seed lac and shellac;
- Marketing of lac products and by products.

VII. Learning outcome

- The students are expected to have good knowledge of lac host trees and their maintenance for lac production.
- It is expected that they should perfect the most suitable techniques for lac producton with a good knowledge about diseases and natural enemies of the lac insect.
- With practical training it is expected that students are able to guide landless labourers, who bring stick lac as forest produce.

VIII. Suggested Reading

David BV and Ramamurthy VV. 2011. *Elements of Economic Entomology*, 6th Edition, Namrutha Publications, Chennai.

Sharma KK and Ramani S. 2010. *Recent advances in lac culture*. ICAR-IINRG, Ranchi.

I. Course Title : Molecular Approaches In Entomology

II. Course Code : ENT 519

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To acquaint students the latest techniques used in molecular biology.

V. Theory

Unit I

Introduction to molecular biology, techniques used in molecular biology.

Unit II

DNA recombinant technology, identification of genes/ nucleotide sequences for traits of interest, techniques of interest in plants and microbes.

Unit III

Genes of interest in entomological research- marker genes for sex identification, peptides and neuropeptides, JH esterase, St toxins and venoms, chitinase, Plant-derived enzyme inhibitors, protease inhibitors, trypsin inhibitors, á-amylase inhibitors, lectins, terepenes and terpenoids; genes of non-plant origin, *Bacillus thuringiensis* endotoxins, mode of action of cry genes, classification and properties, synthetic Bt toxin genes, Other toxin genes, genes derived from entomophagous viruses, transgenic plants for pest resistance.

Unit IV

Genetically engineered microbes and parasitoids in biological control-Genetic engineering in baculoviruses and fungal biocontrol agents for greater efficacy against insect pests. Effects of transgenic plants on pest biology and development, resistance management strategies in transgenic crops, molecular mechanism of insecticide resistance.

Unit V

Genetic-based methods for agricultural insect pest management-insect pest management through sterile insect technique and relase of insects carrying a dominant lethal gene. Methods and application of insect trangenesis, transgenics in silkworm and honeybees. Molecular tools for taxonomy and phylogeny of insect-pests, DNA-based diagnostics. Nano technology and its application.

VI. Practical

- Isolation of DNA/ RNA;
- Agarose gel electrophoresis of DNA, quantification of DNA by spectrophotometirc and agarose gel analysis, PCR amplification of mitochondrial cytochrome oxidase subunit I gene (cox1) and 16S rRNA gene, cloning of PCR amplicons in standard plasmid vectors for sequencing, confirmation of the insert, miniprep of recombinant plasmid DNA, BLAST analysis and multiple sequence alignment of the sequence with sequences already available in GenBank;
- Isolation of host plant proteins, SDS-PAGE of the isolated proteins.

VII. Learning outcome

- The students are expected to be well versed with the basic techniques used in molecular biology.

VIII. Suggested Reading

Bhattacharya TK, Kumar P and Sharma A. 2007. *Animal Biotechnology*. 1st Ed., Kalyani Publication, New Delhi.

Hagedon HH, Hilderbrand JG, Kidwell MG and Law JH. 1990. *Molecular Insect Science*. Plenum Press, New York.

Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.

Oakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology*. Springer Verlag.

Rechcigl JE and Rechcigl NA. 1998. *Biological and Biotechnological Control of Insect Pests*. Lewis Publ., North Carolina.

Roy U and Saxena V. 2007. *A Hand Book of Genetic Engineering*. 1st Ed., Kalyani Publishers, New Delhi.
Singh BD. 2008. *Biotechnology (Expanding Horizons)*. Kalyani Publishers, New Delhi.
Singh P. 2007. *Introductory to Biotechnology*. 2nd Ed. Kalyani Publishers, New Delhi.

I. Course Title : Plant Quarantine, Bio-safety and Bio-security
II. Course Code : ENT 520
III. Credit Hours : 2 (2+0)

IV. Aim of the course

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up. Also, to facilitate students to have agood understanding of the aspects of biosafety and biosecurity.

V. Theory

Unit I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. Insecticide regulatory bodies, synthetic insecticides, bio-pesticides and pheromone registration procdures. History of quarantine legislations, PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; sanitary and phytosanitary measures. Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity. Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, issues related to release of genetically modified crops.

VI. Learning outcome

- Students offering this course are expected to have a good knowledge of the rules and regulations of Plant Quarantine, WTO regulations, GAP, Sanitary and Phytosanitary measures.

VII. Suggested Reading

Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental), CRC Press.
Shukla A and Veda OP. 2007. *Introduction to Plant Quarantine*. Samay Prakashan, New Delhi.

I. Course Title : Edible and Therapeutic Insects
II. Course Code : ENT 521
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To create awareness and acquaint students about the contribution that insects make to ecosystems, diets, food security and livelihoods in developed and developing countries.

V. Theory

Unit I
Edible and therapeutic insects: the concept, definition, and importance.

Unit II
History and origin of insects as food, feed and medication; important insect species and insect products consumed.

Unit III
Edible insect ecology, conservation and management of edible insect resources; environmental opportunities of insect rearing.

Unit IV
Nutritional composition and role of insects in food security.

Unit V
Insect farming: the concept, definitions, and rearing techniques.

Unit VI
Processing edible insects for food and feed.

Unit VII
Food safety and preservation, edible insects for livelihood security.

VI. Practical

- Survey and identification of edible and therapeutic insect species;
- Collection and preservation of edible and therapeutic insect specimens;
- Rearing techniques of edible insect species;
- Harvesting techniques of edible insects from natural environment;
- Analysis of proximate elemental composition, antioxidant and anti-nutritional properties and microbial aspects of preservation.

VII. Learning outcome

- Students are expected to be aware of insects for edible and therapeutic use; their nutritional composition.
- Should know the techniques of farming and processing insects for human and animal consumption.

VIII. Suggested Reading

Halloran A, Flore R, Vantomme P and Roos N 2018. Edible insects in sustainable food systems.
Van Huis A, Itterbeeck JK, Klunder H, Mertens E, Halloran A, Muir G and Vantomme. 2013. Edible insects: future prospects for food and feed security. Food and Agricultural Organization of the United Nations, Rome.

I. Course Title : Medical and Veterinary Entomology

II. Course Code : ENT 522

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To study the major insect, mite, and tick vectors of disease to man and animals. Students will learn to identify and understand the life cycles, morphology, and behavior of mosquitoes, ticks, mites, lice, fleas, and other disease vectors.

V. Theory

Unit I

Introduction to medical, veterinary and forensic entomology; Classification of Arthropod-borne diseases; Hematophagy, disease transmission and epidemiology; flies (Diptera) of medical and veterinary Importance; moth flies: Leishmaniasis and Bartonellosis; biting midges (Ceratapogonidae).

Unit II

Mosquito taxonomy, biology, and behavior; mosquito viruses: EEE, VEE, SLE, yellow fever,mosquito surveillance; malaria; horse flies, deer flies: EIA, anaplasmosis; muscid flies; Myiasis (Muscoidea); myiasis and louse flies; black flies of medical and veterinary Importance; filariasis: mansonellosis, onchocerciasis.

Unit III

Lice of medical and veterinary importance; rickettsial diseases: epidemic typhus, etc.; mites: rickettsial pox; mites and acariasis: mange, scabies, chiggers; spiders and scorpions; fleas (Siphonaptera) of medical and veterinary importance; plague and murine typhus.

Unit IV

Ticks of medical and veterinary importance; lyme disease, rocky mountain spotted fever, tularemia; true bugs (Hemiptera): kissing bugs and bedbugs; chagas disease; tsetse flies; Lepidoptera and Hymenoptera of medical and veterinary importance.

VI. Practical

- Identification of arthropod Classes, Orders and Families of medical and veterinary importance;
- Collection, segregation, curing insect and arachnid specimens, their preservation;
- Management of insect and mite pests of medical and veterinary importance;
- Study of some practical aspects in forensic entomology.

VII. Learning outcome

- Students are expected to identify the arthropods of medical and veterinary importance; identify the diseases transmitted by these arthropod vectors and suggest management options.

VIII. Suggested Reading

David BV and Ramamurthy VV. 2011. *Elements of Economic Entomology*, 6th Edition, Namrutha Publications, Chennai.

Gullan PJ and Cranston PS. 2010. *The Insects: An Outline of Entomology*. 4th Edition, Wiley-Blackwell, West Sussex, UK & New Jersey, US.

Mullen G and Durden L. 2018. *Medical and Veterinary Entomology*, 3rd Edition, Academic Press.

I. Course Title : Forest Entomology

II. Course Code : ENT 523

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To promote a more global theoretical understanding of pest population dynamics and the causes of forest insect outbreaks: covering pests of both natural forests and plantations, the diversity of tropical forest insects, their ecological functions, the concept of pests and the incidence of pests in natural forests, plantations and stored timber.

V. Theory

Unit I

Introduction to forestry in the tropics, tropical forests: characteristics and types of tropical forests, management of tropical forests and the problems in their management; plantation forestry: beginnings, expansion and current status.

Unit II

History of tropical forest entomology, diversity of forest insects: structural and functional diversity – the feeding guilds, concept of pests, ecology of insects in forest environment, concept and functioning of ecosystem, role of insects in ecosystem processes of tropical forests: insects as primary consumers, secondary and tertiary consumers, as decomposers, as food, pollinators and other ecological interactions.

Unit III

Insect pests in natural forests, general pest incidence, pest outbreaks: Lepidoptera, Coleoptera, Hemiptera, and Hymenoptera; insect pests in plantations, nursery pests, sapling pests, pests of older plantations and their impact; insect pests of stored timber, categories of wood destroying insects and their damage: termites and beetles.

Unit IV

Population dynamics, characteristics of population growth, factors affection population growth, principles governing population dynamics, types and causes of forest insect outbreaks; general issues in forest entomology: enemies' hypothesis, resource concentration hypothesis, pest evolution hypothesis; pest problems in plantations of indigenous *vs* exotic species; pest problems in monocultures *vs* mixed plantations.

Unit V

Management of tropical forest insect pests, historical development and present status of tropical forest pest management, overview of pest management options: preventive measures, remedial measures; unique features of forest pest management; constraints to forest pest management in the tropics; guidelines for the practice of forest pest management in the tropics.

Unit VI

Insect pests in plantations: Location-specific case studies.

VI. Practical

- Collection, identification and preservation of important insect pest specimens of forest plants and some damage material;

- Detection of insect infestation and assessment of losses due to insect pests;
- Habitat management for vertebrate and insects pests;
- Fire control methods and devices;
- Familiarization with the meteorological and plant protection equipment, application of pesticides and bio-control agents in the management of insect pests in nurseries and plantations.

VII. Learning outcome

- Students are expected to acquire knowledge of insect pests of forest nurseries, forests and plantations, their nature of damage, life history traits and effective management.
- Likewise, students are expected to have a thorough knowledge of pestiferous insects of stored timber, hide and other forest produce.

VIII. Suggested Reading

Jha LK and Sen Sarna PK. 1994. *Forest Entomology*. Ashish Publishing House, Delhi.

Nair KSS. 2007. *Tropical Forest Insect Pests: Ecology, Impact, and Management*, Cambridge University Press, Edinburgh/ New York.

Stebbings EP. 1977. *Indian Forest Insects*. JK Jain Brothers.

Course Title with Credit Load
Ph.D. in Plant Protection-Entomology

Course Code	Course Title	Credit Hours
ENT 601**	Insect Phylogeny and Systematics	3 (1+2)
ENT 602**	Insect Physiology and Nutrition	3 (2+1)
ENT 603**	Insect Ecology and Diversity	3 (2+1)
ENT 604	Insect Behaviour	2 (1+1)
ENT 605**	Bio-inputs for Pest Management	3 (2+1)
ENT 606**	Insect Toxicology and Residues	3 (2+1)
ENT 607	Plant Resistance to Insects	2 (1+1)
ENT 608	Acarology	2 (1+1)
ENT 609	Molecular Entomology	2 (1+1)
ENT 610	Integrated Pest Management	2 (2+0)
ENT 691	Doctoral Seminar – I	1 (0+1)
ENT 692	Doctoral Seminar – II	1 (0+1)
ENT 699	Doctoral Research	75 (0+75)

**Core courses for Doctoral programme.

Course Contents
Ph.D. in Plant Protection-Entomology

I. Course Title : Insect Phylogeny and Systematics

II. Course Code : ENT 601

III. Credit Hours : 3 (1+2)

IV. Aim of the course

To familiarize the students with different schools of classification, phylogenetics, classical and molecular methods, evolution of different groups of insects. Detailed study about the International Code of Zoological Nomenclature; ethics and procedure for taxonomic publications.

V. Theory

Unit I

Detailed study of three schools of classification- numerical, evolutionary and cladistic. Methodologies employed. Development of phenograms, cladograms, molecular approaches for the classification of organisms. Methods in identification of homology. Species concepts, speciation processes and evidences. Zoogeography.

Unit II

Study of different views on the evolution of insects- alternative phylogenies of insects: Kukalova Peck and Kristensen. Fossil insects and evolution of insect diversity over geological times.

Unit III

Detailed study of International Code of Zoological Nomenclature, including appendices to ICZN; scientific ethics. Nomenclature and documentation protocols and procedures; report preparation on new species; deposition of holotypes, paratypes, and insect specimens as a whole in national and international repositories – requirements and procedures.

Unit IV

Concept of Phylocode and alternative naming systems for animals. A detailed study of selected representatives of taxonomic publications – small publications of species descriptions, works on revision of taxa, monographs, check lists, faunal volumes, etc. Websites related to insect taxonomy and databases. Molecular taxonomy, barcoding species and the progress made in molecular sytematics.

VI. Practical

- Collection, curation and study of one taxon of insects- literature search, compilation of a checklist, study of characters, development of character table, and construction of taxonomic keys for the selected group;
- Development of descriptions, photographing, writing diagrams, and preparation of specimens for "type like" preservation, Submission of the collections made of the group;

- Multivariate analysis techniques for clustering specimens into different taxa, and development of phenograms;
- Rooting and character polarization for developing cladograms and use of computer programmes to develop cladograms.

VII. Learning outcome

- Scholars are expected to understand the concepts of taxonomic hierarchy, study taxonomic characters, variations, intra-specific phenotypic plasticity; prepare taxonomic keys for specific groups and write taxonomic papers and reviews.
- Scholars should be able to identify insects of economic importance up to family/ generic levels and specialize in any one group of insects up to species level identification.

VIII. Suggested Reading

CSIRO 1990. *The Insects of Australia: A Text Book for Students and Researchers*. 2nd Ed. Vols. I and II, CSIRO. Cornell Univ. Press, Ithaca.

Dakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology*. Springer-Verlag, Berlin.

Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.

Hennig W. 1960. *Phylogenetic Systematics*. Urbana Univ. Illinois Press, USA.

Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.

Mayr E and Ashlock PD. 1991. *Principles of Systematic Zoology*. 2nd Ed. McGraw Hill, New York.

Mayr E.1969. *Principles of Systematic Zoology*. McGraw-Hill, New York.

Quicke DLJ. 1993. *Principles and Techniques of Contemporary Taxonomy*. Blackie Academic and Professional, London.

Ross HH. 1974. *Biological Systematics*. Addison Wesley Publ. Co., London.

Wiley EO. 1981. *Phylogenetics: The Theory and Practices of Phylogenetic Systematics for Biologists*. Columbia Univ. Press, USA.

I. Course Title : Insect Physiology and Nutrition

II. Course Code : ENT 602

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge to the students on detailed physiology of various secretory and excretory systems, moulting process, chitin synthesis, physiology of digestion, transmission of nerve impulses, nutrition of insects, pheromones, etc.

V. Theory

Unit I

Physiology and biochemistry of insect cuticle and moulting process. Biosynthesis of chitin, chitin-protein interactions in various cuticles, hardening of cuticlde.

Unit II

Digestive enzymes, digestive physiology in phytophagous, wood boring and wool feeding insects, efficiency of digestion and absorption, role of endosymbionts in insect nutrition, nutritional effects on growth and development; physiology of excretion and osmoregulation, water conservation mechanisms.

Unit III

Detailed physiology of nervous system, transmission of nerve impulses, neuro-transmitters and modulators. Production of receptor potentials in different types of sensilla, pheromones and other semiochemicals in insect life, toxins and defense mechanisms.

Unit IV

Endocrine system and insect hormones, physiology of insect growth and development- metamorphosis, polymorphism and diapause. Insect behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

VI. Practical

- Preparation of synthetic diets for different groups of insects;
- Rearing of insects on synthetic, semi-synthetic and natural diets;
- Determination of co-efficient of utilization;
- Qualitative and quantitative profile of bio-molecules: practicing analytical techniques for analysis of free amino acids of haemolymph;
- Zymogram analyses of amylase;
- Determination of chitin in insect cuticle;
- Examination and count of insect haemocytes.

VII. Learning outcome

- The scholars are expected to have thorough theoretical and practical knowledge of insect physiology that can be made use of in practical/ applied entomological aspects.
- Understand how physiological systems in insects are integrated to maintain homeostasis.

VIII. Suggested Reading

Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.

Bernays EA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, London.

Kerkut GA and Gilbert LI. 1985. *Insect Physiology, Biochemistry and Pharmacology*. Vols. I-XIII. Pergamon Press, Oxford, New York.

Muraleedharan K. 1997. *Recent Advances in Insect Endocrinology*. Association for Advancement of Entomology, Trivandrum, Kerala.

Rockstein, M. 1978. *Biochemistry of Insects*, Academic Press.

Simpson, SJ. 2007. *Advances in Insect Physiology*, Vol. 33, Academic Press (Elsevier), London, UK.

I. Course Title : Insect Ecology and Diversity

II. Course Code : ENT 603

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart advanced practical knowledge of causal factors governing the distribution and abundance of insects and the evolution of ecological characteristics. Study insect-plant interactions; get acquainted with biodiversity and conservation.

V. Theory

Unit I

Characterization of distribution of insects- Indices of Dispersion, Taylor's Power law. Island Biogeography. Population dynamics- Life tables, Leslie Matrix, Stable age distribution, Population projections. Predator-Prey Models- Lotka-Volterra and Nicholson-Bailey Model. Crop Modeling- an introduction.

Unit II

Insect Plant Interactions. Fig-figwasp mutualism and a quantitative view of types of associations. Role of insects in the environment. Adaptations to terrestrial habitats. Evolution of insect diversity and role of phytophagy as an adaptive zone for increased diversity of insects. Evolution of resource harvesting organs, resilience of insect taxa and the sustenance of insect diversity- role of plants. Herbivory, pollination, predation, parasitism. Modes of insect-plant interaction, tri-trophic interactions. Evolution of herbivory, monophagy vs polyphagy. Role of plant secondary metabolites. Meaning of stress- plant stress and herbivory. Consequences of herbivory to plant fitness and response to stress. Constitutive and induced plant defenses. Host seeking behavior of parasitoids.

Unit III

Biodiversity and Conservation- RET species, Ecological Indicators. Principles of Population genetics, Hardy Weinberg Law, Computation of Allelic and Phenotypic frequencies, Fitness under selection, Rates of Evolution under selection. Foraging Ecology- Optimal foraging theory, Marginal Value Theorem, and Patch departure rules, central place foraging, Mean-variance relationship and foraging by pollinators, Nutritional Ecology.

Unit IV

Reproductive ecology- Sexual selection, Mating systems, Reproductive strategies – timing, egg number, reproductive effort, sibling rivalry and parent-offspring conflict. Agro-ecological vs Natural Ecosystems – Characterisation, Pest Control as applied ecology- case studies.

VI. Practical

- Methods of data collection under field conditions;
- Assessment of distribution parameters, Taylor's power law, Iwao's patchiness index, Index of Dispersion, etc.;
- Calculation of sample sizes by different methods;
- Fitting Poisson and Negative Binomial distributions and working out the data transformation methods;
- Hardy-Weinberg Law, Computation of Allelic and Phenotypic Frequencies – Calculation of changes under selection, Demonstration of genetic drift;
- Assessment of Patch Departure rules. Assessment of Resource size by female insects using a suitable insect model, fruit flies/ *Goniozus*/ Female Bruchids, etc.;
- A test of reproductive effort and fitness;
- Construction of Life tables and application of Leslie Matrix – population projections, Stable age distribution;
- Exercises in development of Algorithms for crop modeling;

VII. Learning outcome

- The scholar is expected to develop expertise in methods of data collection for insect population studies, data transformation for analyses, diversity estimates, assessing distribution parameters, study the impact of abiotic and biotic factors on the distribution and abundance of insects.

- Should gain significant knowledge on construction of life tables and their analyses, assessment of resource size by female insects, reproductive effort and fitness.

VIII. Suggested Reading

Barbosa P and Letourneau DK. (Eds.). 1988. *Novel Aspects of Insect-Plant Interactions*. Wiley, London.

Elizabeth BA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, New York.

Freeman S and Herron JC.1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.

Gotelli NJ and Ellison AM. 2004. *A Primer of Ecological Statistics*. Sinauer Associates, Sunderland, MA.

Gotelli NJ. 2001. *A Primer of Ecology*. 3rd Ed., Sinauer Associates, Sunderland, MA, USA.

Krebs C. 1998. *Ecological Methodology*. 2nd Ed. Benjamin-Cummings Publ. Co., New York.

Krebs CJ. 2001 *Ecology: The Experimental Analysis of Distribution and Abundance*. 5th Ed. Benjamin-Cummings Publ. Co., New York.

Magurran AE. 1988. *Ecological Diversity and its Measurement*. Princeton University Press, Princeton.

Real LA and Brown JH. (Eds.). 1991. *Foundations of Ecology: Classic Papers with Commentaries.* University of Chicago Press, USA.

Southwood TRE and Henderson PA. 2000. *Ecological Methods*. 3rd Ed. Wiley Blackwell, London.

Strong DR, Lawton JH and Southwood R. 1984. *Insects on Plants: Community Patterns and Mechanism*. Harward University Press, Harward.

Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold Publ., London.

I. Course Title : Insect Behaviour

II. Course Code : ENT 604

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquaint the students with a thorough understanding of how natural selection has led to various survival strategies manifested as behavior in insects.

V. Theory

Unit I

Defining Behaviour**-** Concept of umwelt, instinct, fixed action patterns, imprinting, complex behavior, inducted behavior, learnt behavior and motivation. History of Ethology- development of behaviorism and ethology, contribution of Darwin, Frisch, Tinbergen and Lorenz; Studying behavior- Proximate and Ultimate approaches, behavioural traits under natural selection, genetic control of behavior and behavioural polymorphism.

Unit II

Orientation- Forms of primary and secondary orientation including taxes and kinesis; Communication- primary and secondary orientation, responses to environmental stimuli, role of visual, olfactory and auditory signals in inter- and intra-specific communication, use of signals in defense, mimicry, polyphenism; evolution of signals.

Unit III

Reproductive behavior- mate finding, courtship, territoriality, parental care, parental investment, sexual selection and evolution of sex ratios; Social behavior- kin selection, parental manipulation and mutualism; Self organization and insect behavior.

Unit IV

Foraging- Role of different signals in host searching (plant and insects) and host acceptance, ovipositional behavior, pollination behavior, co-evolution of plants and insect pollinators. Behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

VI. Practical

- Quantitative methods in sampling behavior;
- Training bees to artificial feeders;
- Sensory adaptation and habituation in a fly or butterfly model, physical cues used in host selection in a phytophagous insect, chemical and odour cues in host selection in phytophagous insect (DBM or gram pod borer), colour discrimination in honey bee or butterfly model, learning and memory in bees, role of self-organization in resource tracking by honeybees;
- Evaluation of different types of traps against fruit flies with respect to signals;
- Use of honey bees/ *Helicoverpa armigera* to understand behavioural polymorphism with respect to learning and response to pheromone mixtures, respectively.

VII. Learning outcome

- Scholars are expected to be well versed with the behavior and orientation of insects towards exploitation as a tool in IPM.

VIII. Suggested Reading

Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.

Awasthi VB. 2001. *Principles of Insect Behaviour*. Scientific Publ., Jodhpur.

Bernays EA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, London.

Brown LB. 1999. *The Experimental Analysis of Insect Behaviour*. Springer, Berlin.

Krebs JR and Davies NB. 1993. *An Introduction to Behavioural Ecology*. 3rd Ed. Chapman and Hall, London.

Manning A and Dawkins MS. 1992. *An Introduction to Animal Behaviour*. Cambridge University Press, USA.

Mathews RW and Mathews JR. 1978. *Insect Behaviour*. A Wiley-InterScience Publ. John Wiley and Sons, New York.

I. Course Title : Bio-inputs for Pest Management

II. Course Code : ENT 605

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To appraise the students with advanced techniques in handling of different bio-agents, modern methods of biological control and scope in cropping system-based pest management in agro-ecosystems.

V. Theory

Unit I

Scope of classical biological control and augmentative bio-control; introduction and handling of natural enemies; nutrition of entomophagous insects and their hosts, dynamics of bio-agents *vis-à-vis* target pest populations.

Unit II

Bio-inputs: mass production of bio-pesticides, mass culturing techniques of bio-agents, insectary facilities and equipments, basic standards of insectary, viable mass-production unit, designs, precautions, good insectary practices.

Unit III

Colonization, techniques of release of natural enemies, recovery evaluation, conservation and augmentation of natural enemies, survivorship analysis and ecological manipulations, large-scale production of bio-control agents, bankable project preparation.

Unit IV

Scope of genetically engineered microbes and parasitoids in biological control, genetics of ideal traits in bio-control agents for introgressing and for progeny selections, breeding techniques of bio-control agents.

VI. Practical

- Mass rearing and release of some commonly occurring indigenous natural enemies;
- Assessment of role of natural enemies in reducing pest populations;
- Testing side effects of pesticides on natural enemies;
- Effect of semio-chemicals on natural enemies, breeding of various bio-control agents, performance of efficiency analyses on target pests;
- Project document preparation for establishing a viable mass-production unit/ insectary;
- Observation of feeding behavior acts of predatory bugs/ beetles.

VII. Learning outcome

- Scholars are expected to learn the mass multiplication techniques of the more common and economically feasible natural enemies to be exploited under IPM programmes.
- They should be able to guide entrepreneurs for establishing a viable mass-production unit/ insectary.

VIII. Suggested Reading

Burges HD and Hussey NW. (Eds.). 1971. *Microbial Control of Insects and Mites*. Academic Press, London.

Coppel HC and James WM. 1977. *Biological Insect Pest Suppression*. Springer Verlag, Berlin.

De Bach P. 1964. *Biological Control of Insect Pests and Weeds*. Chapman and Hall, London.

Dhaliwal, GS and Koul O. 2007. *Biopesticides and Pest Management*. Kalyani Publishers, New Delhi.

Gerson H and Smiley RL. 1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*. Chapman and Hall, New York.

Huffakar CB and Messenger PS. 1976. *Theory and Practices of Biological Control*. Academic Press, London.

I. **Course Title** : **Insecticide Toxicology and Residues**
II. **Course Code** : **ENT 606**
III. **Credit Hours** : **3 (2+1)**

IV. Aim of the course

To acquaint the students with the latest advancements in the field of insecticide toxicology, biochemical and physiological target sites of insecticides, and pesticide resistance mechanisms in insects.

V. Theory

Unit I

Penetration and distribution of insecticides in insect systems; insecticide selectivity; factors affecting toxicity of insecticides. Modes of action of newer insecticide molecules; developments in bio-rational approaches; SPLAT; RNAi technology for pest management.

Unit II

Biochemical and physiological target sites of insecticides in insects; developments in biorationals, biopesticides and newer molecules; their modes of action and structural – activity relationships; advances in metabolism of insecticides.

Unit III

Joint action of insecticides; activation, synergism and potentiation.

Unit IV

Problems associated with pesticide use in agriculture: pesticide resistance; resistance mechanisms and resistant management strategies; pest resurgence and outbreaks; persistence and pollution; health hazards and other side effects.

Unit V

Estimation of insecticidal residues- sampling, extraction, clean-up and estimation by various methods; maximum residue limits (MRLs) and their fixation; bound and conjugated residues, effect on soil fertility; insecticide laws and standards, and good agricultural practices.

VI. Practical

- Residue sampling, extraction, clean-up and estimation of insecticide residues by various methods;
- Calculations and interpretation of data;
- Biochemical and biological techniques for detection of insecticide resistance in insects;
- Preparation of EC formulation using neem oil.

VII. Learning outcome

- Scholars are expected to be well versed with the latest technologies of bioassays, insecticide/ pesticide residue analysis and solving problems associated with insect resistance to insecticides.

VIII. Suggested Reading

Busvine JR. 1971. *A Critical Review on the Techniques for Testing Insecticides*. CABI, London.
Dhaliwal GS and Koul O. 2007. *Biopesticides and Pest Management*. Kalyani Publishers, New Delhi.
Hayes WJ and Laws ER. 1991. *Handbook of Pesticide Toxicology*. Academic Press, New York.

Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action.* Narosa Publ. House, New Delhi.
Matsumura F. 1985. *Toxicology of Insecticides.* Plenum Press, New York.
O' Brien RD. 1974. *Insecticides Action and Metabolism.* Academic Press, New York.
Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998. *Insecticides in Agriculture and Environment.* Narosa Publ. House, New Delhi.
Prakash A and Rao J. 1997. *Botanical Pesticides in Agriculture.* Lewis Publ., New York.

I. Course Title : Plant Resistance to Insects
II. Course Code : ENT 607
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To familiarize the students with recent advances in resistance of plants to insects and acquaint with the techniques for assessment and evaluation of resistance in crop plants.

V. Theory

Unit I

Importance of plant resistance, historical perspective, desirable morphological, anatomical and biochemical adaptations of resistance; assembly of plant species – gene pool; insect sources – behaviour in relation to host plant factors.

Unit II

Physical and chemical environment conferring resistance in plants, role of trypsin inhibitors and protease inhibitors in plant resistance; biochemistry of induced resistance – signal transduction pathways, methyl jasmonate pathways, polyphenol oxidase pathways, salicylic acid pathways; effects of induced resistance; exogenous application of elicitors.

Unit III

Biotechnological approaches in host plant resistance- genetic manipulation of secondary plant substances; incorporation of resistant gene in crop varieties; marker-aided selection in resistance breeding.

Unit IV

Estimation of plant resistance based on plant damage- screening and damage rating; evaluation based on insect responses; techniques and determination of categories of plant resistance; breakdown of resistance in crop varieties.

VI. Practical

- Understanding mechanisms of resistance for orientation, feeding, oviposition, etc., allelochemical bases of insect resistance;
- Macroculturing of test insects like aphids, leaf/ plant hoppers, mites and stored grain pests;
- Field screening- microplot techniques, infester row technique, spreader row technique and plant nurseries;
- Determination of antixenosis index, antibiosis index, tolerance index, plant resistance index.

VII. Learning outcome

- Scholars are expected to identify sources of resistance in different crops and varieties; their utilization in resistance breeding programmes involving screening techniques for specific pests.

VIII. Suggested Reading

Panda N. 1979. *Principles of Host Plant Resistance to Insects*. Allenheld, Osum and Co., New York.

Rosenthal GA and Janzen DH. (Eds.). 1979. *Herbivores – their Interactions with Secondary Plant Metabolites*. Vol. I, II. Academic Press, New York.

Sadasivam S and Thayumanavan B. 2003. *Molecular Host Plant Resistance to Pests*. Marcel Dekker, New York.

Smith CM, Khan ZR and Pathak MD. 1994. *Techniques for Evaluating Insect Resistance in Crop Plants*. CRC Press, Boca Raton, Florida.

I. Course Title : Acarology

II. Course Code : ENT 608

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquire a good working knowledge of identification of economically important groups of mites up to the species level, a detailed understanding of the newer acaricide molecules and utilization of predators.

V. Theory

Unit I

Comparative morphology of Acari, phylogeny of higher categories in mites, knowledge of commonly occurring orders and families of Acari in India. Diagnostic characteristics of commonly occurring species from families Tetranychidae, Tenuipalpidae, Eriophyidae, Tarsonemidae, Phytoseiidae, Bdellidae, Cunaxidae, Stigmaeidae, Pymotidae, Cheyletidae, Acaridae, Pyroglyphidae, Orthogalumnidae, Argasidae, Ixodidae, Sarcoptidae. Soil mites in India.

Unit II

Management of economical important species of mites in agriculture, veterinary and public health; storage acarology.

Unit III

Mites as vectors of plant pathogens; mode of action, structure-activity relationships of different groups of acaricides; problem of pesticide resistance in mites, resurgence of mites.

Unit IV

Predatory mites, their mass production and utilization in managing mite pests, acaropathogenic fungi- identification, isolation and utilization.

VI. Practical

- Identification of commonly occurring mites up to species, preparation of keys for identification;
- Collection of specific groups of mites and preparing their identification keys;
- Rearing phytoseiid mites and studying their role in suppression of spider mites;
- Management of mite pests of crops using acaricides, phytoseiid predators, fungal pathogens, etc.

VII. Learning outcome

- Scholars should be able to identify major mite pests, their management and predatory mites that can be used in biological control.
- They are also expected to learn the rearing techniques of predatory Phytoseiid mites.

VIII. Suggested Reading

Evans GO.1992. *Principles of Acarology*. CABI, London.

Gerson H and Smiley RL. 1990. *Acarine Bio-control Agents- An Illustrated Key and Manual*. Chapman and Hall, New York.

Gupta SK. 1985. *Handbook of Plant Mites of India*. Zoological Survey of India, Calcutta.

Krantz GW. 1970. *A Manual of Acarology*. Oregon State University Book Stores, Corvallis, Oregon.

Sadana GL. 1997. *False Spider Mites Infesting Crops in India*. Kalyani Publ. House, New Delhi.

I. Course Title : Molecular Entomology

II. Course Code : ENT 609

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To familiarize the students with DNA recombinant technology, marker genes, transgenic plants, and biotechnological advances in sericulture and apiculture.

V. Theory

Unit I

Introduction to molecular biology; techniques used in molecular biology.

Unit II

DNA and RNA analysis in insects- transcription and translocation mechanisms. DNA recombinant technology, identification of genes/ nucleotide sequences for characters of interest. Genetic improvement of natural enemies. Cell lines, genetic engineering in baculoviruses, *Bt* and entomopathogenic fungi.

Unit III

Genes of interest in entomological research- marker genes for sex identification, neuropeptides, JH esterase, St toxins and venoms, chitinase, CPTI; lectins and proteases. Transgenic plants for pest resistance and diseases.

Unit IV

Insect gene transformation; biotechnology in relation to silkworms and honey bees; introduction of lectin genes for pest suppression; DNA finger printing for taxonomy and phylogeny. Genetic improvement of inebriate tolerance of natural enemies.

Unit V

DNA-based diagnostics; insect immune systems in comparison to vertebrates; molecular basis of metamorphosis; Sf transgenic technology and implications; molecular biology of baculoviruses; insecticide resistance. Resistance management strategies in transgenic crops.

VI. Practical

- Isolation of DNA/ RNA;
- Purity determinations, purification of total DNA from animal tissues;
- Base pair estimation;

- Agarose gel electrophoresis;
- Quantitative enzyme profile of alimentary canal;
- Restriction mapping of DNA;
- Demonstration of PCR, RFLP and RAPD techniques.

VII. Learning outcome

- The scholars are expected to have mastered the molecular techniques applicable in entomological research like isolation of insect DNA, purification, DNA barcoding and utilizing these techniques in molecular systematics and biological control aspects.

VIII. Suggested Reading

Bhattacharya TK, Kumar P and Sharma A. 2007. *Animal Biotechnology*. 1st Ed., Kalyani Publication, New Delhi.
Hagedon HH, Hilderbrand JG, Kidwell MG and Law JH. 1990. *Molecular Insect Science*. Plenum Press, New York.
Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.
Oakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology*. Springer Verlag.
Rechcigl JE and Rechcigl NA. 1998. *Biological and Biotechnological Control of Insect Pests*. Lewis Publ., North Carolina.
Roy U and Saxena V. 2007. *A Hand Book of Genetic Engineering*. 1st Ed., Kalyani Publishers, New Delhi.
Singh BD. 2008. *Biotechnology* (*Expanding Horizons*). Kalyani Publishers, New Delhi.
Singh P. 2007. *Introductory to Biotechnology*. 2nd Ed. Kalyani Publishers, New Delhi.

I. Course Title : Integrated Pest Management
II. Course Code : ENT 610
III. Credit Hours : 2 (2+0)

IV. Aim of the course

To acquaint the students with recent concepts of integrated pest management; surveillance and data base management; successful national and international case histories of integrated pest management, non-conventional tools in pest management.

V. Theory

Unit I

Principles of sampling and surveillance, database management and computer programming; simulation techniques, system analysis and modeling.

Unit II

Study of case histories of national and international programmes, their implementation, adoption and criticism; global trade and risk of invasive pests; updating knowledge on insect outbreaks and their management.

Unit III

Genetic engineering and new technologies- their progress and limitations in IPM programmes, deployment of benevolent alien genes for pest management- case studies; scope and limitations of bio-intensive and ecological based IPM programmes; application of IPM to farmers' real time situation.

Unit IV

Challenges, needs and future outlook; dynamism of IPM under changing cropping systems and climate; insect pest management under protected cultivation; strategies for pesticide resistance management.

VI. Learning outcome

- Having gained sufficient experience in advanced studies of IPM the scholars should be able to independently frame IPM schedules for major crops/ cropping ecosystems (cereal/ pulse crop/ oilseed crop based/ vegetable crop based agro-ecosystems).

VII. Suggested Reading

Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches.* Kalyani Publishers, New Delhi.

Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi.

Flint MC and Bosch RV. 1981. *Introduction to Integrated Pest Management*. Springer, Berlin.

Koul O and Cuperus GW. 2007. *Ecologically Based Integrated Pest Management.* CABI, London.

Koul O, Dhaliwal GS and Curperus GW. 2004. *Integrated Pest Management –Potential, Constraints and Challenges.* CABI, London.

Maredia KM, Dakouo D and Mota-Sanchez D. 2003. *Integrated Pest Management in the Global Arena.* CABI, London.

Metcalf RL and Luckman WH. 1982. *Introduction to Insect Pest Management.* John Wiley and Sons, New York.

Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management.* Prentice Hall, New Delhi.

Pedigo RL. 1996. *Entomology and Pest Management*. Prentice Hall, New Delhi.

Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products.* Marcel Dekker, New York.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Protection
– Plant Pathology

Course Title with Credit Load
M.Sc. in Plant Pathology

Course Code	Course Title	Credit Hours
PL PATH 501*	Mycology	2+1
PL PATH 502*	Plant Virology	2+1
PL PATH 503*	Plant Pathogenic Prokaryotes	2+1
PL PATH 504*	Plant Nematology	2+1
PL PATH 505*	Principles of Plant Pathology	2+1
PL PATH 506*	Techniques in Detection and Diagnosis of Plant Diseases	0+2
PL PATH 507	Principles of Plant Disease Management	2+1
PL PATH 508	Epidemiology and Forecasting of Plant Diseases	1+0
PL PATH 509	Disease Resistance in Plants	2+0
PL PATH 510	Ecology of Soil-borne Plant Pathogens	1+1
PL PATH 511	Chemicals and Botanicals in Plant Disease Management	2+1
PL PATH 512	Detection and Management of Seed Borne Pathogens	2+1
PL PATH 513	Biological Control of Plant Diseases	1+1
PL PATH 514	Integrated Disease Management	2+1
PL PATH 515*	Diseases of Field and Medicinal Crops	2+1
PL PATH 516	Diseases of Fruits, Plantation and Ornamental Crops	2+1
PL PATH 517	Diseases of Vegetable and Spices Crops	2+1
PL PATH 518	Post Harvest Diseases	2+1
PL PATH 519	Plant Quarantine and Regulatory Measures	1+0
PL PATH 591	Master's Seminar	0+1
PL PATH 521	Master's Research	0+30

*Core Courses for Master's

Course Contents
M.Sc. in Plant Pathology

I. Course Title : Mycology
II. Course Code : PL PATH 501
III. Credit Hours : 2+1

IV. Aim of the course

To study the nomenclature, classification and characters of fungi.

V. Theory

Unit I

Introduction, definition of different terms, basic concepts. Importance of mycology in agriculture, relation of fungi to human affairs. History of mycology. Importance of culture collection and herbarium of fungi. Somatic characters and reproduction in fungi. Modern concept of nomenclature and classification, Classification of kingdom fungi: Stramenopila and Protists.

Unit II

The general characteristics of protists and life cycle in the Phyla Plasmodiophoromycota, Dictyosteliomycota, Acrasiomycota and Myxomycota. Kingdom Stramenopila: characters and life cycles of respective genera under Hypochytriomycota, Oomycota and Labyrinthulomycota.

Unit III

Kingdom fungi: General characters, ultrastructure and life cycle patterns in representative genera under Chytridiomycota, Zygomycota, Ascomycota; Archiascomycetes, Ascomycetous yeasts, Pyrenomycetes, Plectomycetes, Discomycetes, Loculoascomycetes, Erysiphales and anamorphs of ascomycetous fungi.

Unit IV

Basidiomycota; general characters, mode of reproduction, types of basidiocarps and economic importance of Hymenomycetes. Uridinales and Ustilaginales; variability, host specificity and life cycle pattern in rusts and smuts. Mitosporic fungi; status of asexual fungi, their teliomorphic relationships, Molecular characterization of plant pathogenic fungi.

VI. Practical

- Detailed comparative study of different groups of fungi;
- Collection of cultures and live specimens;
- Saccardoan classification and classification based on conidiogenesis;
- Vegetative structures and different types of fruiting bodies produced by slime molds, stramenopiles and true fungi;
- Myxomycotina: Fructification, plasmodiocarp, sporangia, plasmodium and aethalia. Oomycota;

- Somatic and reproductory structures of *Pythium*, *Phytophthora*, downy mildews and *Albugo*, Zygomycetes: Sexual and asexual structures of *Mucor*, *Rhizopus*, General characters of VAM fungi. Ascomycetes; fruiting structures, Erysiphales, and Eurotiales;
- General identification characters of Pyrenomycetes, Discomycetes, Loculo-ascomycetes and Laboulbenio-mycetes, Basidiomycetes; characters, ultrastructures and life cycle patterns in Ustilaginomycetes and Teliomycetes, Deuteromycetes;
- Characters of Hyphomycetes and Coelomycetes and their teliomorphic and anamorphic states, Collection, preservation, culturing and identification of plant parasitic fungi;
- Application of molecular approaches and techniques for identification of fungal pathogens.

VII. Suggested Reading

Ainsworth GC, Sparrow FK and Susman HS. 1973. *The Fungi – An Advanced Treatise*. Vol. IV (A & B). Academic Press, New York.

Alexopoulos CJ, Mims CW and Blackwell M.2000. *Introductory Mycology*. 5th Ed. John Wiley & Sons, New York.

Maheshwari R. 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US.

Mehrotra RS and Arneja KR. 1990. *An Introductory Mycology*. Wiley Eastern, New Delhi.

Sarbhoy AK. 2000. *Text book of Mycology*. ICAR, New Delhi.

Singh RS. 1982. *Plant Pathogens – The Fungi*. Oxford & IBH, New Delhi.

Webster J. 1980. *Introduction to Fungi*. 2nd Ed. Cambridge Univ. Press, Cambridge, New York.

I. Course Title : Plant Virology

II. Course Code : PL PATH 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the structure, virus- vector relationship, biology and management of plant viruses.

V. Theory

Unit I

History and economic significances of plant viruses. General and morphological characters, composition and structure of viruses. Myco-viruses, arbo and baculo viruses, satellite viruses, satellite RNAs, phages, viroids and prions**.** Origin and evolution of viruses and their nomenclature and classification.

Unit II

Genome organization, replication in selected groups of plant viruses and their movement in host. Response of the host to virus infection: biochemical, physiological, and symptomatical changes. Transmission of viruses and virus-vector relationship. Isolation and purification of viruses.

Unit III

Detection and identification of plant viruses by using protein and nucleic acid based diagnostic techniques. Natural (R-genes) and engineering resistance to plant viruses.

Unit IV

Virus epidemiology and ecology (spread of plant viruses in fields, host range and survival). Management of diseases caused by plant viruses.

VI. Practical

- Study of symptoms caused by plant viruses (followed by field visit);
- Isolation and biological purification of plant virus cultures;
- Bioassay of virus cultures on indicator plants and host differentials;
- Transmission of plant viruses (Mechanical, graft and vector and study of disease development);
- Plant virus purification (clarification, concentration, centrifugation, high resolution separation and analysis of virions), Electron microscopy for studying viral particle morphology;
- Antisera production, Detection and diagnosis of plant viruses with serological (ELISA), nucleic acid (Non-PCR–LAMP, Later flow micro array and PCR based techniques);
- Exposure to basic bio-informatic tools for viral genome analysis and their utilization in developing detection protocols and population studies (BLASTn tool, Primer designing software, Bioedit tool, Claustal X/W, MEGA Software).

VII. Suggested Reading

Bos L. 1964. *Symptoms of Virus Diseases in Plants*. Oxford & IBH., New Delhi.

Brunt AA, Krabtree K, Dallwitz MJ, Gibbs AJ and Watson L. 1995. *Virus of Plants: Descriptions and Lists from VIDE Database*. CABI, Wallington.

Gibbs A and Harrison B. 1976. *Plant Virology – The Principles*. Edward Arnold, London. Hull R. 2002. *Mathew's Plant Virology*. 4th Ed. Academic Press, New York.

Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Oxford & IBH, New Delhi.

Wilson C. 2014. *Applied Plant Virology*. CABI Publishing England.

I. Course Title : Plant Pathogenic Prokaryotes

II. Course Code : PL PATH 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with plant pathogenic prokaryote (procarya) and their structure, nutritional requirements, survival and dissemination.

V. Theory

Unit I

Prokaryotic cell: History and development of Plant bacteriology, history of plant bacteriology in India. Evolution of prokaryotic life, Prokaryotic cytoskeletal proteins. Structure of bacterial cell. Structure and composition of gram negative and gram positive cell wall; synthesis of peptidoglycan; Surface proteins; Lipopolysaccaride structure; Membrane transport; fimbrae and pili (Type IV pili); Mechanism of flagellar rotatory motor and locomotion, and bacterial movement; Glycocalyx (S-layer; capsule); the bacterial chromosomes and plasmids; Operon and other structures in cytoplasm; Morphological feature of fastidious bacteria, spiroplasmas and Phytoplasmas.

Unit II

Growth and nutritional requirements. Infection mechanism, role of virulence factors in expression of symptoms. Survival and dispersal of phytopathogenic prokaryotes.

Unit III

Taxonomy of phytopathogenic prokarya: Taxonomic ranks hierarchy; Identification, Classification and nomenclature of bacteria, phytoplasma and spiroplasma. The codes of Nomenclature and characteristics. Biochemical and molecular characterization of phytopathogenic prokaryotes.

Unit IV

Variability among phytopathogenic prokarya: general mechanism of variability (mutation); specialized mechanisms of variability (sexual like process in bacteria-conjugation; transformation; transduction); and horizontal gene transfer.

Unit V

Bacteriophages, L form of bacteria, plasmids and bdellovibrios: Structure; Infection of host cells; phage multiplication cycle; Classification of phages, Use of phages in plant pathology/ bacteriology, Lysogenic conversion; H Plasmids and their types, plasmid borne phenotypes.Introduction to bacteriocins. Strategies for management of diseases caused by phytopathogenic prokaryotes.

VI. Practical

- Study of symptoms produced by phytopathogenic prokaryotes;
- Isolation, enumeration, purification, identification and host inoculation of phytopathogenic bacteria;
- Stains and staining methods;
- Biochemical and serological characterization;
- Isolation of genomic DNA plasmid;
- Use of antibacterial chemicals/ antibiotics;
- Isolation of fluorescent *Pseudomonas*;
- Preservation of bacterial cultures;
- Identification of prokaryotic organisms by using 16S rDNA, and other gene sequences;
- Diagnosis and management of important diseases caused by bacteria and mollicutes.

VII. Suggested Reading

Goto M. 1990. *Fundamentals of Plant Bacteriology*. Academic Press, New York.

Jayaraman J and Verma JP. 2002. *Fundamentals of Plant Bacteriology*. Kalyani Publishers, Ludhiana.

Mount MS and Lacy GH. 1982. *Phytopathogenic Prokaryotes*. Vols. I, II Academic Press, New York.

Salle AJ. 1979. *Fundamental Principles of Bacteriology* 7^{th} *edn.*

Verma JP, Varma A and Kumar D. (Eds). 1995. *Detection of Plant Pathogens and their Management*. Angkor Publ., New Delhi.

I. Course Title : Plant Nematology

II. Course Code : PL PATH 504

III. Credit Hours : 2+1

IV. Aim of the course

To project the importance of nematodes in agriculture and impart basic knowledge on all aspects of plant nematology.

V. Theory

Unit I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity- plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

Unit II

Gross morphology of plant parasitic nematodes; broad classification, nematode biology, physiology and ecology.

Unit III

Types of parasitism; nature of damage and general symptomatology; interaction of plant-parasitic nematodes with other organisms.

Unit IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

Unit V

Principles and practices of nematode management; integrated nematode management.

Unit VI

Emerging nematode problems, Importance of nematodes in international trade and quarantine.

VI. Practical

- Studies on kinds of nematodes- free-living, animal, insect and plant parasites;
- Nematode extraction from soil;
- Extraction of migratory endoparasites, staining for sedentary endoparasites;
- Examination of different life stages of important plant parasitic nematodes, their symptoms and histopathology.

VII. Suggested Reading

Dropkin VH. 1980. *An Introduction to Plant Nematology*. John Wiley & Sons, New York.
Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.
Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed. CABI Publishing: Wallingford, UK.
Perry RN, Moens M, and Starr JL. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.
Sikora RA, Coyne D, Hallman J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture.*3rd edn. CABI Publishing, England.
Thorne G. 1961. *Principles of Nematology*. McGraw Hill, New Delhi.
Walia RK and Bajaj HK. 2003. *Text Book on Introductory Plant Nematology*. ICAR, New Delhi.
Walia RK and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants*, ICAR-AICRP (Nematodes), IARI, New Delhi.

I. Course Title : Principles of Plant Pathology

II. Course Code : PL PATH 505

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the subject of Plant Pathology, its concepts and principles.

V. Theory

Unit I

Importance, definitions and concepts of plant diseases, history and growth of plant pathology, biotic and abiotic causes of plant diseases.

Unit II

Growth, reproduction, survival and dispersal of important plant pathogens, role of environment and host nutrition on disease development.

Unit III

Host parasite interaction, recognition concept and infection, symptomatology, disease development- role of enzymes, toxins, growth regulators; defense strategies- oxidative burst; Phenolics, Phytoalexins, PR proteins, Elicitors. Altered plant metabolism as affected by plant pathogens.

Unit IV

Genetics of resistance; 'R' genes; mechanism of genetic variation in pathogens; molecular basis for resistance; marker-assisted selection; genetic engineering for disease resistance.

VI. Practical

- Basic plant pathological techniques;
- Isolation, inoculation and purification of plant pathogens and proving Koch's postulates;
- Techniques to study variability in different plant pathogens;
- Purification of enzymes, toxins and their bioassay;
- Estimation of growth regulators, phenols, phytoalexins in resistant and susceptible plants.

VII. Suggested Reading

Agrios GN. 2005. *Plant Pathology*. 5th Ed. Academic Press, New York.

Heitefuss R and Williams PH. 1976. *Physiological Plant Pathology*. Springer Verlag, Berlin, New York.

Mehrotra RS and Aggarwal A. 2003. *Plant Pathology*. 2nd Ed. Oxford & IBH, New Delhi.

Singh RP. 2012. *Plant Pathology* 2nd edn. Kalyani Publishers, New Delhi.

Singh RS. 2017. *Introduction to Principles of Plant Pathology*. 5th edn. MedTech, New Delhi.

Singh DP and Singh A. 2007. *Disease and Insect Resistance in Plants.* Oxford & IBH, New Delhi.

Upadhyay RK. and Mukherjee KG. 1997. *Toxins in Plant Disease Development and Evolving Biotechnology*. Oxford & IBH, New Delhi.

I. Course Title : Techniques for Detection and Diagnosis of Plant Diseases

II. Course Code : PL PATH 506

III. Credit Hours : 0+2

IV. Aim of the course

To impart training on various methods/ techniques/ instruments used in the study of plant diseases/ pathogens.

V. Practical

- Detection of plant pathogens 1. Based on visual symptoms, 2. Biochemical test 3.

Using microscopic techniques, 4. Cultural studies; (use of selective media to isolate pathogens). 5. Biological assays (indicator hosts, differential hosts) 6. Serological assays 7. Nucleic acid based techniques (Non-PCR–LAMP, Later flow microarray and PCR based- multiplex, nested, qPCR, immune capture PCR, etc.);

- Phenotypic and genotypic tests for identification of plant pathogens;
- Molecular identification (16S rDNA and 16s-23S rDNA intergenic spacer region sequences-prokaryotic organisms; and eukaryotic organism by ITS region) and whole genome sequencing;
- Volatile compounds profiling by using GC-MS and LC-MS;
- FAME analysis, Fluorescence *in-situ* Hybridization (FISH), Flow Cytometry, Phage display technique, biosensors for detection of plant pathogens;
- Genotypic tools such as genome/ specific gene sequence homology comparison by BLAST (NCBI and EMBL) and electron microscopy techniques of plant virus detection and diagnosis.

VI. Suggested Reading

Baudoin ABAM, Hooper GR, Mathre DE and Carroll RB. 1990. *Laboratory Exercises in Plant Pathology: An Instructional Kit*. Scientific Publ., Jodhpur.

Dhingra OD and Sinclair JB. 1986. *Basic Plant Pathology Methods*. CRC Press, London, Tokyo. Fox RTV. 1993. *Principles of Diagnostic Techniques in Plant Pathology,* CABI Wallington.

Forster D and Taylor SC. 1998. *Plant Virology Protocols: From Virus Isolation to Transgenic Resistance*. *Methods in Molecular Biology*. Humana Press, Totowa, New Jersey.

Mathews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Boca Raton, Tokyo.

Matthews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Florida.

Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Cent. Agic. Pub. Doc. Wageningen.

Pathak VN. 1984. *Laboratory Manual of Plant Pathology*. Oxford & IBH, New Delhi.

Trigiano RN, Windham MT and Windham AS. 2004. *Plant Pathology-Concepts and Laboratory Exercises*. CRC Press, Florida.Chakravarti BP. 2005. *Methods of Bacterial Plant Pathology*. Agrotech, Udaipur.

I. Course Title : Principles of Plant Disease Management

II. Course Code : PL PATH 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with different strategies for management of plant diseases.

V. Theory

Unit I

Principles of plant disease management by cultural, physical, biological, chemical, organic amendments and botanicals methods of plant disease control, integrated control measures of plant diseases. Disease resistance and molecular approach for disease management.

Unit II

History of fungicides, bactericides, antibiotics, concepts of pathogen, immobilization, chemical protection and chemotherapy, nature, properties and mode of action of antifungal, antibacterial and antiviral chemicals. Label claim of fungicides.

Unit III

Application of chemicals on foliage, seed and soil, role of stickers, spreaders and other adjuvants, health *vis-a-vis* environmental hazards, residual effects and safety measures

VI. Practical

- Phytopathometry;
- Methods of *in-vitro* evaluation of chemicals, antibiotics, bio agents against plant pathogens;
- Field evaluation of chemicals, antibiotics, bio agents against plant pathogens;
- Soil solarisation, methods of soil fumigation under protected cultivation;
- Methods of application of chemicals and bio control agents;
- ED and MIC values, study of structural details of sprayers and dusters;
- Artificial epiphytotic and screening of resistance.

VII. Suggested Reading

Fry WE. 1982. *Principles of Plant Disease Management*. Academic Press, New York.

Hewitt HG. 1998. *Fungicides in Crop Protection*. CABI, Wallington. Marsh RW. 1972. Systemic Fungicides. Longman, New York.

Nene YL and Thapliyal PN. 1993. *Fungicides in Plant Disease Control*. Oxford & IBH, New Delhi.

Palti J. 1981. *Cultural Practices and Infectious Crop Diseases*. Springer Verlag, New York.

Vyas SC. 1993 *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi.

I. Course Title : Epidemiology and Forecasting of Plant Diseases

II. Course Code : PL PATH 508

III. Credit Hours : 1+0

IV. Aim of the course

To acquaint with the principles of epidemiology and its application in disease forecasting.

V. Theory

Unit I

Epidemic concepts, simple interest and compound interest disease, historical development. Elements of epidemics and their interaction.Structures and patterns of epidemics. Modelling, system approaches and expert systems in plant pathology.

Unit II

Genetics of epidemics. Models for development of plant disease epidemics. Common and natural logarithms, function fitting, area under disease progress curve and correction factors, inoculum dynamics. Population biology of pathogens, temporal and spatial variability in plant pathogens.

Unit III

Epidemiological basis of disease management. Survey, surveillance and vigilance. Remote sensing techniques and image analysis. Crop loss assessment.

Unit IV

Principles and pre-requisites of forecasting, systems and factors affecting various components of forecasting, some early forecasting and procedures based on weather and inoculum potential, modelling disease growth and disease prediction. Salient features of important forecasting models.

VI. Suggested Reading

Campbell CL and Madden LV. 1990. *Introduction to Plant Disease Epidemiology*. John Wiley & Sons, New York

Cooke B, Jones DM and Gereth KB. 2018 *The Epidemiology of Plant Diseases*. Springer Publications.
Cowling EB and Horsefall JG. 1978. *Plant Disease*. Vol. II. Academic Press, New York.
Laurence VM, Gareth H and Frame Van den Bosch (Eds.). *The Study of Plant Disease Epidemics*. APS, St. Paul, Minnesota.
Nagarajan S and Murlidharan K. 1995. *Dynamics of Plant Diseases*. Allied Publ., New Delhi.
Thresh JM. 2006. *Plant Virus Epidemiology*. Advances in Virus Research 67, Academic Press, New York.
Van der Plank JE. 1963. *Plant Diseases Epidemics and Control*. Academic Press, New York.
Zadoks JC and Schein RD. 1979. *Epidemiology and Plant Disease Management*. Oxford Univ. Press, London.

I. Course Title : Disease Resistance in Plants

II. Course Code : PL PATH 509

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint with the disease resistance mechanisms.

V. Theory

Unit I

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminologies. Disease escape,non-host resistance and disease tolerance.

Unit II

Genetic basis of disease resistance, types of resistance, identification of physiological races of pathogen, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens.

Unit III

Host defence system, morphological and anatomical resistance, pre-formed chemicals in host defence, post infectional chemicals in host defence, phytoalexins, hypersensitivity and its mechanisms. Genetic basis of relationships between pathogen and host, Gene-for-gene concept, protein-for-protein and immunization basis, management of resistance genes. Strategies for gene deployment.

VI. Suggested Reading

Deverall BJ. 1977. *Defence Mechanisms in Plants*. Cambridge Univ. Press, Cambridge, New York.
Mills Dallice *et al.*1996. *Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction*. APS, St Paul, Minnesota.
Parker J. 2008. *Molecular Aspects of Plant Diseases Resistance*. Blackwell Publ.
Robinson RA. 1976. *Plant Pathosystems*. Springer Verlag, New York.
Singh BD. 2005. *Plant Breeding – Principles and Methods*. 7th Ed. Kalyani Publishers, Ludhiana
Van der Plank JE. 1975. *Principles of Plant Infection*. Academic Press, New York.
Van der Plank JE. 1978. *Genetic and Molecular Basis of Plant Pathogenesis*. Springer Verlag. New York.
Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press, New York.
Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press, New York.

I. Course Title : Ecology of Soil Borne Plant Pathogens

II. Course Code : PL PATH 510

III. Credit Hours : 1+1

IV. Aim of the course

To provide knowledge on soil-plant disease relationship.

V. Theory

Unit I

Soil as an environment for plant pathogens, nature and importance of rhizosphere and rhizoplane, host exudates, soil and root inhabiting fungi. Interaction of microorganisms.

Unit II

Types of biocontrol agents. Inoculum potential and density in relation to host and soil variables, competition, predation, antibiosis and fungistasis. Conducive and suppressive soils.

Unit III

Biological control- concepts and potentialities for managing soil borne pathogens. Potential of *Trichoderma* and fluorescent *Pseudomonas* in managing plant diseases.

VI. Practical

- Quantification of rhizosphere and rhizoplane microflora with special emphasis on pathogens;
- Pathogenicity test by soil and root inoculation techniques, correlation between inoculum density of test pathogens and disease incidence, demonstration of fungistasis in natural soils;
- Suppression of test soil-borne pathogens by antagonistic microorganisms;
- Isolation and identification of different biocontrol agents;
- Study of various plant morphological structures associated with resistance, testing the effect of root exudates and extracts on spore germination and growth of plant pathogens;
- Estimating the phenolic substances, total reducing sugars in susceptible and resistant plants;
- Estimating the rhizosphere and root tissue population of microorganisms (pathogens) in plants.

VII. Suggested Reading

Baker KF and Snyder WC. 1965. *Ecology of Soil-borne Plant Pathogens*. John Wiley, New York.

Cook RJ and Baker KF. 1983. *The Nature and Practice of Biological Control of Plant Pathogens*. APS, St Paul, Minnesota.

Garret SD. 1970. *Pathogenic Root-infecting Fungi*. Cambridge Univ. Press,Cambridge, New York.

Hillocks RJ and Waller JM. 1997. *Soil-borne Diseases of Tropical Crops*. CABI, Wallington.

Mondia JL and Timper P 2016. Interactions of microfungi and plant parasitic nematodes. In: *Biology of Microfungi* (De-Wei-Lei Ed.). Springer Publications

Parker CA, Rovira AD, Moore KJ and Wong PTN. (Eds). 1983. *Ecology and Management of Soil-borne Plant Pathogens*. APS, St. Paul, Minnesota.

I. Course Title : Chemicals and Botanicals in Plant Disease Management

II. Course Code : PL PATH 511

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on the concepts, principles and judicious use of chemicals and botanicals in plant disease management.

V. Theory

Unit I

History and development of chemicals; definition of pesticides and related terms; advantages and disadvantages of chemicals and botanicals.

Unit II

Classification of chemicals used in plant disease management and their characteristics.

Unit III

Chemicals in plant disease control, viz., fungicides, bactericides, nematicides, antiviral chemicals and botanicals. Issues related to label claim.

Unit IV

Formulations, mode of action and application of different fungicides; chemotherapy and phytotoxicity of fungicides.

Unit V

Handling, storage and precautions to be taken while using fungicides; compatibility with other agrochemicals, persistence, cost-benefit ratio, factor affecting fungicides. New generation fungicides and composite formulations of pesticides.

Unit VI

Efficacy of different botanicals used and their mode of action. Important botanicals used against diseases. General account of plant protection appliances; environmental pollution, residues and health hazards, fungicidal resistance in plant pathogens and its management.

VI. Practicals

- Acquaintance with formulation of different fungicides and plant protection appliances;
- Formulation of fungicides, bactericides and nematicides;
- *In-vitro* evaluation techniques, preparation of different concentrations of chemicals including botanical pesticides against pathogens;
- Persistence, compatibility with other agro-chemicals;
- Detection of naturally occurring fungicide resistant mutants of pathogen;
- Methods of application of chemicals.

VII. Suggested Reading

Bindra OS and Singh H. 1977. *Pesticides – And Application Equipment*. Oxford & IBH, New Delhi.

Nene YL and Thapliyal PN. 1993. *Fungicides in Plant Disease Control.* 3rd edn. Oxford & IBH, New Delhi.

Torgeson DC. (Ed.). 1969. *Fungicides*. Vol. II. An Advanced Treatise. Academic Press, New York.

Vyas SC. 1993. *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi.

I. Course Title : Detection and Management of Seed Borne Pathogens
II. Course Code : PL PATH 512
III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with seed-borne diseases, their nature, detection, transmission, epidemiology, impacts/ losses and management.

V. Theory

Unit I

History and economic importance of seed pathology in seed industry, plant quarantine and SPS under WTO. Morphology and anatomy of typical monocotyledonous and dicotyledonous infected seeds.

Unit II

Recent advances in the establishment and subsequent cause of disease development in seed and seedling. Localization and mechanism of seed transmission in relation to seed infection, seed to plant transmission of pathogens.

Unit III

Seed certification and tolerance limits, types of losses caused by seed-borne diseases in true and vegetatively propagated seeds, evolutionary adaptations of crop plants to defend seed invasion by seed-borne pathogens. Epidemiological factors influencing the transmission of seed-borne diseases, forecasting of epidemics through seed-borne infection.

Unit IV

Production of toxic metabolites affecting seed quality and its impact on human, animal and plant health, management of seed-borne pathogens/ diseases and procedure for healthy seed production. Seed health testing, methods for detecting microorganism.

VI. Practical

- Conventional and advanced techniques in the detection and identification of seed-borne fungi, bacteria and viruses;
- Relationship between seed-borne infection and expression of the disease in the field.

VII. Suggested Reading

Agarwal VK and Sinclair JB. 1993. *Principles of Seed Pathology*. Vols. I & II, CBS Publ., New Delhi.

Hutchins JD and Reeves JE. (Eds.). 1997. *Seed Health Testing: Progress Towards the 21st Century*. CABI, Wallington.

Paul Neergaard. 1988. *Seed Pathology*. McMillan, London.

Suryanarayana D. 1978. *Seed Pathology*. Vikash Publ., New Delhi.

I. Course Title : Biological Control of Plant Pathogens
II. Course Code : PL PATH 513
III. Credit Hours : 1+1

IV. Aim of the course

To study principles and application of ecofriendly and sustainable management strategies of plant diseases.

V. Theory

Unit I

Concept of biological control, definitions, importance, principles of plant disease management with bioagents, history of biological control, merits and demerits of biological control.

Unit II

Types of biological interactions, competition: mycoparasitism, exploitation for hypovirulence, rhizosphere colonization, competitive saprophytic ability, antibiosis, induced resistance, mycorrhizal associations, operational mechanisms and its relevance in biological control.

Unit III

Factors governing biological control, role of physical environment, agroecosystem, operational mechanisms and cultural practices in biological control of pathogens, pathogens and antagonists and their relationship, biocontrol agents, comparative approaches to biological control of plant pathogens by resident and introduced antagonists, control of soil-borne and foliar diseases. Compatibility of bioagents with agrochemicals and other antagonistic microbes.

Unit IV

Commercial production of antagonists, their delivery systems, application and monitoring, biological control in IDM, IPM and organic farming system, biopesticides available in market. Quality control system of biocontrol agents.

VI. Practical

- Isolation, characterization and maintenance of antagonists, methods of study of antagonism and antibiosis, application of antagonists against pathogen *in-vitro and in vivo* conditions;
- Preparation of different formulations of selected bioagents and their mass production;
- Quality parameters of biocontrol agents;
- One week exposure visit to commercial biocontrol agents production unit.

VII. Suggested Reading

Campbell R. 1989. *Biological Control of Microbial Plant Pathogens*. Cambridge Univ. Press, Cambridge.

Cook RJ and Baker KF. 1983. *Nature and Practice of Biological Control of Plant Pathogens*. APS, St. Paul, Minnesota.

Fokkemma MJ. 1986. *Microbiology of the Phyllosphere*. Cambridge Univ. Press, Cambridge.

Gnanamanickam SS (Eds). 2002. *Biological Control of Crop Diseases*. CRC Press, Florida.

Heikki MT and Hokkanen James M. (Eds.). 1996. *Biological Control – Benefits and Risks*. Cambridge Univ. Press, Cambridge.

Mukerji KG, Tewari JP, Arora DK and Saxena G. 1992. *Recent Developments in Biocontrol of Plant Diseases*. Aditya Books, New Delhi.

I. Course Title : Integrated Disease Management

II. Course Code : PL PATH 514

III. Credit Hours : 2+1

IV. Aim of the course

To emphasize the importance and the need of IDM in the management of diseases of important crops.

V. Theory

Unit I

Introduction, definition, concept and tools of disease management, components of integrated disease management- their limitations and implications.

Unit II

Development of IDM-basic principles, biological, chemical and cultural disease management.

Unit III

IDM in important crops- rice, wheat, cotton, sugarcane, chickpea, rapeseed and mustard, pearl millet, pulses, vegetable crops, fruit, plantation and spice crops.

VI. Practical

- Application of physical, biological and cultural methods;
- Use of chemical and biocontrol agents, theircompatibility and integration in IDM.Demonstration of IDM and multiple disease management in crops of regional importance as project work.

VII. Suggested Reading

Gupta VK and Sharma RC. (Eds). 1995. *Integrated Disease Management and Plant Health*. Scientific Publ., Jodhpur.

Mayee CD, Manoharachary C, Tilak KVBR, Mukadam DS and Deshpande Jayashree (Eds.). 2004. *Biotechnological Approaches for the Integrated Management of Crop Diseases*. Daya Publ. House, New Delhi.

Sharma RC and Sharma JN. (Eds). 1995. *Integrated Plant Disease Management*. Scientific Publ., Jodhpur.

I. Course Title : Diseases of Field and Medicinal Crops

II. Course Code : PL PAT 515

III. Credit Hours : 2+1

IV. Theory

Unit I

Diseases of Cereal crops- Rice, wheat, barley, pearl millet, sorghum and maize.

Unit II

Diseases of Pulse crops- Gram, urdbean, mungbean, lentil, pigeonpea, soybean and cowpea.

Unit III

Diseases of Oilseed crops- Rapeseed and mustard, sesame, linseed, sunflower, groundnut, castor.

Unit IV

Diseases of Cash crops- Cotton, sugarcane.

Unit V

Diseases of Fodder legume crops- Berseem, oats, guar, lucerne.

Unit VI

Medicinal crops- *Plantago*, liquorice, mulathi, rosagrass, sacred basil, mentha, ashwagandha, *Aloe vera*.

V. Practical

- Detailed study of symptoms and host parasite relationship of important diseases of above mentioned crops;
- Collection and dry preservation of diseased specimens of important crops.

Suggested Reading

Joshi LM, Singh DV and Srivastava KD. 1984. *Problems and Progress of Wheat Pathology in South Asia*. Malhotra Publ. House, New Delhi.

Rangaswami G. 1999. *Diseases of Crop Plants in India*. 4th Ed. Prentice Hall of India, New Delhi.

Ricanel C, Egan BT, Gillaspie Jr AG and Hughes CG. 1989. *Diseases of Sugarcane, Major Diseases*. Academic Press, New York.

Singh RS. 2017. *Plant Diseases*. 10th Ed. Medtech, New Delhi.

Singh US, Mukhopadhyay AN, Kumar J and Chaube HS. 1992. *Plant Diseases of Internatiobnal Importance*. Vol. I. *Diseases of Cereals and Pulses*. Prentice Hall, Englewood Cliffs, New Jersey.

I. Course Title : Diseases of Fruits, Plantation and Ornamental Crops

II. Course Code : PL PTH 516

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with diseases of fruits, plantation, ornamental plants and their management.

V. Theory

Unit I

Introduction, symptoms and etiology of different fruit diseases. Factors affecting disease development in fruits like apple, pear, peach, plum, apricot, cherry, walnut, almond, strawberry, citrus, mango, grapes, guava, ber, banana, pineapple, papaya, fig, pomegranate, date palm, custard apple and their management.

Unit II

Symptoms, mode of perpetuation of diseases of plantation crops such as tea, coffee, rubber and coconut and their management.

Unit III

Symptoms and life cycle of pathogens. Factors affecting disease development of ornamental plants such as roses, gladiolus, tulip, carnation, gerbera orchids, marigold, chrysanthemum and their management.

VI. Practical

- Detailed study of symptoms and host parasite relationship of representative diseases of plantation crops;
- Collection and dry preservation of diseased specimens of important crops.

VII. Suggested Reading

Gupta VK and Sharma SK. 2000. *Diseases of Fruit Crops*. Kalyani Publishers, New Delhi.

Pathak VN. 1980. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi.

Singh RS. 2000. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi.

Walker JC. 2004. *Diseases of Vegetable Crops*. TTPP, India.

I. Course Title : Diseases of Vegetable and Spices Crops
II. Course Code : PL PATH 517
III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about symptoms, epidemiology of different diseases of vegetables and spices and their management.

V. Theory

Unit I

Nature, prevalence, factors affecting disease development of tuber, bulb, leafy vegetable, crucifers, cucurbits and solanaceaous vegetables. Diseases of crops under protected cultivation.

Unit II

Symptoms and management of diseases of different root, tuber, bulb, leafy vegetables, crucifers, cucurbits and solanaceaous vegetable crops.

Unit III

Symptoms, epidemiology and management of diseases of different spice crops such as black pepper, nutmeg, saffron, cumin, coriander, turmeric, fennel, fenugreek and ginger. Biotechnological approaches in developing disease resistant transgenics.

VI. Practical

- Detailed study of symptoms and host pathogen interaction of important diseases of vegetable and spice crops.

VII. Suggested Reading

Chaube HS, Singh US, Mukhopadhyay AN and Kumar J. 1992. *Plant Diseases of International Importance*. Vol. II. *Diseases of Vegetable and Oilseed Crops*. Prentice Hall, Englewood Cliffs, New Jersey.
Gupta VK and Paul YS. 2001. *Diseases of Vegetable Crops*. Kalyani Publishers, New Delhi
Gupta SK and Thind TS. 2006. *Disease Problem in Vegetable Production*. Scientific Publ., Jodhpur.
Sherf AF and Mcnab AA. 1986. *Vegetable Diseases and their Control*. Wiley Inter Science, Columbia.
Singh RS. 1999. *Diseases of Vegetable Crops*. Oxford & IBH, New Delhi.
Walker JC. 1952. *Diseases of Vegetable Crops*. McGraw-Hill, New York.

I. Course Title : Post-Harvest Diseases
II. Course Code : PL PATH 518
III. Credit Hours : 1+1

IV. Aim of the course

To acquaint with the post-harvest diseases of agricultural produce and their eco-friendly management.

V. Theory

Unit I

Concept of post-harvest diseases, definitions, importance with reference to management and health, principles of plant disease management as pre-harvest and post-harvest, Types of post-harvest problems both by biotic and abiotic factors.

Unit II

Role of physical environment, agro-ecosystem leading to quiescent infection, operational mechanisms and cultural practices in perpetuation of pathogens, pathogens and antagonist and their relationship, role of biocontrol agents and chemicals in controlling post-harvest diseases, comparative approaches to control of plant pathogens by resident and introduced antagonists.

Unit III

Integrated approaches in controlling diseases and improving the shelf life of produce using nutritional, bio-control agents and other agents, control of aflatoxigenic and mycotoxigenic fungi, application and monitoring for health hazards.

Unit IV

Study of symptoms, toxicosis of various pathogens, knowledge of Codex Alimentarious for each product and commodity. Physical and biological agents/ practices responsible for development/ prevention of post-harvest diseases-traditional and improved practices.

VI. Practical

- Isolation, characterization and maintenance of post-harvest pathogens, application of antagonists against pathogens *in vivo* condition;
- Comparative efficacy of different fungicides and bioagents;
- Study of different post-harvest disease symptoms on cereals, pulses, oilseed, commercial crops, vegetables, fruits and flowers;
- Visit to cold storage.

VII. Suggested Reading

Chaddha KL and Pareek OP. 1992. *Advances in Horticulture* Vol. IV, Malhotra Publ. House, New Delhi.

Pathak VN. 1970. *Diseases of Fruit Crops and their Control*. IBH Publ., New Delhi.

I. Course Title : Plant Quarentine and Regulations

II. Course Code : PL PATH 519

III. Credit Hours : 1+0

IV. Aim of the course

To acquaint the learners about the principles and the role of plant quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

V. Theory

Unit I

Historical development in plant quarantine, Definitions of pest, and transgenics as per Govt. notification; Organizational set up of plant quarantine in India. relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Acts related to registration of pesticides and transgenics. History of quarantine legislations, Salient features of PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures. Visit to plant quarantine station and PEQ facilities.

Suggested Reading

Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.

Course Course Title with Credit Load
Ph.D. in Plant Pathology

Course Code	Course Title	Credits Hours
PL PATH 601	Advances in Mycology	2+1
PL PATH 602	Advances in Virology	2+1
PL PATH 603	Advances in Plant Pathogenic Prokaryotes	2+1
PL PATH 604**	Molecular Basis of Host-pathogen Interaction	2+1
PL PATH 605	Principles and Procedures of Certification	1+0
PL PATH 606	Plant Biosecurity and Biosafety	2+0
PL PATH 691	Doctoral Seminar – I	0+ 1
PL PATH 692	Doctoral Seminar – II	0+ 1
PL PATH 699	Doctoral Research	0+75

**Core Courses for Doctoral Programme

Course Contents
Ph.D. in Plant Pathology

I. Course Title : Advances in Mycology

II. Course Code : PL PATH 601

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the advances in mycology

V. Theory

Unit I

General introduction, historical development and advances in mycology. Recent taxonomic criteria, morphological criteria for classification. Serological, chemical (chemotaxonomy), molecular and numerical (computer based assessment) taxonomy. Interaction between groups: Phylogeny, Micro conidiation, conidiogenesis and sporulating structures of fungi imperfecti.

Unit II

Population biology, pathogenic variability/ vegetative compatibility. Heterokaryosis and parasexual cycle. Sex hormones in fungi. Pleomorphism and speciation in fungi. Mechanism of nuclear inheritance. Mechanism of extra-nuclear inheritance. Biodegradation.

Unit III

Ultra structures and chemical constituents of fungal cells, functions of cell organelles. Mitosis, meiosis, gene action and regulation. Effects of fungal interaction with host plants and other microorganisms; parasitism, symbiosis and commensalism.

Unit IV

Genetic Improvement of Fungal strains. Fungal biotechnology. Fungi mediated synthesis of nano particles – characterization process and application. Mycotoxins problems and its management.

VI. Practical

- Isolation, purification and identification of cultures, spores and mating type determination;
- Study of conidiogenesis-Phialides, porospores, arthospores;
- Study of fruiting bodies in Ascomycotina;
- Identification of fungi up to species level;
- Study of hyphal anastomosis;
- Morphology of representative plant pathogenic genera form different groups of fungi;
- Molecular characterization of fungi.

VII. Suggested Reading

Alexopoulos CJ, Mims CW and Blackwell M. 1996. *Introductory Mycology*. John Wiley & Sons, New York.

Dube HC. 2005. *An Introduction to Fungi*. 3rd Ed. Vikas Publ. House, New Delhi.
Kirk PM, Cannon PF, David JC and Stalpers JA. (Eds.). 2001. *Ainsworth and Bisby's Dictionary of Fungi*. 9th Ed., CABI, Wallington.
Maheshwari R. 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US.
Ulloa M and Hanlin RT. 2000. *Illustrated Dictionary of Mycology*. APS, St. Paul, Minnesota.
Webster J and Weber R. 2007. *Introduction to Fungi*. Cambridge University Press, Cambridge.

I. Course Title : Advances in Plant Virology
II. Course Code : PL PATH 602
III. Credit Hours : 2+1

IV. Aim of the course

To educate about the advanced techniques and new developments in plant virology.

V. Theory

Unit I

Origin, evolution and interrelationship with animal viruses. Virus morphology, structure, architecture, replication (overview of host and viral components required), assembly and virus specific cytological effects in infected plant cells. Mechanisms leading to the evolution of new viruses/ strains: mutation, recombination, pseudo-recombination, component re-assortment, etc.

Unit II

Major vector groups of plant viruses and their taxonomy, virus-vector relationship, molecular mechanism of virus transmission by vectors. Terminologies used in immunology and serology. Classification, structure and functions of various domains of Immunoglobulins. Production of Polyclonal and monoclonal antibodies for detection of viruses. Immuno/ serological assays (Slide agglutination tests, Test tube precipitation test, Double agar diffusion test, ELISA (DAC, DAS, TAS), Dot Immuno Binding Assay, and nucleic acid based assays for detection of plant viruses.

Unit III

Polymerase Chain Reaction based (PCR, reverse transcriptase PCR, multiplex PCR, Nested PCR, Real time/ q PCR) and non PCR based: LAMP, Fluorescent *in situ* hybridization (FISH), dot blot hybridization. Plant virus genome organization (General properties of plant viral genome- information content, coding and non-coding regions), replication, transcription and translational strategies of pararetroviruses, geminiviruses, tobamo-, poty-, bromo, cucumo, ilar, tospoviruses, satellite viruses and satellite RNA.

Unit IV

Gene expression, regulation and viral promoters.Genetic engineering with plant viruses, viral suppressors, RNAi dynamics and resistant genes. Virus potential as vectors, genetically engineered resistance, transgenic plants. Techniques and application of tissue culture for production of virus free planting materials. Phylogenetic grouping system based on partial/ complete sequences of virus genomes and using of next generation sequencing technology in plant virus discovery.

VI. Practical

- Purification of viruses, SDS-PAGE for molecular weight determination, production of polyclonal antiserum, purification of IgG and conjugate preparation;
- Acquaintance with different serological techniques (i) DAC- ELISA (ii) DAS-ELISA

(iii) DIBA (iv) Western blots (v) (ab) 2-ELISA. Nucleic acid isolation, DOT-blot, southern hybridization, probe preparation,and autoradiography;

- PCR application and viral genome cloning of PCR products, plasmid purification, enzyme digestion, sequencing, annotation of genes, analysis of viral sequences (use of gene bank, blast of viral sequences and phylogeny);
- Bioinformatics analysis tools for virology (ORF finder, Gene mark, Gene ontology, BLAST, Clustal X/W, Tm pred and Phylogeny programs).

VII. Suggested Reading

Davies 1997. *Molecular Plant Virology: Replication and Gene Expression*. CRC Press, Florida.

Fauquet *et al*. 2005. *Virus Taxonomy*. VIII Report of ICTV. Academic Press, New York.

Gibbs A and Harrison B. 1976. *Plant Virology – The Principles*. Edward Arnold, London.

Jones P, Jones PG and Sutton JM. 1997. *Plant Molecular Biology: Essential Techniques*. John Wiley & Sons, New York.

Khan J A and Dijkstra. 2002. *Plant Viruses as Molecular Pathogens*. Howarth Press, New York.

Maramorosch K, Murphy FA and Shatkin AJ. 1996. *Advances in Virus Research*. Vol. 46. Academic Press, New York.

Pirone TP and Shaw JG. 1990. *Viral Genes and Plant Pathogenesis*. Springer Verlag, New York.

Roger Hull. 2002. *Mathew's Plant Virology* (4th Ed.). Academic Press, New York.

Thresh JM. 2006. *Advances in Virus Research*. Academic Press, New York.

I. Course Title : Advances in Plant Pathogenic Prokaryotes

II. Course Code : PL PATH 603

III. Credit Hours : 2+1

IV. Aim of the course

To learn about the latest developments in all the plant pathogenic prokaryotes as a whole.

V. Theory

Unit I

Prokaryotic cell: Molecular basis for **o**rigin and evolution of prokaryotic life, RNA world, prokaryotic cytoskeletal proteins. Flagella structure, assembly and regulation. Structure and composition **(bacteria)** cell wall/ envelop, Types of secretion systems (TI to TIV) and their molecular interaction, fimbriae and pili (Type IV pili), Bacterial chromosomes and plasmids, other cell organelles. Growth, nutrition and metabolism in prokaryotes (Embden-Meyerhof-Parmas (EMP) pathway, Phosphoketolase Pathway and Entner Doudoroff Pathway).

Unit II

Current trends in taxonomy and identification of phytopathogenic prokarya**:** International code of nomenclature, Polyphasic approach, New/ special detection methods for identification of bacterial plant pathogens. Taxonomic ranks hierarchy; Identification, Advances in classification and nomenclature.

Unit III

Bacterial genetics**:** General mechanism of variability (mutation), specialized mechanisms of variability. Transposable genetic elements in bacteria-integron and prophages, Mechanism of gene transfer. Pathogenicity islands, horizontal gene transfer, Bacterial Pan-Genome.

Unit IV

Bacteriophages: Composition, structure and infection. Classification and use of phages in plant pathology/ bacteriology. Host pathogen interactions: Molecular mechanism of pathogenesis: Pathogenicity factors of soft rot, necrosis, wilt, canker, etc. Immunization, induced resistance/ Systemic Acquired Resistance, Quorum sensing. Bacterial pathogenicity and virulence: Molecular mechanism of virulence and pathogenesis, bacterial secretion systems, pathogenicity of bacterial enzymes that degrade the cell walls, Role of hrp/ hrc genes and TALE effectors. Synthesis and regulation of EPSs.

Unit V

Beneficial Prokaryotes-Endophytes, PGPR, Phylloplane bacteria and their role in disease management. Endosymbionts for host defence. Advances in management of diseases caused by prokaryotes: genetic engineering, RNA silencing; CRISPR cas9.

VI. Practical

- Pathogenic studies and race identification, plasmid profiling of bacteria, fatty acid profiling of bacteria, RFLP profiling of bacteria and variability status, Endospore, Flagella staining, Test for secondary metabolite production, cyanides, EPS, siderophore, specific detection of phytopathogenic bacteria using species/ pathovar specific primers;
- Basic techniques in diagnostic kit development, Molecular tools to identify phytoendosymbionts;
- Important and emerging diseases and their management strategies.

VII. Suggested Reading

Dale JW and Simon P. 2004. *Molecular Genetics of Bacteria*. John Wiley & Sons, New York.

Garrity GM, Krieg NR and Brenner DJ. 2006. *Bergey's Manual of Systematic Bacteriology: The Proteobacteria*. Vol. II. Springer Verlag, New York.

Gnanamanickam SS. 2006. *Plant-Associated Bacteria*. Springer Verlag, New York.

Mount MS and Lacy GH. 1982. *Plant Pathogenic Prokaryotes*. Vols. I, II. Academic Press, New York.

Sigee DC. 1993. *Bacterial Plant Pathology: Cell and Molecular Aspects*. Cambridge Univ. Press, Cambridge.

Starr MP. 1992. *The Prokaryotes*. Vols. I–IV. Springer Verlag, New York.

I. Course Title : Molecular Basis of Host-pathogen Interaction

II. Course Code : PL PATH 604

III. Credit Hours : 2+1

IV. Aim of the course

To understand the concepts of molecular biology and biotechnology in relation to host plant- pathogen interactions.

V. Theory

Unit I

History of host plant resistance and importance to Agriculture. Importance and role of biotechnological tools in plant pathology. Basic concepts and principles to study host pathogen relationship. Molecular genetics, imaging and analytical chemistry tools for studying plants, microbes, and their interactions.

Unit II

Different forms of plant-microbe interactions and nature of signals/ effectors underpinning these interactions. Plant innate immunity: PAMP/ DAMP. Molecular basis of host-pathogen interaction-fungi, bacteria, viruses and nematodes; recognition system, signal transduction.

Unit III

Induction of defence responses- HR, Programmed cell death, reactive oxygen species, systemic acquired resistance, induced systemic resistance, pathogenesis related proteins, phytoalexins and virus induced gene silencing. Molecular basis of gene-for-gene hypothesis; R-gene expression and transcription profiling, mapping and cloning of resistance genes and marker-aided selection, pyramiding of R genes. Gene for gene systems: Background, genetics, phenotypes, molecular mechanisms, races, breakdown of resistance (boom-and-bust cycles), Coevolution-arms race and trench warfare models, Metapopulations, cost of resistance, cost of unnecessary virulence, GFG in agricultural crops vs. natural populations, Durability of resistance, erosion of quantitative resistance.

Unit IV

Pathogen population genetics and durability, viruses vs cellular pathogens.Gene deployment, cultivar mixtures. Disease emergence, host specialization. Circadian clock genes in relation to innate immunity. Biotechnology and disease management; development of disease resistance plants using genetic engineering approaches, different methods of gene transfer, biosafety issues related to GM crops.

VI. Practical

- Protein, DNA and RNA isolation, plasmid extraction, PCR analysis, DNA and Protein electrophoresis, bacterial transformation;
- Gene mapping and marker assisted selection;
- Development and use of molecular markers in identification and characterization of resistance to plant pathogens and their management.

VII. Suggested Reading

Chet I. 1993. *Biotechnology in Plant Disease Control*. John Wiley & Sons, New York.

Gurr SJ, McPohersen MJ and Bowlos DJ. (Eds.). 1992. *Molecular Plant Pathology – A Practical Approach*. Vols. I & II, Oxford Univ. Press, Oxford.

Mathew JD. 2003. *Molecular Plant Pathology*. Bios Scientific Publ., UK.

Ronald PC. 2007. *Plant-Pathogen Interactions: Methods in Molecular Biology*. Humana Press, New Jersey.

Stacey G and Keen TN. (Eds.). 1996. *Plant Microbe Interactions*. Vols. I-III. Chapman & Hall, New York; Vol. IV. APS Press, St. Paul, Minnesota.

I. Course Title : Principles and Procedures of Certification

II. Course Code : PL PATH 605

III. Credit Hours : (1+0)

IV. Aim of the course

To acquaint with the certification procedures of seed and planting material.

V. Theory

Unit I

Introduction to certification. International scenario of certification and role of ISTA, EPPO, OECD, etc. in certification and quality control. Case studies of certification systems of USA and Europe. National Regulatory mechanism and certification system including seed certification, minimum seed certification standards. National status of seed health in seed certification. Methods for testing genetic identity, physical purity, germination percentage, seed health, etc. Fixing tolerance limits for diseases and insect pests in certification and quality control programmes.

Unit II

Methods used in certification of seeds, vegetative propagules and *in-vitro* cultures. Accreditation of seed testing laboratories. Role of seed/ planting material health certification in national and international trade.

VI. Reference

Association of Official Seed Certifying Agencies. Hutchins D and Reeves JE. (Eds.). 1997.

Seed Health Testing: Progress Towards the 21st Century. CABI, UK. ISHI-veg Manual of Seed Health Testing Methods.

ISHI-F Manual of Seed Health Testing Methods.

ISTA Seed Health Testing Methods.

Tunwar NS and Singh SV. 1988. Indian Minimum Seed Certification Standards. Central Seed Certification Board, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi. US National Seed Health System.

e-Resources

http://www.aosca.org/index.htm.

http://www.worldseed.org/enus/international_seed/ishi_vegetable.html

http://www.worldseed.org/en-us/international _seed/ ishi_f.html

http://www.seedtest.org/en/content—1—1132—241.html

http://www.seedhealth.org

I. Course Title : Plant Biosecurity and Biosafety

II. Course Code : PATH 606

III. Credit Hours : 2+0

IV. Aim of the course

To facilitate deeper understanding on plant biosecurity and biosafety issues in agriculture.

V. Theory

Unit I

History of biosecurity, Concept of biosecurity, Components of biosecurity, Quarantine, Invasive Alien Species, Biowarfare, Emerging/ resurgence of pests and diseases. Introduction and History of biosecurity and its importance.

Unit II

National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures. World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, Issues related to release of genetically modified crops. Emerging/ resurgence of pests and diseases in the changing scenario of climatic conditions. Issues related to release of genetically modified crops.

VI. Suggested Reading

Biosecurity: A Comprehensive Action Plan.

Biosecurity Australia.

Biosecurity for Agriculture and Food Production.

FAO Biosecurity Toolkit 2008.

Grotto Andrew J and Jonathan B Tucker. 2006. Biosecurity Guidance.

Khetarpal RK and Kavita Gupta 2006. Plant Biosecurity in India – Status and Strategy. Asian Biotechnology and Development Review **9**(2): 3963.

Randhawa GJ, Khetarpal RK, Tyagi RK and Dhillon BS (Eds.). 2001. Transgenic Crops and Biosafety Concerns. NBPGR, New Delhi.

e-Resources

http://www.inspection.gc.ca/english/anima/heasan/fad/biosecure.*sht ml*

www.fao.org/docrep/010/a1140e/a1140e00.htm Laboratory

http://www.who.int/csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf

http://www.americanprogress.org/kf/biosecurity_ a_comprehensive_ action_plan.pdf

www.biosecurity.govt.nz DEFRA. www.defra.gov.uk/animalh/diseases/control/biosecurity/index.htm

www.daff.gov.au/ba;www.affa.gov.au/biosecurityaustralia Biosecurity New Zealand.

http://www.fao.org/biosecurity/ CFIA.

VII. List of Journals

- *Annals of Applied Biology* – Cambridge University Press, London
- *Annals of Plant Protection Sciences*- Society of Plant Protection, IARI, New Delhi
- *Annual Review of Phytopathology* – Annual Reviews, Palo Alto, California
- *Annual Review of Plant Pathology* – Scientific Publishers, Jodhpur
- *Canadian Journal of Plant Pathology* – Canadian Phytopathological Society, Ottawa
- *Indian Journal of Biotechnology* – National Institute of Science Communication and Information Resources, CSIR, New Delhi
- *Indian Journal of Mycopathological Research* – Indian Society of Mycology, Kolkata.
- *Indian Journal of Plant Protection* – Plant Protection Association of India, NBPGR, Hyderabad.
- *Indian Journal of Virology* – Indian Virological Society, New Delhi
- *Indian Phytopathology*-Indian Phytopathological Society, IARI New Delhi.
- Journal of Mycology and Plant Pathology – Society of Mycology and Plant Pathology, Udaipur.
- *Journal of Plant Disease Science*- Association of Plant Pathologists (Central India) PDKV, Akola.
- *Journal of Phytopathology* – Blackwell Verlag, Berlin
- *Mycologia* – New York Botanical Garden, Pennsylvania
- *Mycological Research* – Cambridge University Press, London
- *Physiological Molecular Plant Pathology* – Academic Press, London – *Phytopathology* – American Phytopathological Society, USA
- *Plant Disease* – The American Phytopathological Society, USA
- *Plant Disease Research* – Indian Society of Plant Pathologists, Ludhiana
- *Plant Pathology* – British Society for Plant Pathology, Blackwell Publ.

- *Review of Plant Pathology* – CAB International, Wallingford
- *Virology*- New York Academic Press e-Resources
- www.shopapspress.org
- www.apsjournals.apsnet.org
- www.apsnet.org/journals
- www.cabi_publishing.org
- www.springer.com/life+Sci/agriculture
- www.backwellpublishing.com
- www.csiro.au
- www.annual-reviews.org

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Protection
– Nematology

Course Title with Credit Load
M.Sc. in Nematology

Course Code	Course Title	Credit Hours
NEMA 501*	Principles of Nematology	2+1
NEMA 502$/ ENT 503	Principles of Taxonomy	2+0
NEMA 503*	Structural Organization of Nematodes	2+1
NEMA 504*	Nematode Systematics	2+1
NEMA 505*	Nematological Techniques	1+2
NEMA 506*	Nematode Diseases of Crops	3+1
NEMA 507	Nematode Biology and Physiology	2+1
NEMA 508	Nematode Ecology	2+1
NEMA 509	Nematode Interactions with Other Organisms	2+1
NEMA 510*	Nematode Management	2+1
Nema 511	Beneficial Nematodes	1+1
NEMA 512/ ENT 510$	Principles of Integrated Pest Management	1+1
NEMA 513/ PL PATH 513@	Disease Resistance in Plants	2+0
NEMA 514/ ENT 520$	Plant Quarantine, Biosafety and Biosecurity	2+0
NEMA 515/ PATH 521/ ENT 524	IPM in Protected Cultivation	2+1
NEMA 591	Master's Seminar	1+0
NEMA 599	Master's Research	0+30

*Core Courses for Master's

Course Contents
M.Sc. in Nematology

I. Course Title : Principles of Nematology
II. Course Code : NEMA 501
III. Credit Hours : 2+1

IV. Aim of the course

To project the importance of nematodes in agriculture and impart basic knowledge on all aspects of plant nematology.

V. Theory

Unit I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity- plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

Unit II

Gross morphology of plant parasitic nematodes; broad classification, nematode biology, physiology and ecology.

Unit III

Types of parasitism; nature of damage and general symptomatology; interaction of plant-parasitic nematodes with other organisms.

Unit IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

Unit V

Principles and practices of nematode management; integrated nematode management.

Unit VI

Emerging nematode problems, Importance of nematodes in international trade and quarantine.

VI. Practical

- Studies on kinds of nematodes- free-living, animal, insect and plant parasites;
- Nematode extraction from soil;
- Extraction of migratory endoparasites, staining for sedentary endoparasites;
- Examination of different life stages of important plant parasitic nematodes, their symptoms and histopathology.

VII. Suggested Reading

Dropkin VH. 1980. *An Introduction to Plant Nematology*. John Wiley & Sons, New York.
Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.

Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed. CABI Publishing: Wallingford, UK.
Perry RN, Moens M and Starr J.L. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.
Thorne G. 1961. *Principles of Nematology*. McGraw Hill, New Delhi.
Walia RK and Bajaj HK. 2003. *Text Book on Introductory Plant Nematology*. ICAR, New Delhi.
Walia RK. and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants,* ICAR-AICRP (Nematodes), IARI, New Delhi.

I. Course Title : Principles of Taxonomy
II. Course Code : NEMA 502
III. Credit Hours : 2+0

IV. Aim of the course

To sensitize the students on the theory and practice of classifying organisms and the rules governing the same.

V. Theory

Unit I

Introduction to history and principles of systematics and importance. Levels and functions of systematics. Identification, purpose, methods- character matrix, taxonomic keys. Descriptions- subjects of descriptions, characters, nature of characters, analogy vs homology, parallel vs convergent evolution, intra-specific variation in characters, polythetic and polymorphic taxa, sexual dimorphism.

Unit II

Classification of animals: Schools of classification- Phenetics, Cladistics and Evolutionary classification. Components of Biological Classification: Hierarchy, Rank, Category and Taxon. Species concepts, cryptic, sibling and etho-species, infra-specific categories. Introduction to numerical, biological and cytogenetical taxonomy.

Unit III

Nomenclature: Common vs Scientific names. International Code of Zoological Nomenclature, criteria for availability of names, validity of names. Categories of names under consideration of ICZN. Publications, Principles of priority, and homonymy, synonymy, type concept in zoological nomenclature. Speciation, anagenesis vs cladogenesis, allopatric, sympatric and parapatric processes.

VI. Suggested Reading

Blackwelder RE. 1967. *Taxonomy – A Text and Reference Book*. John Wiley & Sons, New York.
Kapoor VC. 1983. *Theory and Practice in Animal Taxonomy*. Oxford & IBH, New Delhi.
Mayr E. 1971. *Principles of Systematic Zoology*. Tata McGraw-Hill, New Delhi.
Quicke DLJ. 1993. Principles and Techniques of Contemporary Taxonomy. Black i.e, London.

I. Course Title : Structural and Functional Organization of Nematodes
II. Course Code : NEMA 503
III. Credit Hours : 2+1

IV. Aim of the course

Familiarization with structural organization of nematode body so as to enable the students to understand biology, physiology and classification of nematodes.

V. Theory

Unit I

Introduction and general organization of nematode body; Morphology and anatomy of nematode cuticle, hypodermis, musculature and pseudocoelom.

Unit II

Digestive system- Structural variations of stoma, oesophagus, intestine and rectum in nematodes.

Unit III

Reproductive system- Variations in female and male reproductive systems, types of reproduction, spermatogenesis and oogenesis.

Unit IV

Types and structure of excretory-secretory systems; nervous system and associated sense organs.

Unit V

Embryogenesis, Cell lineage and postembryonic development; Process of hatching and moulting.

VI. Practical

- Studies on variations in nematode shapes and sizes, morphological details of cuticle, cuticular markings and ornamentation, variations in stoma, oesophagus, rectum;
- Types and parts of female and male reproductive systems, sense organs, and excretory system.

VII. Suggested Reading

Bird AF and Bird J. 1991. *The Structure of Nematodes*. Academic Press, New York.

Chitwood BG and Chitwood MB. 1950. *An Introduction to Nematology*. Univ. Park Press, Baltimore.

Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.

Malakhov VV. 1994. *Nematodes: Structure, Development, Classification and Phylogeny*. Smithsonian Institution Press, Washington DC.

I. Course Title : Nematode Systematics

II. Course Code : NEMA 504

III. Credit Hours : 2+1

IV. Aim of the course

Understanding concepts in nematode taxonomy, development of skills in the identification of plant parasitic nematodes up to genera and species levels.

V. Theory

Unit I

Gross morphology, principles of nematode taxonomy -levels of taxonomy, systematics vs. taxonomy, morpho-taxonomy, molecular taxonomy, identification, classification, taxonomic categories, taxonomic characters, morphometry, Zoological nomenclature, species concept and speciation (allopatric and sympatric).

Unit II

Taxonomic position of nematodes and their relationships with allied groups;

Classification and diagnoses of nematodes up to ordinal rank (Secernentea and Adenophorea)

Unit III

Taxonomy of free living nematodes

Unit IV

Classification of plant parasitic nematodes; Order Tylenchida and diagnoses of its sub-orders, super families, families and important genera; Order Aphelenchida, Dorylaimida and Triplonchida and diagnoses of their important genera.

VI. Practicals

- Collection of soil and plant samples from different habitats, processing and preservation of samples; and preparation of temporary mounts, processing of nematode specimens and permanent mounts;
- Preparation of en face view and TS of nematodes, perineal pattern of root knot nematodes and cone-top structure for cyst nematodes;
- Identification of soil and plant nematodes from nematode suspension and mounted slides;
- Camera lucida drawing of nematodes, measurement of nematodes using traditional as well as image analyzing software;
- Procedures for PCR- Taxonomy.

VII. Suggested Reading

Ahmad W and Jairajpuri MS. 2010. *Mononchida: The Predatory Soil Nematodes, Series: Nematology Monographs and Perspectives*, Volume: 7, Brill.

Geraert E. 2006. *Tylenchida*. Brill.

Hunt DJ. 1993. *Aphelenchida, Longidoridae and Trichodoridae – their Systematics and Bionomics*. CABI, Wallingford.

Jairajpuri MS and Ahmad W. 1992. *Dorylaimida: Free-Living, Predaceous and Plant-Parasitic Nematodes*, Brill.

Mai WF, Mullin PG, Lyon HH and Loeffler K. 1996. Plant-Parasitic Nematodes: A Pictorial Key to Genera, 5th ed., Cornell University Press, London.

Siddiqi MR. 2000. *Tylenchida: Parasites of Plants and Insects*. 2^{nd} Ed. CABI, Wallingford.

I. Course Title : Techniques in Nematology

II. Course Code : NEMA 505

III. Credit Hours : (1+2)

IV. Aim of the course

Understanding the principles, theoretical aspects and developing skills in nematological techniques.

V. Theory

Unit I

Principles and use of light, scanning and transmission electron microscopes, and other laboratory equipments.

Unit II

Survey and surveillance methods; collection of soil and plant samples; techniques for extraction of nematodes from soil and plant material; estimation of population densities.

Unit III

Killing, fixing, clearing and mounting nematodes; measurements, preparation of perineal patterns, vulval cones of cyst nematodes, en-face views and body section of nematodes.

Unit IV

In-vitro and *in vivo* culturing techniques of plant parasitic, bacteriophagous, mycophagus and omnivorous nematodes.

Unit V

Staining nematodes in plant tissues; microtomy for histopathological studies; collection of plant root exudates and their bioassay; preparation of plant materials for exhibition.

Unit VI

Application of molecular techniques in Nematology.

VI. Practical

- Collection of soil and plant samples;
- Extraction of nematodes from soil by Baermann funnel, sieving and decanting, elutriation and sugar centrifugal methods;
- Extraction of cysts from soil;
- Extraction of nematodes from plant material;
- Estimation of population densities;
- Staining plant material for nematodes;
- Killing and fixing nematodes, clearing nematodes by slow and Seinhorst's methods;
- Preparation of temporary and permanent mounts;
- Measurements, drawing, microphotography, special preparation of nematodes – perineal patterns, vulval cones, en-face and body sections;
- Collection of root exudates, preparation of exhibits of nematode diseased plant material, *in-vitro* culturing techniques of nematodes- callous culture, excised root and carrot disc techniques.

VII. Suggested Reading

Ayoub SM. 1981. *Plant Nematology – An Agricultural Training Aid*.

Barker KR, Carter CC and Sasser JN. 1985. *An Advanced Treatise on* Meloidogyne. Vol. II. *Methodology*. International *Meloidogyne* Project, NCSU, Raleigh. USA.

Manzanilla-Loìpez, RH and Marbaìn-Mendoza N. 2012. *Practical Plant Nematology*, Montecillo, Texcoco: Biblioteca Basica de Agricultura.

Sikora RA, Coyne D, Hallman J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture.*3rd edn. CABI Publishing, England.

Southey JF. 1986. *Laboratory Methods for Work with Plant and Soil Nematodes*. HMSO, London.

Subbotin SA, Mundo-Ocampo M and Baldwin J. 2010. *Systematics of The Genus Heterodera in Systematics of Cyst Nematodes* (Nematoda: Heteroderinae), Part B, Series: Nematology Monographs and Perspectives, Volume: 8B, Brill.

Zuckerman BM, Mai WF and Harrison MB. 1985. *Plant Nematology Laboratory Manual*. Univ. of Massachusetts.

I. Course Title : Nematode Diseases of Crops

II. Course Code : NEMA 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about the causal organism, nature of damage, symptoms and control of nematode diseases of agricultural and horticultural crops.

V. Theory

Diagnosis of causal organism, distribution, host range, biology and life cycle, nature of damage, symptoms, interaction with other organisms, and management of nematode diseases in different crops.

Unit I

Cereal crops- Ear-cockle and *tundu* diseases of wheat, *molya* disease of wheat and barley; rice root nematode, rice root-knot and cyst nematode problems, *ufra* and white tip diseases of rice; lesion nematodes, cyst nematodes of maize and sorghum.

Unit II

Pulses, Sugar, Fibre, Fodder and Oilseed crops- Pigeon pea cyst nematode, root knot nematode, reniform nematode, lesion, lance nematode, sugarbeet cyst and soybean cyst nematode problems.

Unit III

Vegetable crops- root-knot disease, reniform nematode, potato cyst nematode; stem and bulb nematode. Nematode problems of protected cultivation.

Unit IV

Fruit crops- root-knot nematode, reniform nematode, slow decline of citrus. Flowers- root-knot nematode, foliar nematodes, bulb nematodes, Mushroom- nematode problems.

Unit V

Plantation, medicinal and aromatic crops- burrowing nematode problem of banana, spices and condiments, root-knot and lesion nematode problems of coffee and tea, red ring disease of coconut. Forests- Pine wilt disease.

VI. Practical

- Diagnosis of causal organisms;
- Identification of different life cycle stages;
- Study of symptoms and histopathology of nematode damage in different crops, study tours for field diagnosis of nematode problems.

VII. Suggested Reading

Bhatti DS and Walia RK. 1992. *Nematode Pests of Crops*. CBS, New Delhi.

Bridge J and Starr JL. 2007. *Plant Nematodes of Agricultural Importance: A Colour Handbook*, CRC Press

Evans AAF, Trudgill DL and Webster JM. 1994. *Plant Parasitic Nematodes in Temperate Agriculture*. CABI, Wallingford.

Nickle WR. 1991. *Manual of Agricultural Nematology*. Marcel Dekker, New York.

Perry RN and Moens M. 2006. *Plant Nematology*. CABI, Wallingford.

Perry RN, Moens M and Jones JT. 2018. *Cyst Nematodes*, CABI Publishing: Wallingford, UK.

Perry RN, Moens M and Starr JL. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.

Sikora R, Coyne D, Hallmann J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*, 3rd Ed., CABI, UK.

Walia RK and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants, ICAR-AICRP* (*Nematodes*), IARI, New Delhi.

I. Course Title : Nematode Biology and Physiology

II. Course Code : NEMA 507

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of life cycle patterns, feeding and metabolic processes in hytonematodes which have implications in their management.

V. Theory

Unit I

Host finding and invasion, feeding, hatching, moulting; life cycle patterns in different types of nematodes.

Unit II

Types of reproduction, gametogenesis, embryogenesis and post embryogenesis.

Unit III

Chemical composition of nematodes, hydrolytic enzymes, pseudocoelom and function of transport.

Unit IV

Physiology of digestive system, intermediary metabolism.

Unit V

Osmoregulation, physiology of excretory-secretory and neuromuscular systems.

VI. Practical

- Studies on embryogenesis and post-embryogenesis, hatching, moulting, life cycle development, feeding, enzymatic assay by electrophoresis.

VII. Suggested Reading

Croll NA. 1970. *The Behaviour of Nematodes: The Activity, Senses and Responses*. Edward Arnold, London.

Croll NA and Mathews BE. 1977. *Biology of Nematodes*. Blackie, Glasgow. Lee DL. 2002. *The Biology of Nematodes*. Taylor & Francis, London.

Lee DL and Atkinson HJ. 1976. *Physiology of Nematodes*. MacMillan, London.

Perry RN and Wright DJ. 1998. *The Physiology and Biochemistry of Free- living and Plant Parasitic Nematodes*. CABI, Wallingford.

Wallace HR. 1963. *The Biology of Plant Parasitic Nematodes*. Edward Arnold, London.

I. Course Title : Nematode Ecology

II. Course Code : NEMA 508

III. Credit Hours : 2+1

IV. Aim of the course

To understand the life of plant parasitic nematodes in their environment; their survival strategies, and how to exploit these for their control.

V. Theory

Unit I

Definition and scope; components of environment; evolution of nematodes; ecological classification, prevalence, distribution and dispersal of nematodes.

Unit II

Role of nematodes in the food web; habitat and niche characteristics; community analysis and population estimation models.

Unit III

Effects of abiotic and biotic factors on nematodes.

Unit IV

Environmental extremes and nematode behaviour- aggregation, swarming, orientation, feeding and reproduction.

Unit V

Survival strategies of nematodes in adverse environment and absence of host.

Unit VI

Modeling population dynamics and relations with crop performance; ecological considerations in nematode management, data interpretation and systems simulation.

VI. Practical

- Study of nematode fauna in varied agro-ecological systems;
- Community analysis of nematode populations;
- Laboratory exercises on influence of abiotic factors on movement and hatching, green-house experiments on effect of abiotic factors on nematode populations and plant growth.

VII. Suggested Reading

Croll NA. 1970. *The Behaviour of Nematodes*: *The Activity, Senses and Responses*. Edward Arnold, London.

Croll NA and Mathews BE. 1977. *Biology of Nematodes*. Blackie, Glasgow. Lee DL. 2002. *The Biology of Nematodes*. Taylor & Francis, London.

Gaugler R and Bilgrami AL. 2004. *Nematode Behaviour*, CABI, UK.

Norton DC. 1978. *Ecology of Plant Parasitic Nematodes*. John Wiley. Poinar G. 1983. *Natural History of Nematodes*. Prentice Hall, Englewood Cliffs.

Wallace HR. 1973. *Nematode Ecology and Plant Disease*. Edward Arnold, London.

I. Course Title : Nematode Interactions with Other Organisms

II. Course Code : NEMA 509

III. Credit Hours : 2+1

IV. Aim of the course

To understand the role of nematodes in disease complexes involving fungal, bacterial, viral and other organisms.

V. Theory

Unit I

Concept of interaction and its importance in disease complexes and their management involving nematode and other organisms.

Unit II

Interaction of plant parasitic nematodes with wilt causing fungal pathogens and microfungi.

Unit III

Interaction of plant parasitic nematodes with root rot and other fungal pathogens.

Unit IV

Interaction of plant parasitic nematodes with bacterial pathogens, other nematode species and arthropods.

Unit V

Virus transmission by nematodes.

VI. Practical

- Green-house experiments to study the role of plant parasitic nematodes in wilt/ rot causing fungal and bacterial pathogens.

VII. Suggested Reading

Khan MW. 1993. *Nematode Interactions*. Chapman & Hall, New York.

Lamberti F, Taylor CE and Seinhorst JW. 1975. *Nematode Vectors of Plant Viruses*. Plenum Press, London.

Mondia JL and Timper P. 2016. Interactions of microfungi and plant parasitic nematodes. In: *Biology of Microfungi* (De-Wei-Lei Ed.). Springer Publications

Sasser JN and Jenkins WR. 1960. *Nematology: Fundamentals and Recent Advances with Emphasis on Plant Parasitic and Soil Forms*. Eurasia Publ. House, New Delhi.

I. Course Title : Nematode Management

II. Course Code : NEMA 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart comprehensive knowledge about the principles and practices of nematode management.

V. Theory

Unit I

Concepts and history of nematode management; crop loss estimation, ecological and socio-economic aspects, cost-benefit ratios and pest risk analysis.

Unit II

Chemical methods- nematicides, their types, classification, mode of action, applicators and application methods, antidotes, and economizing nematicidal use.

Unit III

Cultural practices- crop rotations and cropping sequences, fallowing, flooding, soil solarisation, time of sowing, organic amendments of soil, bio-fumigation, antagonistic and trap crops, sanitation, etc. Physical methods- use of heat, hot water treatment and other methods of disinfestations of planting material.

Unit IV

Biological methods- concepts and terminology, use of predators and parasites as biological control agents, their mass multiplication and field use; phytotherapeutic methods – use of antagonistic plants and antinemic plant products.

Unit V

Genetic methods- plant resistance; legal methods- quarantine regulations; integrated nematode management- concepts and applications.

VI. Practical

- *In-vitro* screening of synthetic chemicals and plant products for nematicidal activity, and their application methods;
- Methods for screening of crop germplasm for resistance against nematodes, laboratory exercises on biocontrol potential of fungal, bacterial parasites, and predacious fungi and nematodes.

VII. Suggested Reading

Bhatti DS and Walia RK. 1994. *Nematode Pest Management in Crops*. CBS, New Delhi.
Brown GL. 1977. *The Nematode Destroying Fungi*. CBP, Guelph.
Brown RH and Kerry BR. 1987. *Principles and Practice of Nematode Control in Crops*. Academic Press, Sydney.
Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. II: Nematode Management and Utilization*. CABI, Wallingford.
Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed., CABI, Wallingford, London.
Starr JL, Cook R and Bridge J. 2002. *Plant Resistance to Parasitic Nematodes*. CABI, Wallingford.
Stirling GR. 2014. *Biological Control of Plant parasitic Nematodes,* 2nd Ed., CAB International, UK.
Whitehead AG. 1997. *Plant Nematode Control*. CABI, Wallingford.

I. Course Title : Beneficial Nematodes
II. Course Code : NEMA 511
III. Credit Hours : 1+1

IV. Aim of the course

To sensitize about the use of nematodes for the biological control of insect pests of crops, and application of some nematodes as biological models and as indicators of environmental pollution.

V. Theory

Unit I

Beneficial nematode fauna – predators, parasites of insects, molluscs and other pests; Entomophilic nematodes- important groups, types of nematode- insect associations; taxonomic characteristics of nematode parasites of insects.

Unit II

Host-parasite relations and life cycle of mermithids, entaphelenchids, thelastomids, sphaerularids and tylenchids.

Unit III

Entomopathogenic nematodes- *Steinernema, Heterorhabditis, Oscheius* their morphological characteristics, taxonomic status, biology and mode of action.

Unit IV

Entomopathogenic nematodes- mass multiplication techniques, formulations, field applications and efficacy, success stories.

Unit V

Nematodes as biological models, nematodes as indicators of pollution, role of nematodes in organic matter recycling.

VI. Practical

- Isolation, identification, mass rearing and application methods of entomopathogenic nematodes.

VII. Suggested Reading

Gaugler R and Kaya HK. 1990. *Entomopathogenic Nematodes in Biological Control*. CRC Press, Boca Raton, Florida.

Gaugler R. 2002. *Entomophilic Nematology*. CABI, Wallingford. Grewal PS, Ehlars RU and Shapiro DI. 2005. *Nematodes as Biocontrol Agents*. CABI, Wallingford.

Jairajpuri MS and Khan MS. 1982. *Predatory Nematodes (Mononchida)*. Associated Publ. Co., New Delhi.

Wood WB. 1998. *The Nematode* Caenorhabditis elegans. Cold Spring Harbor Press.

Woodring JL and Kaya HK. 1988. *Steinernematid and Heterorhabditid Nematodes: A Handbook of Techniques*. Southern Coop. Bull., Ark. Ag. Ext. Sta.

Zuckerman BM. (Ed.). 1980. *Nematodes as Biological Models*. Vols. I, II. Academic Press, New York.

I. Course Title : Principles of Integrated Pest Management

II. Course Code : NEMA 512/ ENT 510

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM. Train students in computation of ETL, implementing IPM programmes.

V. Theory

Unit I

History and origin, definition and evolution of various related terminologies.

Unit II

Concept and philosophy, ecological principles, economic threshold concept, and economic consideration.

Unit III

Tools of pest management and their integration- legislative, cultural, physical and mechanical methods; pest survey and surveillance, forecasting, types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost-benefit ratios and partial budgeting; case studies of successful IPM programmes.

VI. Practical

- Characterization of agro-ecosystems;
- Sampling methods and factors affecting sampling;
- Population estimation methods;
- Crop loss assessment- direct losses, indirect losses, potential losses, avoidable losses, unavoidable losses;
- Computation of EIL and ETL;
- Crop modeling; designing and implementing IPM system.

VII. Suggested Reading

Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches.*

Kalyani Publishers, New Delhi.
Dhaliwal GS, Ram Singh and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi. Flint MC and Bosch RV. 1981. *Introduction to Integrated Pest Management*. 1st Ed., Springer, New York.
Horowitz AR and Ishaaya I. 2004. *Insect Pest Management: Field and Protected Crops*. Springer, New Delhi.
Ignacimuthu SS and Jayaraj S. 2007. *Biotechnology and Insect Pest Management*. Elite Publ., New Delhi.
Metcalf RL and Luckman WH. 1982. *Introduction of Insect Pest Management*. John Wiley & Sons, New York.
Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management*. Prentice Hall, New Delhi.
Pedigo RL. 2002. *Entomology and Pest Management*. 4th Ed. Prentice Hall, New Delhi.
Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York.

I. Course Title : Disease Resistance in Plants
II. Course Code : NEMA 513/ PL PATH 513
III. Credit Hours : 2+0

IV. Aim of the course

To acquaint with disease resistance mechanisms in plants.

V. Theory

Unit I

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminology.

Unit II

Disease escape, disease tolerance, disease resistance, types of resistance, identification of physiological races of pathogens, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens.

Unit III

Host defence system, morphological and anatomical resistance, preformed chemicals in host defence, post infectional chemicals in host defence, phytoalexins, hypersensitivity and its mechanisms.

Unit IV

Gene-for-gene concept, protein-for-protein and immunization basis, management of resistance genes. Strategies for gene deployment.

VI. Suggested Reading

Dallice M *et al.*1996. *Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction*. APS, St Paul, Minnesota.
Deverall, B.J. 1977. *Defence Mechanisms in Plants*. Cambridge Univ. Press, Cambridge, New York.
Parker J. 2008. *Molecular Aspects of Plant Diseases Resistance*. Blackwell Publ.
Robinson RA. 1976. *Plant Pathosystems*. Springer Verlag, New York. Singh BD. 2005. *Plant Breeding – Principles and Methods*. 7th Ed. Kalyani Publishers, Ludhiana.
Van der Plank JE. 1975. *Principles of Plant Infection*. Academic Press, New York.
Van der Plank JE. 1978. *Genetic and Molecular Basis of Plant Pathogenesis*. Springer Verlag, New York.

Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press, New York.

Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press, New York.

I. Course Title : Plant Quarantine, Biosafety and Biosecurity

II. Course Code : NEM 514/ ENT 520

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

V. Theory

Unit I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. History of quarantine legislations, PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures.

VI. Suggested Reading

Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.

Shukla A and Veda OP. 2007. *Introduction to Plant Quarantine*. Samay Prakashan, New Delhi.

I. Course Title : IPM in Protected Cultivation

II. Course Code : NEMA 515/ PATH 521/ ENT 524

III. Credit Hours : 2+1

IV. Aim of the course

To sensitize the pest and disease scenario developing in crops raised under protected cultivation and to impart knowledge about the remedy.

V. Theory

Unit I

Characteristics of protected cultivation and tools for sustainable crop production;

outline of major biotic stresses in protected cultivation including: fungi, bacteria, virus, nematode, insects and mites.

Unit II

Sampling and monitoring pests and diseases; epidemiology and damage relationships; loss assessment; population dynamics of biotic stress agents; factors responsible for severity of pests and diseases.

Unit III

Host plant resistance to pathogens and insects; management strategies for protected cultivation: disinfestation of soil and growth media; preventive, scouting and early detection; and curative measures: biological control of sap sucking pests, leaf miners; soil- and air-borne pathogens; pesticides selectivity, applications and resistance management; buzz pollination.

VI. Practical

- Visit to familiarize with pest and disease situations developing in protected cultivation;
- Symptomatology and damages; identification of the causes; estimation of population densities; management tactics/ approaches and recommendations; production and commercialization of biological agents.

VII. Learning outcome

Students are expected to be well versed with the crop pest and disease problems associated with protected cultivation and their management.

VIII. Suggested Reading

Gullino ML, Albajes, R and Nicot P. 2019. *Integrated Pest and Disease Management in Greenhouse Crops*. Ed. 2nd, Springer, New York.

Rathee *et al*. 2018. Integrated Pest Management under Protected Cultivation—A Review. *Journal of Entomology and Zoology Studies*, 6 (2): 1201–1208.

IX. List of Journals

- *Annals of Applied Nematology* – Society of Nematologists, USA
- *Current Nematology* – Bioved Research Society, Allahabad, India
- *Egyptian Journal of Agronematology* – Egyptian Society of Agricultural Nematology
- *Indian Journal of Nematology* – Nematological Society of India
- International Journal of Nematology – Afro-Asian Society of Nematologists, Luton
- *Japanese Journal of Nematology* – Japanese Nematological Society
- *Journal of Nematology* – Society of Nematologists, USA
- *Journal of Nematode Morphology and Systematics* –Jaen, Universidad de Jaen
- *Nematologia Brasiliera* – Brazilian Nematological Society
- *Nematologia Mediterranea* – Istituto per la Protezione delle Plante (IPP) – Sect. of Bari of the CNR, Italy
- *Nematology* – EJ Brill Academic Publishers, UK
- *Nematropica* – Organization of Nematologists of Tropical America
- *Pakistan Journal of Nematology* – Pakistan Society of Nematologists
- *Russian Journal of Nematology* – Russian Society of Nematologists

e-Resources

http://www.nematologists.org/ (The Society of Nematologists)
http://nematology.ucdavis.edu/ (Deptt. of Nematology, Univ. of California, Davis)
http://www.ifns.org/ (International Federation of Nematology Societies)

http://www.inaav.ba.cnr.it/nemmed.html (Nematologia Mediterranea)
http://nematode.unl.edu/Nemajob.htm (Nematology Employment Bulletin Board)
http://nematode.unl.edu/ (University of Nebraska – Lincoln Nematology)
http://nematode.unl.edu/wormsite.htm (Links to Other Nematology Resources)
http://nematode.unl.edu/SON/jon.htm (Journal of Nematology)
http://www.nematology.ucr.edu/ (Deptt. of Nematology, Univ. of California, Riverside)
http://entnemdept.ifas.ufl.edu/ (Univ. of Florida, Entomology and Nematology Dept.)
http://www.brill.nl/m_catalogue_sub6_id8548.htm (Nematology – journal)
http://www.ars.usda.gov/main/site_main.htm?modecode=12752900 (Nematology Lab., USDA)
http://flnem.ifas.ufl.edu/history/nem_history.htm (Nematology history)
http://www.nematology.ugent.be/ (Nematology Unit, Ghent University)
http://www.entm.purdue.edu/nematology/ (The Purdue Nematology Lab.)
http://www.bspp.org.uk/ppigb/nematolo.htm#a-z (Links to Nematology labs)
http://www.nem.wur.nl/UK/ (Laboratory of Nematology, Wageningen Univ.)
http://onta.ifas.ufl.edu/ (The Organization of Nematologists of Tropical America)
http://www.openj-gate.org/Articlelist.asp?Source=1&Journal_ID=103267. (Nematology Newsletter)
http://nematology.umd.edu/nematology.html (Plant Nematology Laboratory, Maryland)
http://www.biology.leeds.ac.uk/nem/ (Plant Nematology Lab., University of Leeds)
http://www.plantpath.iastate.edu/dept/labs/tylka/ (Iowa State University, Nematology Lab)
http://nematologists.org.au/newsletters.html (Australasian Association of Nematologists)
http://soilplantlab.missouri.edu/nematode/ (Plant Nematology Laboratory, Missouri)
http://www.eumaine.ugent.be/ (European Master of Science in Nematology)
http://www.jstage.jst.go.jp/browse/jjn (The Japanese Journal of Nematology)

Suggested Broad Topics for Master's and Doctoral Research

- Identification of key nematode pests emerging in regional agro-ecosystems
- Development of molecular diagnostic tools of phytonematodes
- Nematode problems of peri-urban and protected agriculture systems, and their management
- Role of nematodes in organic matter recycling
- Modelling nematode populations for disease forecasting and predicting yield losses
- Nematodes as indicators of environmental pollution
- Identification of cost effective nematode-suppressive cropping systems for specific agro-ecosystems
- Isolation, identification and characterization of phytochemicals for nematoxicity
- Disinfection of nematode-infected planting material through eco-friendly sanitary methods
- Characterization of molecular markers and genes governing resistance to key nematode pests
- Management of nematodes with antagonistic bacteria
- Bionomics of potential bio-control agents and their field efficacy
- Devising non-chemical methods of nematode management in mushroom cultivation
- Development of nematode management modules for IPM systems
- Field efficacy and formulation of entomopathogenic nematodes against foliar and soil-borne insect pests of crops
- Study of disease complex involving nematodes and other plant pathogens.
- Nematode suppressive rhizospheric microorganisms.
- Nematode suppressive endophytes.
- Management of nematodes using RNAi
- Factors related to entomopathogenic nematode- bacterium symbionts
- Management of root knot nematodes in protected cultivation system
- Assessment of nematode damage and yield losses in organic farming system

Course Title with Credit Load
Ph.D. in Nematology

Course Code	Course Title	Credit Hours
NEMA 601**	Nematode Phylogeny and Systematics	2+1
NEMA 602**	Nematode Disease Development and Host Resistance	2+1
NEMA 603**	Advances in Nematode Management	2+1
NEMA 604**	Physiological and Molecular Nematology	2+1
NEMA 605/ PL PATH 606@	Plant Biosecurity and Biosafety	2+0
NEMA 691	Doctoral Seminar I	1+0
NEMA 692	Doctoral Seminar II	1+0
NEMA 699	Doctoral Research	75

**Core Courses for Doctoral Programme; @Cross-listed with Plant Pathology; $Cross-listed with Entomology

Course Contents
Ph.D. in Nematology

I. Course Title : Nematode Phylogeny and Systematics
II. Course Code : NEMA 601
III. Credit Hours : 2+1

IV. Aim of the course

Concepts in Systematics, understanding nematode diversity, evaluation and analysis of taxonomic characters for inferring interrelationships among nematode groups, modern methods and tools for identification of nematodes, and phylogenetic analysis.

V. Theory

Unit I

Phylogenetic systematics – Evolutionary systematics, Cladistics, phylogenetic trends (morphological) and molecular phylogenetic framework for the phylum Nematoda, phylogenomics

Unit II

Taxonomic characters, numerical taxonomy, morphometry, variations, statistics in taxonomic descriptions, description of new species, preparation of illustrations, keys and compendia for nematode species.

Unit III

Identification of common species of root knot nematodes by esterase phenotypes and race/ pathotypes of root knot/ cyst/ reniform nematodes by differential host tests.

Unit IV

Recent advances in nematode identification- molecular, biochemical, immunodiagnostic, molecular characterization and DNA finger-printing techniques.

VI. Practical

- Detailed studies of morphological structures and identification of plant parasitic nematodes up to species level;
- Preparation of compendia and keys;
- Drawing and measurements using camera lucida and computer software;
- Procedures for identification of species/ races of root-knot/ cyst/ reniform nematodes.
- Isozyme analysis for identification of common species of root knot nematodes. rDNA-RFLP for diagnosis of nematode species;
- Sequence analysis, alignment, phylogenetic analysis, preparation of phylogenetic tree and interpretation.

VII. Suggested Reading

Andraìssy I. 1976. *Evolution as a basis for the systematization of nematodes*. Pitman Publishing Ltd, London.

Blackwelder RE. 1967. *Taxonomy – A Text and Reference Book*. John Wiley & Sons, New York.

Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. I. Nematode Morphology, Physiology and Ecology*. CABI, Wallingford.
Fortuner R. 1988. *Nematode Identification and Expert System Technology*. NATO Science Series A: Springer US.
Geraert E. 2006. *Nematology Monographs and Perspectives*. Vol. IV. EJ. Brill.
Kapoor VC. 1983. *Theory and Practice in Animal Taxonomy*. Oxford & IBH, New Delhi.
Mayr E. 1969. *Principles of Systematic Zoology*. Tata McGraw-Hill, New Delhi.
Quicke DLJ. 1993. *Principles and Techniques of Contemporary Taxonomy*. Blackie, London.
Stone AR, Platt HM and Khalil LF. 1983. *Concepts in Nematode Systematics, the Systematics Association Special Volume* No. 22, Academic Press, London and NY.

I. Course Title : Nematode Disease Development and Host Resistance

II. Course Code : NEMA 602

III. Credit Hours : 2+1

IV. Aim of the course

To update knowledge on the recent research trends in the field of plant nematode relationships at genetic and molecular level.

V. Theory

Unit I

Mechanisms of pathogenesis, cytological and biochemical changes induced by nematode feeding.

Unit II

Plant defense systems, role of phytoalexins, etc. against major plant parasitic nematodes.

Unit III

Genetic basis of plant resistance to nematodes and identification of resistance genes against economically important nematodes.

Unit IV

Application of biotechnological methods in the development of nematode resistant crop cultivars; resistance markers; incorporation of resistance by conventional breeding and transgenic approaches.

Unit V

Influence of microorganisms on plant nematode interactions.

VI. Practical

- Microtomy for study of histopathological changes induced by important nematodes, screening techniques for assessment of resistance in crop germplasm against nematodes.

VII. Suggested Reading

Barker KR, Pederson GA and Windham GL. 1998. *Plant and Nematode Interactions*. CABI, Wallingford.
Fenoll C, Grundler FMW and Ohl SA. 1997. *Cellular and Molecular aspects of Plant-Nematode Relationships*. Kluwer Academic Press, Dordrecht.
Lamberti F, Giorgi C and Bird D. 1994. *Advances in Molecular Plant Nematology*. Plenum Press.

I. Course Title : Advances in Nematode Management

II. Course Code : NEMA 603

III. Credit Hours : 2+1

IV. Aim of the course

To keep abreast ith latest developments and trends in nematode management.

V. Theory

Unit I

Isolation, identification, host specificity, mode of action, culturing and field application potential of promising bio-control agents- predacious and parasitic fungi; nematoxic fungal culture filtrates.

Unit II

Isolation, identification, host specificity, mode of action, culturing and field application potential of promising bio-control agents- parasitic and nematode antagonistic bacteria; predacious mites and predacious nematodes.

Unit III

Mass culturing, formulation, quality control, bio-safety and registration protocols of bio-control agents.

Unit IV

Phytoalexins, allelochemicals, phytotherapeutic substances, novel nematicides, deployment of resistant varieties and non-host crops in nematode suppressive cropping systems, emergence of resistance breaking biotypes, recent regulatory provisions and methods, quarantine and disinfection.

Unit V

Nematode management modules for integrated pest and disease management in cropping systems. Nematode management options and approaches for organic farming, precision farming and protected cultivation system. Application of GIS and GPS technology for surveillance and management.

VI. Practical

- Green-house experiments on the efficacy of fungal and bacterial bio-control agents, botanicals.

VII. Suggested Reading

Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives Vol. II. Nematode Management and Utilization.* CABI, Wallingford.

Jana BL. 2008. *Precision Farming*. Research Books and Periodicals Pvt. Ltd., Delhi.

Lillesend TW, Kiefer RW and Chipman JW. 1979. *Remote Sensing and Image Interpretation*. John Wiley & Sons, New York.

Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed., CABI, Wallingford, London.

Poinar GO Jr and Jansson H-B. 1988. *Diseases of Nematodes*. Vols. I, II. CRC Press, Boca Raton, Florida. Scientific Publ., Jodhpur.

Starr JR, Cook R and Bridge J. 2002. *Plant Resistance to Parasitic Nematodes*. CABI, Wallingford.

Stirling GR. 2014. *Biological Control of Plant parasitic Nematodes,* 2nd Ed., CAB International, UK

Tarafdar JC, Priputhi KP and Kumar M. 2007. *Organic Agriculture*. Upadhyaya RK, Walia RK and Dubey OP. 2004. *IPM Systems in Agriculture. Vol. IX. Phytonematology*. Aditya Books, New Delhi.

I. Course Title : Physiological and Molecular Nematology

II. Course Code : NEMA 604

III. Credit Hours : 2+1

IV. Aim of the course

Appraisal on the application of modern biotechnological tools in Nematology.

V. Theory

Unit I

Cell biology- Structural and functional aspects; genetics and evolution in plant parasitism in nematodes.

Unit II

Caenorhabditis elegans- a model system for gerontology, cytogenetics, physiology, nutritional, toxicological and pharmacological studies; *Heterodera glycines* as a model for biology, proteomic and genomic studies.

Unit III

Chemoreception, neurobiology, and biochemical basis of communication in nematodes, molecular basis of host recognition, Nematode-Associated Molecular Patterns (NAMPs), molecular pathways of plant-nematode interaction.

Unit IV

Biochemical, genetical and molecular basis of plant nematode interaction; histopathological, cellular and molecular changes in host feeding cells, resistance genes, genome editing, sequencing of genome, Transcriptome and Proteome analysis of plant parasitic nematodes, RNAi technology,

Unit V

Biochemical and molecular basis of survival strategies in nematodes, molecular mechanism of host resistance against plant parasitic nematodes, molecular and novel approaches for nematode management.

VI. Practical

- Isolation and quantification of proteins from nematode juveniles and eggs;
- Molecular weight determination of nematode protein;
- Buffer preparation for molecular techniques, PCR, â-esterase polymorphism in root-knot nematode;
- Nematode DNA isolation from juveniles and eggs;
- RFLP of nematode DNA;
- Nematode DNA amplification using PCR for nematode identification, RNAi technology.

VII. Suggested Reading

Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. I. Nematode Morphology, Physiology and Ecology*. CABI, Wallingford.

Fenoll C, Grundler FMW and Ohl SA. 1997. *Cellular and Molecular aspects of Plant-Nematode Relationships*. Kluwer Academic Publ., Dordrecht.

Gommers EJ and Maas PW. 1992. *Nematology from Molecule to Ecosystem*. European Soc. of Nematologists.

Lamberti F, Giorgi C and Bird D. 1994. *Advances in Molecular Plant Nematology*. Plenum Press.

Perry RN and Wright DJ. 1998. *The Physiology and Biochemistry of Free- living and Plant Parasitic Nematodes*. CABI, London.
Riddle DL. 1997. *C. elegans II*. Cold Spring Harbor Press.
Wood WB. 1988. *The Nematode Caenorhabditis elegans*. Cold Spring Harbor Press, US
Zuckerman BM. 1980. *Nematodes as Biological Models*. Vols. I, II. Academic Press, New York.

I. Course Title : Plant Biosecurity and Biosafety
II. Course Code : NEMA 605/ PL PATH 606
III. Credit Hours : 2+0

IV. Aim of the course

To facilitate deeper understanding of plant biosecurity and biosafety issues in agriculture.

V. Theory

Unit I

History of biosecurity, concept of biosecurity, components of biosecurity, Quarantine, Invasive Alien Species, biowarfare, emerging/ resurgence of pests and diseases.

Unit II

National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures/ World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, issues related to release of genetically modified crops.

VI. Suggested Reading

Biosecurity: A Comprehensive Action Plan.
Biosecurity Australia.
Biosecurity for Agriculture and Food Production.
FAO Biosecurity Toolkit 2008.
Grotto Andrew J and Jonathan B Tucker. 2006. Biosecurity Guidance.
Khetarpal RK and Kavita Gupta. 2006. Plant Biosecurity in India – Status and Strategy. Asian Biotechnology and Development Review 9(2): 3963.
Randhawa GJ, Khetarpal RK, Tyagi RK and Dhillon. BS (Eds.). 2001. Transgenic Crops and Biosafety Concerns. NBPGR, New Delhi.

e-Resources

http://www.inspection.gc.ca/english/anima/heasan/fad/biosecure.sht ml
www.fao.org/docrep/010/a1140e/a1140e00.htm Laboratory
http://www.who.int/csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf
http://www.americanprogress.org/kf/biosecurity_ a_comprehensive_ action_plan.pdf
www.biosecurity.govt.nz DEFRA. www.defra.gov.uk/animalh/diseases/control/biosecurity/index.htm

www.daff.gov.au/ba;www.affa.gov.au/biosecurityaustralia Biosecurity New Zealand. http://www.fao.org/biosecurity/ CFIA.

VII. List of Journals

- *Annals of Applied Nematology* – Society of Nematologists, USA
- *Current Nematology* – Bioved Research Society, Allahabad, India
- *Egyptian Journal of Agronematology* – Egyptian Society of Agricultural Nematology
- *Indian Journal of Nematology* – Nematological Society of India
- International Journal of Nematology – Afro-Asian Society of Nematologists, Luton
- *Japanese Journal of Nematology* – Japanese Nematological Society
- *Journal of Nematology* – Society of Nematologists, USA
- *Journal of Nematode Morphology and Systematics* –Jaen, Universidad de Jaen
- *Nematologia Brasiliera* – Brazilian Nematological Society
- *Nematologia Mediterranea* – Istituto per la Protezione delle Plante (IPP) – Sect. of Bari of the CNR, Italy
- *Nematology* – EJ Brill Academic Publishers, UK
- *Nematropica* – Organization of Nematologists of Tropical America
- *Pakistan Journal of Nematology* – Pakistan Society of Nematologists
- *Russian Journal of Nematology* – Russian Society of Nematologists

e-Resources

http://www.nematologists.org/ (The Society of Nematologists)
http://nematology.ucdavis.edu/ (Deptt. of Nematology, Univ. of California, Davis)
http://www.ifns.org/ (International Federation of Nematology Societies)
http://www.inaav.ba.cnr.it/nemmed.html (Nematologia Mediterranea)
http://nematode.unl.edu/Nemajob.htm (Nematology Employment Bulletin Board)
http://nematode.unl.edu/ (University of Nebraska – Lincoln Nematology)
http://nematode.unl.edu/wormsite.htm (Links to Other Nematology Resources)
http://nematode.unl.edu/SON/jon.htm (Journal of Nematology)
http://www.nematology.ucr.edu/ (Deptt. of Nematology, Univ. of California, Riverside)
http://entnemdept.ifas.ufl.edu/ (Univ. of Florida, Entomology and Nematology Dept.)
http://www.brill.nl/m_catalogue_sub6_id8548.htm (Nematology – journal)
http://www.ars.usda.gov/main/site_main.htm?modecode=12752900 (Nematology Lab., USDA)
http://flnem.ifas.ufl.edu/history/nem_history.htm (Nematology history)
http://www.nematology.ugent.be/ (Nematology Unit, Ghent University)
http://www.entm.purdue.edu/nematology/ (The Purdue Nematology Lab.)
http://www.bspp.org.uk/ppigb/nematolo.htm#a-z (Links to Nematology labs)
http://www.nem.wur.nl/UK/ (Laboratory of Nematology, Wageningen Univ.)
http://onta.ifas.ufl.edu/ (The Organization of Nematologists of Tropical America)
http://www.openj-gate.org/Articlelist.asp?Source=1&Journal_ID=103267. (Nematology Newsletter)
http://nematology.umd.edu/nematology.html (Plant Nematology Laboratory, Maryland)
http://www.biology.leeds.ac.uk/nem/ (Plant Nematology Lab., University of Leeds)
http://www.plantpath.iastate.edu/dept/labs/tylka/ (Iowa State University, Nematology Lab)
http://nematologists.org.au/newsletters.html (Australasian Association of Nematologists)
http://soilplantlab.missouri.edu/nematode/ (Plant Nematology Laboratory, Missouri)
http://www.eumaine.ugent.be/ (European Master of Science in Nematology)
http://www.jstage.jst.go.jp/browse/jjn (The Japanese Journal of Nematology)

Suggested Broad Topics for Master's and Doctoral Research

- Identification of key nematode pests emerging in regional agro-ecosystems
- Development of molecular diagnostic tools of phytonematodes
- Nematode problems of peri-urban and protected agriculture systems, and their management
- Role of nematodes in organic matter recycling
- Modelling nematode populations for disease forecasting and predicting yield losses

- Nematodes as indicators of environmental pollution
- Identification of cost effective nematode-suppressive cropping systems for specific agro-ecosystems
- Isolation, identification and characterization of phytochemicals for nematoxicity
- Disinfection of nematode-infected planting material through eco-friendly sanitary methods
- Characterization of molecular markers and genes governing resistance to key nematode pests
- Management of nematodes with antagonistic bacteria
- Bionomics of potential bio-control agents and their field efficacy
- Devising non-chemical methods of nematode management in mushroom cultivation
- Development of nematode management modules for IPM systems
- Field efficacy and formulation of entomopathogenic nematodes against foliar and soil-borne insect pests of crops
- Study of disease complex involving nematodes and other plant pathogens.
- Nematode suppressive rhizospheric microorganisms.
- Nematode suppressive endophytes.
- Management of nematodes using RNAi
- Factors related to entomopathogenic nematode- bacterium symbionts
- Management of root knot nematodes in protected cultivation system
- Assessment of nematode damage and yield losses in organic farming system

ANNEXURE I

List of BSMA Committee Members for Plant Protection

(Entomology/ Nematology/ Plant Pathology)

Name	Address	Specialization
Dr S Lingaraju Emeritus Professor	University of Agricultural Sciences, Residential address: No. 32, 'Vruddhi' Siddarameswar Colony Ranichannamimanagar Dharwad-580 001 Karnataka lingaraju_s@rediffmail.com; lingarajus@uasd.in Mob.: 09886560055	Chairman
Dr AK Bhaumick Head	Department of Entomology, Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur, Madhya Pradesh dr.bhowmick@gmail.com Mob.: 09424313301	Convener
Dr Ataur Rahman Professor and Head	Department of Entomology Faculty of Agriculture Assam Agricultural University Jorhat-785 013 Assam rahmanataur86@yahoo.com Mob.: 09435489475	Member
Dr R Swaminathan Former Dean	Department of Entomology Maharana Pratap University of Agriculture and Technology Udaipur-313 001 Rajasthan House No. 5, Shiv Badi, kharol Colony Fatehpura, Udaipur-313 004 (Rajasthan) udaiswami57@gmail.com; Mob.: 09950964908	Member
Dr BA Patel Professor and Head	Department of Nematology Anand Agricultural University Anand, Gujarat bapatel@aau.in; Mob.: 09916063028	Member
Dr KT Rangaswamy	Department of Plant Pathology University of Agricultural Sciences Bengaluru, Karnataka ktr_uasb@rediffmail.com; Mob.: 09916063028	Member
Dr MS Joshi	Department of Plant Pathology DBSKVV, Dapoli, Maharashtra majoshi1234@rediffmail.com; Mob.: 09420639320	Member

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 1

Horticultural Sciences

- Fruit Science (FSC)
- Vegetable Sciences (VSC)
- Floriculture and Landscaping (FLS)
- Plantation, Spices, Medicinal and Aromatic Crops (PSMA)
- Post Harvest Management (PHM)

Contents

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We place on record our profound gratitude to Dr Trilochan Mohapatra, the Hon. Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG education in Horticulture. Our heartfelt thanks are due to Dr Narendra Singh Rathore, Former DDG (Education), ICAR and Dr Arvind Kumar, Hon. Vice Chancellor, RLBCAU, Jhansi and Chairman, National Core Committee for providing support and guidance in this important academic venture. Dr G. Venkateswarlu, ADG (EQR) and Dr K.L. Khurana, Principal Scientist, Education Division, ICAR requires special mention for their support and guidance. The support of Prof. Rajesh Bhalla, Hon'ble Vice Chancellor, VSCGUUHF, Bharsar and Prof. B.P. Nautiyal, Professor, VSCGUUHF, Bharsar and Local Nodal Officer of 1^{st} BSMA-Horticulture is of immense value to begin the task through organizing the 1^{st} meeting in a well planned way. The experience shared by Dr S.K. Gupta, Dean, College of Forestry, Ranichauri about the BSMA-Forestry workshop provided good insight about the task ahead.

We express our heartfelt gratitude to Dr D.D. Patra, Hon'ble Vice Chancellor; Prof. P. Hazra, Professor of Vegetable Science and Dean Post Graduate Studies and their team, BCKV, Kalyani for hosting the national level workshop wherein 33 esteemed delegates representing 22 SAUs/ SHUs/ DUs/ ICAR institutes; 5 Deans and Directors of BCKV, 4 University HoDs and 9 senior horticulture faculty from BCKV deliberated on the syllabi revision for three days. Committee is much obliged to Dr Rintu Banerjee, Sr. Academician, IIT, Kharagpur and Dr A.K. Chakrabarthy, Former Principal Scientist, Vegetable Crops, IARI, New Delhi for being accepted our invitation and participated in the deliberations of the workshop at BCKV, Kalyani.

Our sincere thanks are due to Dr A.K. Singh, Hon. Director IARI for hosting the 2^{nd} meeting of BSMA Horticulture. The efforts of Dr S.K. Singh, Division-Head, and Dr V.B. Patel, Sr. Scientist, Division of Fruits and Horticulture Technology are gratefully acknowledged for arranging the meeting in befitting manner. The active participation of Horticulture fraternity of IARI, New Delhi in the meeting deliberations and discussions, has been gratefully acknowledged.

The expertise support and gesture extended by Dr K.L. Chadha, Former National Professor, Former DDG (Hort.) and Dr S.K. Pal, Former Director, NRC Pomegranate, Solapur for being accepted our invitation and added thoughts and strength to the 2^{nd} meeting proceedings at IARI, New Delhi.

All support extended by Dr K.M. Indiresh, Hon. Vice Chancellor, University of Horticultural Sciences, Bagalkot for providing administrative and financial support in completing the task is highly appreciated and acknowledged.

Our thanks are due to all Hon. Vice Chancellors of State Agricultural and or Horticultural Universities in their support and readiness to nominate the senior horticulture faculty from their universities/ institutes to the workshop at BCKV, Kalyani.

The technical support extended by the College level committee lead by Dr Vishnuvardhan, Dean along with Dr G.K. Seetharamu, Assoc. Professor (FLA); Dr P.M. Munikrishnappa, Assoc. Professor (FLA); Dr H.C. Krishna, Asst. Professor (PHT);

Dr B.N. Marutiprasad, Asst. Professor (PSMA); Dr G.K. Ramegowda, Asst. Professor (Ag. Ent.); Dr G.K. Sadananda, Asst. Professor (PHT); Dr Jyothi Kattegoudar, Asst. Professor (VSC) and Mr Sreekanth, H. S., Asst. Professor (FSC) for processing this document and the typographic assistance by Mr Srikanth, H.C., is greatly acknowledged. The finance and accounts support extended by Mrs Bharathi M. Bongale, Assistant Comptroller; Mr Ajith Kumar, K.B., Sr. Assistant and Mr Girish M. Hebbal, Asst. Cum Computer Operator for timely arrangement and settlement of accounts.Above all, but not the least the cooperation and support extended to the convener of the committee by Dr R.C. Jagadeesha, Dean and Dr Vishnuvardhan, Former Dean, College of Horticulture, UHSB Campus, GKVK, Bengaluru is highly acknowledged.

Chairman, Convener and Members
BSMA-Horticulture Sciences-2019

General Introduction

Horticulture plays a pivotal role in the food and livelihood security of India. Though horticulture crops occupy only 8.5 per cent of areable land, they contribute 25.5 per cent of the Agriculture GDP. Plantation crops especially tea, coffee and rubber crops just occupying 0.95 per cent to of cropped area have stake of 15.1 per cent of the total expert earnings of agricultural produce. Therefore, the country has considered horticultural and plantation sector as the growth engine of Agricultural economy. It is important to mention here that the horticultural crop production in the country surpassed food production for the first time during 2013–14. The trend has been continuing and production for the year 2017–18 has been in order of 321 million tones. Over last decades, the area under horticultural crops grew by about 3 per cent per annum with increase in annual production by 5.4 per cent and the share of horticulture output in agriculture being more than 33 per cent.

Coming to the genesis and development of horticultural education in the country it dates back to mid 1930's where horticulture was considered as a part of Economic Botany in the College of Agriculture, Pune. It became independent department, subsequently, in several SAU's. At present, the discipline of horticulture has been further bifurcated upto five departments in may agri-horticultural universities in the country.

The BSMA constituted by the ICAR vide OO. No.F.No.13(1)/2007-EQR dated January 14, 2008 under Chairmanship of Dr K.V. Peter, Former Vice-Chancellor, formulated the common PG Syllabus for Horticulture discipline for the first time and recommended for implementation of the same uniformly throughout the country. The document was published by the ICAR during April 2009. The said committee, considered four discipline in horticulture science, viz., Fruit Science, Vegetable Science, Floriculture and Landscape Architecture and Plantation, Spices, Medicinal and Aromatic Crops, instead of one composite discipline, viz., Horticulture.

The ICAR in its O.O.F.No.7/6/2017 EQR dt: 04.04.2018 has constituted 19 BSMA Committees based on the National Core Group recommendations to look into various issues related to PG Programmes with the following terms of reference.

1. Development of Academic Regulations for Master and Ph.D. program
2. Refining names and curricula of Master's and Ph.D. disciplines for uniformity.
3. Revision of syllabi for courses and Master's and Ph.D. degree programmes.

Overall Recommendations

1. It was decided to reintroduce the degree programme in M.Sc. (Hort.)/ Ph.D. (Hort.) in Post-harvest Management.
2. It was decided to adopt common Academic regulation proposed by the Rani Laxmi Bai Central Agricultural University, Jhansi, Madhya Pradesh as presented and discussed during review meeting during 23–24, April 2019, NASC, New Delhi.
3. It was recommended to have degree nomenclatures in Postgraduate programmes of Horticulture are as follows.
   (a) M.Sc. (Hort.)/ Ph.D. (Hort.) Vegetable Science
   (b) M.Sc. (Hort.)/ Ph.D. (Hort.) Fruit Science
   (c) M.Sc. (Hort.)/ Ph.D. (Hort.) Floriculture and Landscaping

(d) M.Sc. (Hort.)/ Ph.D. (Hort.) Plantation, Spices, Medicinal and Aromatic Crops
(e) M.Sc. (Hort.)/ Ph.D. (Hort.) Post-harvest Management

4. It was also recommended to propose names of department on the same lines to bring the uniformity among SAU's, CAU's, Deemed Universities, etc.
5. It was decided to include common compulsory courses as finalized by other BSMA Committees for those courses which are common across disciplines.

Discipline-wise Restructured Syllabi

The course structure and minimum credit requirement as evolved through a series of meetings and workshops of BSMA-Horticultral Scienes and Review meetings by NCG are as follows:

	Masters' Programme	Doctoral Programme
(i) **Course work**		
Major Courses	20	12
Minor Courses	08	06
Supporting Course(s)	06	05
Common compulsory courses	05	–
Seminar	01	02
(ii) **Comprehensive Exam**	–	Non-credit course
(iii) **Thesis/ Research**	30	75
Total	**70**	**100**

Major Courses: The courses in the Department/ Discipline in which a student takes admission.

Minor Courses: The courses closely related to a student's major discipline (Horticultural Sciences).

Supporting Courses: The courses not related to the major discipline. It could be any course considered relevant for student's research work or necessary for building his overall competence.

Common Compulsory Courses: These following courses will be offered preferably as e-courses for all students undergoing Master's degree programme. The Courses, PGS-503 and PGS-505 are already in the form of e-courses.

Common compulsory courses

Course Code	Course Title	Credit Hours
PGS-501	Library and Information Services	0+1
PGS-502	Technical Writing and Communications Skills	0+1
PGS-503	Intellectual Property and its Management in Agriculture	1+0
PGS-504	Basic Concepts in Laboratory Techniques	0+1
PGS-505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

Restructured and Revised
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Vol. 1

Horticultural Sciences
– Fruit Science

Preamble

(Fruit Science)

India is one of the top ranking fruit producing countries in the world. It is evident from current estimates that India is producing to the tune of 100 million metric tonnes on annual basis with average productivity of 14-15 tonnes per hectare. Diverse and peculiar agro-ecological conditions prevalent in the country lays down a suitable platform to grow wide range of tropical, subtropical and temperate fruits including nuts. Given the statistics, India is the largest producer of fruits like mango, banana, papaya and pomegranate achieving highest productivity in grape, banana and papaya on the global scenario. Several fruits like mango, banana, grapes, etc. are being exported besides several others have untapped export potential to earn foreign exchange. On the whole, horticulture contributes about 30 per cent to GDP of agriculture, with major contributions coming from cultivation and processing of fruits and nuts. It is worth mentioning that fruit production occupies a special role in today's multi-faceted agriculture.

Per capita consumption of fruits have increased significantly owing to consumer's awareness for healthy foods rich in vitamins, minerals and antioxidants coupled with enhanced levels of productivity leading to increased availability. Fruit production has witnessed tremendous developments owing to systematic research efforts in the past few decades. Notable examples are making available quality planting material including rootstocks through genetic improvement and efficient propagation protocols; judicious and integrated use of water and nutrients through micro-irrigation approaches; biotic and abiotic stress management practices; high density planting systems; crop regulation and pre- and post harvest management.

The above mentioned wide ranging advancements in the field of fruit science necessitate their precise inclusion in the course curricula for delivering and assuring quality education in an updated manner. This specifically aims to develop an especially trained cadre of human resource equipped with holistic and updated knowledge in fruit science. Thus, the various courses so developed constitute the State-of-Art framework of modern practices in fruit production and orchard management. The course design lays requisite emphasis on skill development in addition to addressing the educational requirements of the post-graduate students *vis-a-vis* latest know-how. Course contents have been framed to encompass various related fields like physiology, biochemistry, genetic and molecular biology to draw better insight and understanding into the different mechanisms underlying sustainable fruit production systems.

In short, course restructuring can be viewed as a comprehensive package drawing deeper insight into cultural and management practices extending from superior cultivars/ rootstocks, planting systems, propagation methods, training and pruning, orchard floor management, plant protection measures, crop regulation, maturation and harvesting. The existing courses have been redesigned to include the technological interventions, molecular approaches and hi-tech innovations made in the last decade or so. Courses have been added on Systematics, Nutrition, Research Ethics and Methodologies, Smart Fruit Production to broaden the student's reach of understanding of principles and modern trends in fruit growing.

Course Title with Credit Load
M.Sc. (Hort.) in Fruit Science

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FSC 501*	Tropical Fruit Production	2+1
FSC 502*	Sub-Tropical and Temperate Fruit Production	2+1
FSC 503*	Propagation and Nursery Management of Fruit Crops	2+1
FSC 504*	Breeding of Fruit Crops	2+1
FSC 505	Systematics of Fruit Crops	2+1
FSC 506	Canopy Management in Fruit Crops	1+1
FSC 507	Growth and Development of Fruit Crops	2+1
FSC 508	Nutrition of Fruit Crops	2+1
FSC 509	Biotechnology of Fruit Crops	2+1
FSC 510	Organic Fruit Culture	2+1
FSC 511	Export Oriented Fruit Production	2+1
FSC 512	Climate Change and Fruit Crops	1+0
FSC 513	Minor Fruit Production	2+1
	Minor Courses	**08**
	Supporting Courses	**06**
	Common compulsory courses	**05**
FSC 591	Seminar	0+1
FSC 599	Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Fruit Science

I. Course Title : Tropical Fruit Production

II. Course Code : FSC 501

III. Credit Hours : (2+1)

IV. Why this course ?

Tropical fruits occupy a distinct place in global fruit production. Apart from ecological specificities, tropical fruits enjoy favour among masses being delicious and nutritious. As such, the course has been designed to provide update knowledge on various production technologies of tropical fruits on sustainable basis.

V. Aim of the course

To impart comprehensive knowledge to the students on cultural and management practices for growing tropical fruits.

The course is organised as follows:

No.	Blocks	Units	
1	Introduction	I	Importance and Background
2	Agro-Techniques	I	Propagation, Planting and Orchard Floor Management
3	Crop Management	I	Flowering, Fruit-Set and Harvesting

VI. Theory

Block 1: Introduction

Unit I: Importance and Background: Importance, origin and distribution, major species, rootstocks and commercial varieties of regional, national and international importance, eco-physiological requirements.

Block 2: Agro-techniques

Unit I: Propagation, Planting and Orchard Floor Management: Asexual and sexual methods of propagation, planting systems and planting densities, training and pruning methods, rejuvenation, intercropping, nutrient management, water management, fertigation, use of bio-fertilizers, role of bio-regulators, abiotic factors limiting fruit production.

Block 3: Crop Management

Unit I: Flowering, Fruit-Set and Harvesting: Physiology of flowering, pollination management, fruit set and development, physiological disorders – causes and remedies, crop regulation, quality improvement by management practices; maturity indices, harvesting, grading, packing, storage and ripening techniques; insect and disease management.

Crops

Mango, Banana, Guava, Pineapple, Papaya, Avocado, Jackfruit, Annonas, Aonla, Ber, etc.

VII. Practicals

- Distinguished features of tropical fruit species, cultivars and rootstocks (2);
- Demonstration of planting systems, training and pruning (3);
- Hands on practices on pollination and crop regulation (2);
- Leaf sampling and nutrient analysis (3);
- Physiological disorders-malady diagnosis (1);
- Physico-chemical analysis of fruit quality attributes (3);
- Field/ Exposure visits to tropical orchards (1);
- Project preparation for establishing commercial orchards (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The students are expected to equip themselves with know-how on agro-techniques for establishment and management of an orchard leading to optimum and quality fruit production of tropical fruits.

X. Suggested Reading

Bartholomew DP, Paull RE and Rohrbach KG. 2002. *The Pineapple: Botany, Production, and Uses*. CAB International.

Bose TK, Mitra SK and Sanyal D. 2002. *Fruits of India – Tropical and Sub-Tropical*.3rd Edn. Naya Udyog, Kolkata.

Dhillon WS. 2013. *Fruit Production in India*. Narendra Publ. House, New Delhi.

Iyer CPA and Kurian RM. 2006. *High Density Planting in Tropical Fruits: Principlesand Practices*. IBDC Publishers, New Delhi.

Litz RE. 2009. *The Mango: Botany, Production and Uses*. CAB International.

Madhawa Rao VN. 2013. *Banana*. ICAR, New Delhi.

Midmore D. 2015. *Principles of Tropical Horticulture*. CAB International.

Mitra SK and Sanyal D. 2013. *Guava,* ICAR, New Delhi.

Morton JF. 2013. *Fruits of Warm Climates*. Echo Point Book Media, USA.

Nakasome HY and Paull RE. 1998. *Tropical Fruits*. CAB International.

Paull RE and Duarte O. 2011. *Tropical Fruits* (Vol. 1). CAB International.

Rani S, Sharma A and Wali VK. 2018. *Guava* (*Psidium guajava* L.). Astral, New Delhi.

Robinson JC and Saúco VG. 2010. *Bananas and Plantains*. CAB International.

Sandhu S and Gill BS. 2013. *Physiological Disorders of Fruit Crops*. NIPA, New Delhi.

Schaffer B, Wolstenholme BN and Whiley AW. 2013. *The Avocado: Botany, Production and Uses*. CAB International.

Sharma KK and Singh NP. 2011. *Soil and Orchard Management*. Daya Publishing House, New Delhi.

Valavi SG, Peter KV and Thottappilly G. 2011. *The Jackfruit*. Stadium Press, USA.

I. Course Title : Subtropical and Temperate Fruit Production

II. Course Code : FSC 502

III. Credit Hours : (2+1)

IV. Why this course ?

Agro-climatic diversity in India facilitates growing a wide range of fruits extending from tropical to subtropical to temperate fruits and nuts. To highlight their ecological specificities, seasonal variations and pertinent cultural practices, a course is designed exclusively for subtropical and temperate fruits.

V. Aim of the course

To impart comprehensive knowledge to the students on cultural and management practices for growing subtropical and temperate fruits.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	Importance and Background
2	Agro-Techniques	Propagation, Planting and Orchard Floor Management
3	Crop Management	Flowering, Fruit-Set and Harvesting

VI. Theory

Block 1: Introduction

Unit I: Importance and Background: Origin, distribution and importance, major species, rootstocks and commercial varieties of regional, national and international importance, eco-physiological requirements.

Block 2: Agro-Techniques

Unit I: Propagation, Planting and Orchard Floor Management: Propagation, planting systems and densities, training and pruning, rejuvenation and replanting, intercropping, nutrient management, water management, fertigation, use of bio-fertilizers, role of bio-regulators, abiotic factors limiting fruit production.

Block 3: Crop Management

Unit I: Flowering, Fruit-Set and Harvesting: Physiology of flowering, pollination management, fruit set and development, physiological disorders- causes and remedies, crop regulation, quality improvement by management practices; maturity indices, harvesting, grading, packing, storage and ripening techniques; insect and disease management.

Crops

Citrus, Grapes, Litchi, Pomegranate, Apple, Pear, Peach, Plum, Apricot, Cherries, Berries, Persimmon, Kiwifruit, Nuts- Walnut, Almond, Pecan, etc.

VII. Practicals

- Distinguished features of fruit species, cultivars and rootstocks (2);
- Demonstration of planting systems, training and pruning (3);
- Hands on practices on pollination and crop regulation (2);
- Leaf sampling and nutrient analysis (3);

- Physiological disorders-malady diagnosis (1);
- Physico-chemical analysis of fruit quality attributes (3);
- Field/ Exposure visits to subtropical and temperate orchards (1);
- Project preparation for establishing commercial orchards (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the student are expected to equip themselves with principles and practices of producing subtropical (citrus, grapes, litchi, pomegranate, etc.) and temperate fruits (apple, pear, peach, plum, apricot, cherries, berries, kiwifruit, etc.) and nuts (almond, walnut, pecan, etc.)

X. Suggested Reading

Chadha KL and Awasthi RP. 2005. *The Apple*. Malhotra Publishing House, New Delhi.
Chadha TR. 2011. *A Text Book of Temperate Fruits*. ICAR, New Delhi
Childers NF, Morris JR and Sibbett GS. 1995. *Modern Fruit Science: Orchard and Small Fruit Culture*. Horticultural Publications, USA.
Creasy G and Creasy L. 2018. *Grapes*. CAB International.
Davies FS and Albrigo LG. 1994. *Citrus*. CAB International.
Dhillon WS. 2013. *Fruit Production in India*. Narendra Publishing House, New Delhi.
Jackson D, Thiele G, Looney NE and Morley-Bunker M. 2011. *Temperate and Subtropical Fruit Production*. CAB International.
Ladanyia M. 2010. *Citrus Fruit: Biology, Technology and Evaluation*. Academic Press.
Layne DR and Bassi D. 2008. *The Peach: Botany, Production and Uses*. CABI.
Menzel CM and Waite GK. 2005. *Litchi and Longan: Botany, Production and Uses*. CAB International.
Pandey RM and Randey SN. 1996. *The Grape in India*. ICAR, New Delhi.
Rajput CBS, and Haribabu RS. 2006. *Citriculture,* Kalyani Publishers, New Delhi.
Sandhu S and Gill BS. 2013. *Physiological Disorders of Fruit Crops*. NIPA, New Delhi.
Sharma RM, Pandey SN and Pandey V. 2015. *The Pear – Production, Post-harvest Management and Protection*. IBDC Publisher, New Delhi.
Sharma RR and Krishna H. 2018. *Textbook of Temperate Fruits*. CBS Publishers and Distributors Pvt. Ltd., New Delhi.
Singh S, Shivshankar VJ, Srivastava AK and Singh IP. 2004. *Advances in Citriculture*. NIPA, New Delhi.
Tromp J, Webster AS and Wertheim SJ. 2005. *Fundamentals of Temperate Zone Tree Fruit Production*.Backhuys Publishers, Lieden, The Netherlands.
Webster A and Looney N. *Cherries: Crop Physiology, Production and Uses*. CABI.
Westwood MN. 2009. *Temperate Zone Pomology:Physiology and Culture*. Timber Press, USA.

I. Course Title : Propagation and Nursery Management in Fruit Crops

II. Course Code : FSC 503

III. Credit Hours : (2+1)

IV. Why this course ?

Availability of sufficient and healthy planting material is pivotal for expanding fruit culture. This necessitates requisite skill and efficient multiplication protocols for raising plants and their in house management prior to distribution or field transfer, hence the course is developed.

V. Aim of the course

To understand the principles and methods of propagation and nursery management in fruit crops.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	I General Concepts and Phenomena
2	Propagation	I Conventional Asexual Propagation
		II Micropropagation
3	Nursery	I Management Practices and Regulation

VI. Theory

Block 1: Introduction

Unit 1: General Concepts and Phenomena: Introduction, understanding cellular basis for propagation, sexual and asexual propagation, apomixis, polyembryony, chimeras. Factors influencing seed germination of fruit crops, dormancy, hormonal regulation of seed germination and seedling growth. Seed quality, treatment, packing, storage, certification and testing.

Block 2: Propagation

Unit I: Conventional Asexual Propagation: Cutting– methods, rooting of soft and hardwood cuttings under mist and hotbeds. Use of PGR in propagation, Physiological, anatomical and biochemical aspects of root induction in cuttings. Layering – principle and methods.

Budding and grafting – principles and methods, establishment and management of bud wood bank. Stock, scion and inter stock relationship – graft incompatibility, physiology of rootstock and top working.

Unit II: Micropropagation: Micro-propagation – principles and concepts, commercial exploitation in horticultural crops. Techniques – *in-vitro* clonal propagation, direct organogenesis, embryogenesis, micrografting, meristem culture, genetic fidelity testing. Hardening, packaging and transport of micro-propagules.

Block 3: Nursery

Unit I: Management Practices and Regulation: Nursery – types, structures, components, planning and layout. Nursery management practices for healthy propagule production. Nursery Act, nursery accreditation, import and export of seeds and planting material and quarantine.

VII. Practical

- Hands on practices on rooting of dormant and summer cuttings (3);
- Anatomical studies in rooting of cutting and graft union(1);
- Hands on practices on various methods of budding and grafting (4);
- Propagation by layering and stooling (2);

- Micropropagation- explant preparation, media preparation, culturing – meristem tip culture, axillary bud culture, micro-grafting, hardening (4);
- Visit to commercial tissue culture laboratories and accredited nurseries (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The student would be expected to equip to acquire skills and knowledge on principles and practices of macro and micropropagation and the handling of propagated material in nursery.

X. Suggested Reading

Bose TK, Mitra SK and Sadhu MK. 1991. *Propagation of Tropical and Subtropical Horticultural Crops*. Naya Prokash, Kolkatta.

Davies FT, Geneve RL and Wilson SB. 2018. *Hartmann and Kester's Plant Propagation-Principles and Practices*. Pearson, USA/ PrenticeHall of India. New Delhi.

Gill SS, Bal JS and Sandhu AS. 2016. *Raising Fruit Nursery*. Kalyani Publishers,New Delhi.

Jain S and Ishil K. 2003. *Micropropagation of Woody Trees and Fruits*. Springer.

Jain S and Hoggmann H. 2007. *Protocols for Micropropagation of Woody Trees and Fruits*. Springer.

Joshi P. 2015. *Nursery Management of Fruit Crops in India*. NIPA, New Delhi.

Love *et al*. 2017. *Tropical Fruit Tree Propagation Guide*. UH-CTAHR F_N_49. College of Tropical Agriculture and Human Resources University of Hawaii at Manwa, USA.

Peter KV, eds. 2008. *Basics of Horticulture*. New India Publishing Agency, New Delhi.

Rajan S and Baby LM. 2007. *Propagation of Horticultural Crops*. NIPA, New Delhi.

Sharma RR. 2014. *Propagation of Horticultural Crops*. Kalyani Publishers, New Delhi.

Sharma RR and Srivastav M. 2004. *Propagation and Nursery Management*. Intl. Book Publishing Co., Lucknow.

Singh SP. 1989. *Mist Propagation*. Metropolitan Book Co.

Singh RS. 2014. *Propagation of Horticultural Plants: Arid and Semi-Arid Regions*. NIPA, New Delhi.

Tyagi S. 2019. *Hi-Tech Horticulture*. Vol I: *Crop Improvement, Nursery and Rootstock Management*. NIPA, New Delhi.

I. Course Title : Breeding of Fruit Crops

II. Course Code : FSC 504

III. Credit Hours : (2+1)

IV. Why this course ?

Development of genetically improved varieties and rootstock is a continuous process which is realized through selection and breeding approaches. This is necessary to enhance the productivity and meet ever-changing climatic conditions and market/ consumer preferences. As such, a course is formulated to generate know-how on genetic and breeding aspects of fruit crops.

V. Aim of the course

To impart comprehensive knowledge on principles and practices of fruit breeding.

The course organisation is as under:

No.	Blocks	Units
1	Introduction	Importance, Taxonomy and Genetic Resources
2	Reproductive Biology	Blossom Biology and Breeding Systems
3	Breeding approaches	Conventional and Non-Conventional Breeding

VI. Theory

Block 1: Introduction

Unit I: Importance, Taxonomy and Genetic Resources: Introduction and importance, origin and distribution, taxonomical status – species and cultivars, cytogenetics, genetic resources.

Block 2: Reproductive Biology

Unit I: Blossom Biology and Breeding Systems: Blossom biology, breeding systems – spontaneous mutations, polyploidy, incompatibility, sterility, parthenocarpy, apomixis, breeding objectives, ideotypes.

Block 3: Breeding Approaches

Unit I: Conventional and Non-Conventional Breeding: Approaches for crop improvement – direct introduction, selection, hybridization, mutation breeding, polyploid breeding, rootstock breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses, biotechnological interventions, achievements and future thrusts.

Crops

Mango, Banana, Pineapple, Citrus, Grapes, Litchi, Guava, Pomegranate, Papaya, Apple, Pear, Plum, Peach, Apricot, Cherries, Strawberry, Kiwifruit, Nuts

VII. Practicals

- Exercises on bearing habit, floral biology (2);
- Pollen viability and fertility studies (1);
- Hands on practices in hybridization (3);
- Raising and handling of hybrid progenies (2);
- Induction of mutations and polyploidy (2);
- Evaluation of biometrical traits and quality traits (2);
- Screening for resistance against abiotic stresses (2);
- Developing breeding programme for specific traits (2);
- Visit to research stations working on fruit breeding (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students are expected to

- Have an understanding on importance and peculiarities of fruit breeding

- Have an updated knowledge on reproductive biology, genetics and inherent breeding systems.
- Have detailed knowledge of various methods/ approaches of breeding fruit crops

X. Suggested Reading

Abraham Z. 2017. *Fruit Breeding*. Agri-Horti Press, New Delhi.
Badenes ML and Byrne DH. 2012. *Fruit Breeding*. Springer Science, New York.
Dinesh MR. 2015. *Fruit Breeding*, New India Publishing Agency, New Delhi.
Ghosh SN, Verma MK and Thakur A. 2018. *Temperate Fruit Crop Breeding- Domestication to Cultivar Development*. NIPA, New Delhi.
Hancock JF. 2008. *Temperate Fruit Crop Breeding: Germplasm to Genomics*. Springer Science, New York.
Jain SN and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Tropical Species*. Springer Science, New York.
Jain S and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Temperate Species*. Springer Science, New York.
Janick J and Moore JN. 1996. *Fruit Breeding*. Vols. I–III. John Wiley & Sons, USA.
Kumar N. 2014. *Breeding of Horticultural Crops:Principles and Practices*. NIPA, N. Delhi.
Moore JN and Janick J. 1983. *Methods in Fruit Breeding*. Purdue University Press, USA.
Ray PK. 2002. *Breeding Tropical and Subtropical Fruits*. Narosa Publ. House, New Delhi.

I. Course Title : Systematics of Fruit Crops
II. Course Code : FSC 505
III. Credit Hours : (2+1)

IV. Why this course ?

Life forms and their behaviour are best understood if properly described to the stake holders. Therefore, identification and characterization are pre-requisites to distinctly describe the plant species. The fruit crop species are no exception, and thus an exclusive course on their categorisation and description exhibiting a great deal of variation.

V. Aim of the course

To acquaint with the classification, nomenclature and description of various fruit crops.

The course is organised as under:

No.	Blocks	Units
1	Biosystematics	Nomenclature and Classification
2	Botanical Keys and Descriptors	Identification and Description
3	Special Topics	Registration and Modern Systematics

VI. Theory

Block 1: Biosystematics

Unit I: Nomenclature and Classification: Biosystematics – introduction and significance; history of nomenclature of cultivated plants, classification and nomenclature systems; International code of nomenclature for cultivated plants

Block 2: Botanical Keys and Descriptors

Unit I: Identification and Description: Methods of identification and description of cultivated fruit and nut species and their wild relatives features; development of plant keys for systematic identification and classification.

Development of fruit crop descriptors- based upon Bioversity International Descriptors and UPOV/ DUS test guidelines, botanical and pomological description of major cultivars and rootstocks of tropical, subtropical and temperate fruits and nut crops

Block 3: Special Topics

Unit I: Registration and Modern Systematics: Registration, Use of chemotaxonomy, biochemical and molecular markers in modern systematics

VII. Practicals

- Exercises on identification and pomological description of various fruit species and cultivars (6);
- Development of descriptive blanks *vis-a-vis* UPOV/ DUS test guidelines and Bioversity International (4);
- Descriptors for developing fruit species and cultivar descriptive databases (4);
- Visits to major germplasm centres and field genebanks (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students would be able to—

- Categorise different fruit species into broad groups.
- Identify various fruit cultivars on basis of distinguishing features
- Characterize fruit cultivars for description, registration and protection

X. Suggested Reading

ASHS. 1997. *The Brooks and Olmo Register of Fruit and NutVarieties*. 3rd Ed. ASHS Press.

Bhattacharya B and Johri BM. 2004. *Flowering Plants: Taxonomy and Phylogeny*. Narosa Pub. House, New Delhi.

Pandey BP. 1999. *Taxonomy of Angiosperms*. S. Chand & Co. New Delhi.

Pareek OP and Sharma S. 2017. *Systematic Pomology*. Scientific Publishers, Jodhpur.

Sharma G, Sharma OC and Thakur BS. 2009. *Systematics of Fruit Crops*. NIPA, New Delhi.

Simpson M. 2010. *Plant Systematics*. 2ndEdn. Elsevier.

Spencer RR, Cross R and Lumley P. 2003. *Plant Names*. 3rd Ed. *A Guide to Botanical Nomenclature,* CISRO, Australia.

Srivastava U, Mahajan RK, Gangopadyay KK, Singh M and Dhillon BS. 2001. *Minimal Descriptors of Agri-Horticultural Crops. I: Fruits*. NBPGR, New Delhi.

Zielinski QB. 1955. *Modern Systematic Pomology*. Wm. C. Brown Co., Iowa, USA.

I. Course Title : Canopy Management of Fruit Crops
II. Course Code : FSC 506
III. Credit Hours : (1+1)

IV. Why this course ?

Plant architecture plays an important role in enhancing photosynthetic efficiency and resultant quantity and quality of the fruit produce. Manipulation of plant growth and development can be done by employing different training and pruning procedures besides through the use of growth regulators, specific rootstocks, etc. Hence this course is developed to address the aforesaid issues.

V. Aim of the course

To impart knowledge on principles and practices in management of canopy architecture for quality fruit production.

The course organisation is as follows:

No.	Blocks	Units
1	Canopy Architecture	Introduction, types and Classification
2	Canopy Management	Physical Manipulation and Growth regulation

VI. Theory

Block 1: Canopy Architecture

Unit I: Introduction, Types and Classification: Canopy management – importance and factors affecting canopy development. Canopy types and structures, canopy manipulation for optimum utilization of light and its interception. Spacing and utilization of land area – Canopy classification.

Block 2: Canopy Management

Unit I: Physical Manipulation and Growth Regulation: Canopy management through rootstock and scion. Canopy management through plant growth regulators, training and pruning and management practices. Canopy development and management in relation to growth, flowering, fruiting and fruit quality.

VII. Practicals

- Study of different types of canopies (2);
- Training of plants for different canopy types (2);
- Canopy development through pruning (2);
- Understanding bearing behaviour and canopy management in different fruits (2);
- Use of plant growth regulators (2);
- Geometry of planting (1);
- Development of effective canopy with support system (2);
- Study on effect of different canopy types on production and quality of fruits (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations

- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students are expected to learn

- The basic principles of canopy management to modify plant architecture
- The skills on training and pruning of fruit crops, and growth regulation

X. Suggested Reading

Bakshi JC, Uppal DK and Khajuria HN. 1988. *The Pruning of Fruit Trees and Vines*. Kalyani Publishers, New Delhi.

Chadha KL and Shikhamany SD. 1999. *The Grape, Improvement, Production and Post Harvest Management*. Malhotra Publishing House, Delhi.

Iyer CPA and Kurian RM. 2006. *High Density Planting in Tropical Fruits: Principles and Practices*. IBDC Publishers, New Delhi.

Pradeepkumar T. 2008. *Management of Horticultural Crops*. NIPA, New Delhi.

Singh G. 2010. *Practical Manual on Canopy Management in Fruit Crops*. Dept. of Agriculture and Co-operation, Ministry of Agriculture (GoI), New Delhi.

Srivastava KK. 2012. *Canopy Management in Fruits*. ICAR, New Delhi

I. Course Title : Growth and Development of Fruit Crops

II. Course Code : FSC 507

III. Credit Hours : (2+1)

IV. Why this course ?

The underlying principles and parameters of growth and development needs to be understood for harnessing maximum benefits in term of yield and quality. External environment and inherent hormonal and metabolic pathways considerably determine growth dynamics. Thus, a course is formulated to develop know-how on physiological and physical aspects of growth and development processes.

V. Aim of the course

To develop comprehensive understanding on growth and development of fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Principles
2	Environment and Development	Climatic Factors, Hormones and Developmental Physiology
3	Stress Management	Strategies for Overcoming Stress

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Principles: Growth and development- definition, parameters of growth and development, growth dynamics and morphogenesis.

Block 2: Environment and Development

Unit I: Climatic Factors, Hormones and Developmental Physiology: Environmental impact on growth and development- effect of light, temperature, photosynthesis and photoperiodism, vernalisation, heat units and thermoperiodism. Assimilate partitioning, influence of water and mineral nutrition in growth and development; concepts of plant hormone and bioregulators, history, biosynthesis and physiological role of auxins, gibberellins, cytokinins, abscissic acid, ethylene, growth inhibitors and retardant, brasssinosteroids, other New PGRs. Developmental physiology and biochemistry during dormancy, bud break, juvenility, vegetative to reproductive interphase, flowering, pollination, fertilization and fruit set, fruit drop, fruit growth, ripening and seed development.

Block 3: Stress Management

Unit I: Strategies for Overcoming Stress: Growth and developmental process during stress – manipulation of growth and development, impact of pruning and training, chemical manipulations and Commercial application of PGRs in fruit crops, molecular and genetic approaches in plant growth and development.

VII. Practicals

- Understanding dormancy mechanisms in fruit crops and seed stratification (2);
- Techniques of growth analysis (2);
- Evaluation of photosynthetic efficiency under different environments (2);
- Exercises on hormone assays (2);
- Practicals on use of growth regulators (2);
- Understanding ripening phenomenon in fruits (2);
- Study on impact of physical manipulations on growth and development (1);
- Study on chemical manipulations on growth and development (1);
- Understanding stress impact on growth and development (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

Consequent upon successful completion of the course, the students are expected to have

- Equipped with understanding of various growth and development processes
- Learned about the role of environment and growth substances
- Acquired the skills to realise optimum growth and development under stress conditions

X. Suggested Reading

Bhatnagar P. 2017. *Physiology of Growth and Development of Horticultural Crops*. Agrobios (India).

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, NY, USA.

Dhillon WS and Bhatt ZA. 2011. *Fruit Tree Physiology*. Narendra Publishing House, New Delhi.

Durner E. 2013. *Principles of Horticultural Physiology*. CAB International.

Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. John Wiley & Sons, NY, USA.
Faust M. 1989. *Physiology of Temperate Zone Fruit Trees*. John Willey & Sons, NY, USA.
Fosket DE. 1994. *Plant Growth and Development: a Molecular Approach*. Academic Press, USA.
Leopold AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rd Ed. McGraw-Hill, New Delhi.
Roberts J, Downs S and Parker P. 2002. Plant Growth Development. In: Salisbury FB and Ross CW. (Eds.) *Plant Physiology*. 4th Ed.Wadsworth Publications, USA.
Schafeer, B. and Anderson, P. 1994. *Handbook of Environmental Physiology of Fruit Crops*. Vol. 1 & 2. CRC Press. USA.
Seymour GB, Taylor JE and Tucker GA. 1993. *Biochemistry of Fruit Ripening*. Chapman & Hall, London.

I. Course Title : Nutrition of Fruit Crops
II. Course Code : FSC 508
III. Credit Hours : (2+1)

IV. Why this course ?

Nutrients play a significant role in almost every growth and development process determining vigour, yield and quality of fruits. Henceforth, a course is designed to have an in depth study of various nutrients, their uptake and use efficiency in realizing sustainable fruit production

V. Aim of the course

To acquaint with principles and practices involved in nutrition of fruit crops
The course is organised as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Principles
2	Requirements and Applications	Diagnostics, Estimation and Application
3	Newer Approaches	Integrated Nutrient Management (INM)

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Principles: Importance and history of nutrition in fruit crops, essential plant nutrients, factors affecting plant nutrition; nutrient uptake and their removal from soil.

Block 2: Requirements and Applications

Unit I: Diagnostics, Estimation and Application: Nutrient requirements, root distribution in fruit crops, soil and foliar application of nutrients in major fruit crops, fertilizer use efficiency. Methods and techniques for evaluating the requirement of macro- and micro-elements, Diagnostic and interpretation techniques including DRIS. Role of different macro- and micro-nutrients, their deficiency and toxicity disorders, corrective measures to overcome deficiency and toxicity disorders.

Block 3: Newer Approaches

Unit I: Integrated Nutrient Management (INM): Fertigation in fruit crops, bio-fertilizers and their use in INM systems.

VII. Practicals

- Visual identification of nutrient deficiency symptoms in fruit crops (2);
- Identification and application of organic, inorganic and bio-fertilizers (1);
- Soil/ tissue collection and preparation for macro- and micro-nutrient analysis (1);
- Analysis of soil physical and chemical properties- pH, EC, Organic carbon (1);
- Determination of N,P,K and other macro- and micronutrients (6);
- Fertigation in glasshouse and field grown horticultural crops (2);
- Preparation of micro-nutrient solutions, their spray and soil applications (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students would be expected to

- Know the importance and various types of nutrients and their uptake mechanisms
- Analyse soil and plant status with respect to various nutrients
- Make use of corrective measures to overcome deficiency or toxicity

X. Suggested Reading

Atkinson D, Jackson JE and Sharples RO. 1980. *Mineral Nutrition of Fruit Trees*. Butterworth – Heinemann.

Bould C, Hewitt EJ and Needham P. 1983. *Diagnosis of Mineral Disorders in Plants Vol.1 Principles*. Her Majesty's Stationery Office, London.

Cooke GW. 1972. *Fertilizers for maximizing yield*. Grenada Publishing Ltd, London.

Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. Wiley Eastern Ltd.

Kanwar JS. 1976. *Soil Fertility-Theory and Practice*. ICAR, New Delhi.

Marchner Horst. 1995. *Mineral Nutrition of Higher Plants*, 2nd Ed. Marschner, Academic Press Inc. San Diego, CA.

Mengel K and Kirkby EA. 1987. *Principles of Plant Nutrition*. 4th Ed. International Potash Institute, Worblaufen-Bern, Switzerland.

Prakash M. 2013. *Nutritional Disorders in Fruit Crops: Diagnosis and Management*. NIPA, New Delhi.

Tandon HLS. 1992. *Management of Nutrient Interactions in Agriculture*. Fertilizer Development and Consultation Organization, New Delhi.

Westerman RL. 1990. *Soil Testing and Plant Analysis*, 3rd Ed. Soil Science Society of America, Inc., Madison, WI.

Yawalkar KS, Agarwal JP and Bokde S. 1972. *Manures and Fertilizers*. 3rd Ed. Agri Horticultural Publishing House, Nagpur.

I. Course Title : Biotechnology of Fruit Crops

II. Course Code : FSC 509

III. Credit Hours : (2+1)

IV. Why this course ?

In the recent times, biotechnological interventions in fruit crops have contributed in enhanced yield, biotic and abiotic stress management and improved quality traits to a considerable extent. Hence, a course is designed to educate on the possibilities and progress made through biotechnology for improved fruit production.

V. Aim of the course

To impart knowledge on the principles and tools of biotechnology.

Structure of the course is as under:

No.	Blocks	Units
1	General Background	Introduction, History and Basic Principles
2	Tissue Culture	*In-vitro* Culture and Hardening
3	Genetic Manipulation	*In-vitro* Breeding, Transgenics and Gene Technologies

VI. Theory

Block 1: General Background

Unit I: Introduction, History and Basic Principles: Introduction and significance, history and basic principles, influence of explant material, physical, chemical factors and growth regulators on growth and development of plant cell, tissue and organ culture.

Block 2: Tissue Culture

Unit I: *In-vitro* Culture and Hardening: Callus culture – types, cell division, differentiation, morphogenesis, organogenesis, embryogenesis; Organ culture – meristem, embryo, anther, ovule culture, embryo rescue, somaclonal variation, protoplast culture. Use of bioreactors and *in-vitro* methods for production of secondary metabolites, suspension culture, nutrition of tissues and cells, regeneration of tissues. Hardening and *ex vitro* establishment of tissue cultured plants.

Block 3: Genetic Manipulation

Unit I: *In-vitro* Breeding, Transgenics and Gene Technologies: Somatic cell hybridisation, construction and identification of somatic hybrids and cybrids, wide hybridization, *in-vitro* pollination and fertilization, haploids, *in-vitro* mutation, artificial seeds, cryopreservation, *In-vitro* selection for biotic and abiotic stress. Genetic engineering- principles and methods, transgenics in fruit crops, use of molecular markers and genomics. Gene silencing, gene tagging, gene editing, achievements of biotechnology in fruit crops.

VII. Practicals

- An exposure to low cost, commercial and homestead tissue culture laboratories (2);
- Media preparation, Inoculation of explants for clonal propagation, callus induction and culture, regeneration of plantlets from callus (3);
- Sub-culturing techniques on anther, ovule, embryo culture, somaclonal variation (4);
- *In-vitro* mutant selection against abiotic stress (2);
- Protoplast culture and fusion technique (2);
- Development of protocols for mass multiplication (2);
- Project development for establishment of commercial tissue culture laboratory (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals

- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After the successful completion of the course, the students are expected to know

- Basic principles and methods of plant tissue culture and other biotechnological tools.
- The use and progress of biotechnology in fruit crops.

X. Suggested Reading

Bajaj YPS. Eds., 1989. *Biotechnology in Agriculture and Forestry*. Vol. V, *Fruits*. Springer, USA.

Brown TA. 2001. *Gene Cloning and DNA Analysis and Introduction*. Blackwell Publishing, USA.

Chahal GS and Gosal SS. 2010. *Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches*. Narosa, New Delhi.

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology – Concepts, Methods and Applications*. Oxford & IBH, New Delhi.

Kale C. 2013. Genome Mapping and Molecular Breeding in Plant, Vol 4. *Fruit and Nuts*. Springers.

Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Tissue Culture and Gene Transfer*. Orient & Longman, Universal Press, US.

Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Biotechnology of Horticultural Crops*. Vols. I, II. NIPA, New Delhi.

Litz RE. 2005. *Biotechnology of Fruit and Nut Crops*. CABI, UK.

Miglani GS. 2016. *Genetic Engineering – Principles, Procedures and Consequences*. Narosa Publishing House, New Delhi.

Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vols. I–III. Naya Prokash, Kolkata.

Peter KV. 2013. *Biotechnology in Horticulture: Methods and Applications*. NIPA, New Delhi.

Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic Hybridization and Genetic Manipulation in Plants. Plant Regulation and World Agriculture*. Platinum Press, UK.

I. Course Title : Organic Fruit Culture

II. Course Code : FSC 510

III. Credit Hours : (2+1)

IV. Why this course ?

Considering threats to environment and human health on account of excessive use of chemicals and synthetic fertilizers, organic farming is looked upon as an alternative. Though the organic and other natural farming practices are in evolving phase and are yet to be time scale tested, there is a general perception that these would hold good. As such a course is customised to educate the Graduates on various issues related to organic farming.

V. Aim of the course

To develop understanding on organic production of fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	General Aspects	Principles and Current Scenario
2	Organic Culture	Farming System and Practices
3	Certification	Inspection, Control Measures and Certification

VI. Theory

Block 1: General Aspects

Unit I: Principles and Current Scenario: Organic horticulture, scope, area, production and world trade, definition, principles, methods and SWOT analysis.

Block 2: Organic Culture

Unit I: Farming System and Practices: Organic farming systems including biodynamic farming, natural farming, homa organic farming, rishi krishi, EM technology, cosmic farming; on-farm and off-farm production of organic inputs, role of bio-fertilizers, bio enhancers, legumes, inter cropping, cover crops, green manuring, zero tillage, mulching and their role in organic nutrition management. Organic seeds and planting materials, soil health management in organic production, weed management practices in organic farming, biological management of pests and diseases, trap crops, quality improvement in organic production of fruit crops.

Block 3: Certification

Unit I: Inspection, Control Measures and Certification: Inspection and certification of organic produce, participatory guarantee system (PGS), NPOP, documentation and control, development of internal control system (ICS), Concept of group certification, constitution of grower group as per NPOP, preparation of ICS manual, internal and external inspection, concept of third party verification, certification of small farmer groups (Group Certification), transaction certificate, group certificate, critical control points (CCP) and HACCP, IFOAM guidelines on certification scope and chain of custody, certification trademark – The Logo, accredited certification bodies under NPOP. Constraints in certification, IFOAM and global scenario of organic movement, postharvest management of organic produce. Economics of organic fruit production.

VII. Practicals

- Design of organic orchards/ farms management (1);
- Conversion plan (1);
- Nutrient management and microbial assessment of composts and bio-enhancers (2);
- Preparation and application of composts, bio-enhancers and bio-pesticides (2);
- Organic nursery raising (1);
- Application of composts, bio-enhancers, bio-fertilisers and bio-pesticides, green manure, cover, mulching (2);
- Preparation and use of neem based products (1);

- Biodynamic preparations and their role in organic agriculture, EM technology and products, biological/ natural management of pests and diseases (2);
- Soil solarisation (1);
- Frame work for GAP (1);
- Documentation for certification (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

On successful completion of the course, the students are expected to be able to

- Familiarize with the concepts and practices of organic and other natural farming systems
- Generate know-how on procedures, policies and regulation for inspection and certification of organic produce

X. Suggested Reading

Claude A. 2004. *The Organic Farming Sourcebook*. Other India Press, Mapusa, Goa, India.

Dabholkar SA. 2001. *Plenty for All*. Mehta Publishing House, Pune, Maharashtra.

Das HC and Yadav AK. 2018. *Advances in Organic Production of Fruit Crops*. Westville Publishing House, New Delhi.

Deshpande MS. 2003. *Organic Farming with respect to Cosmic Farming*. Mrs. Pushpa Mohan Deshpandey, Kolhapur, Maharashtra.

Deshpande WR. 2009. *Basics of Organic Farming*. All India Biodynamic and Organic Farming Association, Indore. MP.

Gaur AC, Neblakantan S and Dargan KS. 1984 *Organic Manures*. ICAR, New Delhi.

Lampkin, N. and Ipswich, S. 1990. *Organic Farming*. Farming Press. London, UK.

Lind K, Lafer G, Schloffer K, Innershofer G and Meister H. 2003. *Organic Fruit Growing*. CAB International.

Palaniappan SP and Annadurai K. 2008. *Organic Farming- Theory and Practice*. Scientific Publishers, Jodhpur, Rajasthan, India.

Palekar S. 2004. *The Technique of Spritual Farming*. Chandra Smaritee, Sai Nagar, Amrawati, Maharashtra.

Proctor P. 2008. Biodynamic Farming and Gardening. Other India Press, Mapusa, Goa.

Ram RA and Pathak RK. 2017. Bioenhancers. Lap Lambert Academic Publishing, AP.

I. Course Title : Export Oriented Fruit Production

II. Course Code : FSC 511

III. Credit Hours : (2+1)

IV. Why this course ?

India is a top ranking country in production of fruit crops especially with respect mangoes, bananas, and grapes. WTO regime opens new vistas for exploring export opportunities of different fruit commodities. Already, India export mangoes, litchi, grapes, walnuts, apples, etc. and there lies a huge potential in this sector. As such a course has been developed to highlights government policies, standards, infrastructural development and export potential vis-à-vis international scenario.

V. Aim of the course

To acquaints with the national and international standards and export potential of fruit crops

The course is organised as under:-

No.	Blocks	Units
1	Introduction	Statistics and World Trade
2	Regulations	Policies, Norms and Standards
3	Quality Assurance	Infrastructure and Plant Material

VI. Theory

Block 1: Introduction

Unit I: Statistics and World Trade: National and international fruit export and import scenario and trends; Statistics and India's position and potentiality in world trade; export promotion zones in India. Government Policies.

Block 2: Regulations

Unit I: Policies, Norms and Standards: Scope, produce specifications, quality and safety standards for export of fruits, viz., mango, banana, grape, litchi, pomegranate, walnut, apple and other important fruits. Processed and value-added products, post harvest management for export including packaging and cool chain; HACCP, Codex alimentarius, ISO certification; WTO and its implications, sanitary and phyto-sanitary measures.

Block 3: Quality Assurance

Unit I: Infrastructure and Plant Material: Quality fruit production under protected environment; different types of structures – Automated greenhouses, glasshouse, shade net, poly tunnels – Design and development of low cost greenhouse structures. Seed and planting material; meeting export standards, implications of plant variety protection – patent regimes.

VII. Practicals

- Export promotion zones and export scenario of fresh fruits and their products (1);
- Practical exercises on quality standards of fruits for export purpose (2);
- Quality standards of planting material and seeds (2);
- Hi-tech nursery in fruits (1);
- Practicals on ISO specifications and HACCP for export of fruits (3);
- Sanitary and phyto-sanitary measures during export of horticultural produce (2);
- Post harvest management chain of horticultural produce for exports (2);
- Visit to export oriented units/ agencies like APEDA, NHB, etc.

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

Consequent upon successful completion of the course, the students are expected to have learnt about

- National and international trade scenario of fruit crops
- Set norms and standards for export of fruit crops
- Requisite infrastructure and growing practices meeting export standards

X. Suggested Reading

Chadha KL. 1995. *Advances in Horticulture*. Vol. XII. Malhotra Publ. House, New Delhi.

Chetan GF. 2015. *Export Prospects of Fruits and Vegetables from India: A study of Export market in EU. A project report*. Anand Agricultural University, Anand, Gujarat.

Dattatreylul M. 1997. *Export potential of Fruits, Vegetables and Flowers from India*. NABARD, Mumbai.

Islam, C.N. 1990. *Horticultural Export of Developing Countries: Past Preferences, Future Prospects and Policies*. International Institute of Food Policy Research, USA.

e-Resources

http://apeda.gov.in
http://nhb.gov.in
http://indiastat.com

I. Course Title : Climate Change and Fruit Crops

II. Course Code : FSC 512

III. Credit Hours : (1+0)

IV. Why this course ?

In the changing climatic scenario, the fruit crops get affected adversely due to one or more unfavourable environmental factors. Shifting of temperate fruits to higher altitudes due to insufficient chilling, occurrence of drought and frost in warmer areas are notable examples. In order to educate on extent of damage and strategies to mitigate the effect of climate change, a course has been formulated.

V. Aim of the course

To understand the impact of climate change and its management in fruit production.

The course is structured as under:-

No.	Blocks	Units
1	General Aspects	Introduction, Global Warming and Climatic Variability
2	Climate Change and Management	Impact Assessment and Mitigation
3	Case Studies	Response to Climate Change

VI. Theory

Block 1: General Aspects

Unit I: Introduction, Global Warming and Climatic Variability: Introduction to climate change. Factors directly affecting climate change. Global warming, effect of climate change on spatio-temporal patterns of temperature and rainfall, concentrations of greenhouse gasses in atmosphere. pollution levels such as tropospheric ozone, change in climatic variability and extreme events.

Block 2: **Climate Change and Management**

Unit I: Impact Assessment and Mitigation: Sensors for recording climatic parameters, plants response to the climate changes, premature bloom, marginally overwintering or inadequate winter chilling hours, longer growing seasons and shifts in plant hardiness for fruit crops.

Climate mitigation measures through crop management- use of tolerant rootstocks and varieties, mulching – use of plastic- windbreak- spectral changes- protection from frost and heat waves. Climate management in greenhouse- heating – vents – CO_2 injection – screens – artificial light. Impact of climate changes on invasive insect, disease, weed, fruit yield, quality and sustainability. Climate management for control of pests, diseases, quality, elongation of growth and other plant processes- closed production systems.

Block 3: **Case Studies**

Unit I: Response to Climate Change: Case studies – responses of fruit trees to climatic variability *vis-a-vis* tolerance and adaptation; role of fruit tree in carbon sequestration.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students are expected to have learnt

- Nature and extent of altered behaviour or damage due to climate change
- Methods to assess the adverse effects
- Approaches to mitigate the effect due to climatic variability

IX. Suggested Reading

Dhillon WS and Aulakh PS. 2011. *Impact of Climate Change in Fruit Production*. Narendra Publishing House, New Delhi.

Peter KV. 2008. *Basics in Horticulture*. New India Publishing Agency, New Delhi.

Ramirez F and Kallarackal J. 2015. *Responses of Fruit Trees to Global Climate Change*. Spinger-Verlag.

Rao GSLHV. 2008. *Agricultural Meteorology*. Prentice Hall, New Delhi.

Rao GSLHV, Rao GGSN, Rao VUM and Ramakrishnan YS. 2008. *Climate Change and Agriculture over India*. ICAR, New Delhi.

Schafeer B and Anderson P. 1994. *Handbook of Environmental Physiology of Fruit Crops*.Vol. 1 & 2. CRC Press. USA.

I. Course Title : Minor Fruit Production

II. Course Code : FSC 513

III. Credit Hours : (2+1)

IV. Why this course ?

Apart from commercially grown fruits, several other fruits inspite of being rich in nutrients and potential future crops, remains neglected/ underexploited. The hardy nature coupled with the possibility of diversification (newly domesticated crops) further adds to their importance. The course outlines the efforts made in standardizing agro-techniques for propagation and cultivation besides know-how on their nutraceutical value and other uses.

V. Aim of the course

To import basic knowledge underexploited minor fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	Introduction	Occurrence, Adoption and General Account
2	Agro-Techniques	Propagation and Cultural Practices
3	Marketing and utilization	Post-Harvest Management

VI. Learning outcome

On successful completion of the course, the students are expected to know about

- Various minor fruits hitherto neglected and their commercial value
- Efforts made to domesticate minor fruits and standardization of agro-techniques.
- Their utilization in processing industry.

VII. Theory

Block 1: Introduction

Unit I: Occurrence, Adoption and General Account: Importance – occurrence and distribution, climate adaptation in fragile ecosystem and wastelands.

Block 2: Agro-Techniques

Unit I: Propagation and Cultural Practices: Traditional cultural practices and recent development in agro-techniques; propagation, botany-floral biology, growth patterns, mode of pollination, fruit set, ripening, fruit quality.

Block 3: Marketing and Utilization

Unit I: Post-Harvest Management: Post harvest management, marketing; minor fruit crops in terms of medicinal and antioxidant values; their uses for edible purpose and in processing industry

Crops

Bael, chironji, fig, passion fruit, jamun, phalsa, karonda, woodapple, cactus pear, khejri, kair, pilu, lasoda, loquat, tamarind, dragon fruit, monkey jack, mahua, khirni, amra, kokum, cape gooseberry, kaphal, persimmon, pistachio, seabuckthorn, hazel nut and other minor fruits of regional importance

VIII. Practicals

- Visits to institutes located in the hot and cold arid regions of the country (2);
- Identification of minor fruits plants/ cultivars (2);
- Collection of leaves and preparation of herbarium (1);
- Allelopathic studies (2);
- Generating know-how on reproductive biology of minor fruits (4);
- Fruit quality attributes and biochemical analysis (3);
- Project formulation for establishing commercial orchards in fragile ecosystems (1).

IX. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

X. Suggested Reading

Ghosh SN, Singh A and Thakur A. 2017. *Underutilized Fruit Crops: Importance and Cultivation*. Jaya Publication House, New Delhi.

Krishna H and Sharma RR, 2017. *Fruit Production: Minor Fruits*. Daya Publishing House, New Delhi.

Mazumdar BC. 2014. *Minor Fruit Crops of India: Tropical and Subtropical*. Daya Publication House, New Delhi.

Nath V, Kumar D, Pandey V and Pandey D. 2008. *Fruits for the Future*. Satish Serial Publishing House, New Delhi.

Pareek OP, Sharma S, and Arora RK. 2007. *Underutilised Edible Fruits and Nuts*, IPGRI, Rome.

Peter KV. 2010. *Underutilized and Underexploited Horticultural Crops*. NIPA, New Delhi.

Rana JC and Verma VD. 2011. *Genetic Resources of Temperate Minor Fruit* (*Indigenous and Exotic*). NBPGR, New Delhi.

Saroj PL and Awasthi OP. 2005. *Advances in Arid Horticulture*, Vol. II: *Production Technology of Arid and Semiarid Fruits*. IBDC, Lucknow.

Saroj PL, Dhandar DG and Vashishta BB. 2004. *Advances in Arid Horticulture*, Vol.-1 *Present Status*. IBDC, Lucknow.

Singh *et al*. 2011. *Jamun*. ICAR, New Delhi.

Course Title with Credit Load
Ph.D. (Hort.) in Fruit Science

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
FSC 601*	Innovative Approaches in Fruit Breeding	3+0
FSC 602*	Modern Trends in Fruit Production	3+0
FSC 603	Recent Developments in Growth Regulation	3+0
FSC 604	Advanced Laboratory Techniques	1+2
FSC 605	Arid and Dry Land Fruit Production	2+0
FSC 606	Abiotic Stress Management in Fruit Crops	2+1
FSC 607	Biodiversity and Conservation of Fruit Crops	2+1
FSC 608	Smart Fruit Production	2+0
	Minor courses	06
	Supporting courses	05
FSC 691	Seminar-I	0+1
FSC 692	Seminar-II	0+1
FSC 699	Research	0+75
	Total Credits	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Fruit Science

I. Course Title : Innovative Approaches in Fruit Breeding

II. Course Code : FSC 601

III. Credit Hours : (3+0)

IV. Why this course ?

Modern day fruit culture witnesses rapid changes in production technologies and market trends. Ever changing environment and consumer preferences warrant constant development and adoption of genetically improved varieties.There is more thrust on novelty and distinctness in view of ever increasing competition with enhanced emphasis on tailor made and trait specific designer varieties and rootstocks. The course is thus designed to integrate updated information on inherent breeding systems and innovative gene manipulation technologies enhancing breeding efficiency.

V. Aim of the course

To update knowledge on current trends and innovative approaches in fruit breeding.

The structural organisation of the course is as under:-

No.	Blocks	Units
1	Introduction	Current Trends and Status
2	Genetic Mechanisms	Inheritance Patterns and Breeding Systems
3	Breeding for Specific Traits	Plant Architecture, Stress Tolerance and Fruit Quality
4	Fast-Track Breeding	Transgenics, Markers and Genomics

VI. Theory

Block 1: Introduction

Unit I: Current Trends and Status: Modern trends in fruit breeding –with major emphasis on precocity, low tree volume, suitability for mechanization, health benefits, etc.

Block 2: Genetic Mechanisms

Unit I: Inheritance Patterns and Breeding Systems: Genetics of important traits and their inheritance pattern, variations and natural selection, spontaneous mutations, incompatibility systems in fruits.

Block 3: Breeding for Specific Traits

Unit I: Plant Architecture, Stress Tolerance and Fruit Quality: Recent advances in crop improvement efforts- wider adaptation, plant architecture, amenability to mechanization, fruit quality attributes, stress tolerance, crop specific traits; use of apomixis, gene introgression and wide hybridization (alien genes).

Block 4: Fast-Track Breeding

Unit I: Transgenics, Markers and Genomics: Molecular and transgenic approaches in improvement of selected fruit crops; fast track breeding–marker assisted selection and breeding (MAS and MAB), use of genomics and gene editing tehnologies.

Crops

Mango, banana, guava, papaya, Citrus, grapes, pomegranate, litchi, apple, pear, strawberry, kiwifruit, plums, peaches, apricot, cherries, nectarines, nut crops

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

On successful completion of the course, the students are expected to

- Develop updated knowledge on current breeding objectives and trends
- Equip with information on innovative approaches enhancing breeding efficiency

IX. Suggested Reading

Al-Khayari J, Jain SN and Johnson DV. 2018. *Advances in Plant Breeding Strategies. Vol. 3: Fruits*. Springer.

Badenes S and Byrne DH. 2012. *Fruit Breeding*. Springer.

Hancock JF. 2008. *Temperate Fruit Crop Breeding: Germplasm to Genomics*. Springer.

Kole C and Abbott AG. 2012. *Genetics, Genomics and Breeding of Stone fruits*. CRC.

Kole, C. 2011. *Wild Crops Relatives: Genomics and Breeding Resources: Tropical and Subtropical Fruits*. Springer-Verlag.

Kole C. 2011. *Wild Crops Relatives: Genomics and Breeding Resource: Temperate Fruits*. Springer -Verlag.

Jain SN and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Tropical Species*; *Temperate Species*. Springer -Verlag.

Janick J and Moore JN, 1996. *Fruit Breeding*. Vols.I-III. John Wiley & Sons, USA.

Orton T. 2019. *Methods in Fruit Breeding*. Elsevier.

Singh SK, Patel VB, Goswami AK, Prakash J and Kumar C. 2019. *Breeding of Perennial Horticultural Crops*. Biotech Books. Delhi.

I. Course Title : Modern Trends in Fruit Production

II. Course Code : FSC 602

III. Credit Hours : (3+0)

IV. Why this course ?

Recent technological developments in propagation and cultural practices paves the way to grow fruit crops in an intensive and mechanised mode. As such a course has been developed to provide latest knowledge and updated account of modern production systems enhancing overall productivity.

V. Aim of the course

To keep abreast with latest developments and trends in production technologies of tropical, subtropical and temperate fruits.

The course structure is as follows:-

No.	Blocks	Units
1	Introduction	General Concepts and Current Scenario
2	Advanced Technologies	Propagation, Planting Systems and Crop Regulation
3	Management Practices	Overcoming Stress and Integrated Approaches

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Current Scenario: National and International scenario, national problems.

Block 2: Advanced Technologies

Unit I: Propagation, Planting Systems and Crop Regulation: Recent advances in propagation – root stocks, planting systems, High density planting, crop modeling, Precision farming, decision support systems – aspects of crop regulation- physical and chemical regulation.

Block 3: Management Practices

Unit I: Overcoming Stress and Integrated Approaches: Effects on physiology and development, influence of stress factors, strategies to overcome stress effects, integrated and modern approaches in water and nutrient management, Physiological disorders, Total quality management (TQM) – Current topics.

Crops

Mango, Banana, Grapes, Citrus, Papaya, Litchi, Guava, Pomegranate, Apple, Pear, Peach, Plum, Apricot, Cherry, Almond, Walnut, Pecan, Strawberry, Kiwifruit.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students would have

- Updated knowledge on current trends in fruit production.

IX. Suggested Reading

Bartholomew DP, Paull RE and Rohrbach KG. eds. 2002. *The Pineapple: Botany, Production, and Uses*. CAB International.

Bose TK, Mitra SK and Sanyol D. Eds. 2002. *Fruits of India – Tropical and Sub- Tropical*. 3rd Ed. Vols. I, II. Naya Udyog, Kolkata, India.

Dhillon WS and Bhatt ZA. 2011. *Fruit Tree Physiology*. Narendra Publishing House, New Delhi.

Dhillon WS. 2013. *Fruit Production in India*. Narendra Publishing House, New Delhi.

Gowen S. 1995. *Bananas and Plantains*. Chapman & Hall Publication, US.

Litz RE. ed. 2009. *The Mango: Botany, Production and Uses*. CAB International.

Peter KV. 2016. *Innovations in Horticulture*. NIPA, New Delhi.

Robinson JC and Saúco VG. 2010. *Bananas and Plantains* (Vol. 19). CAB International.

Samson JA. 1980. *Tropical Fruits*. Longman, USA.

Sharma RR and Krishna H. 2014. *Fruit Production: Major Fruits*. Daya Publishing House, Delhi.
Singh S, Shivankar VJ, Srivastava AK and Singh IP. 2004. *Advances in Citriculture*. Jagmander Book Agency, New Delhi.
Stover RH and Simmonds NW. 1991. *Bananas*. Longman, USA.
Chadha KL, Ahmed N, Singh SK and Kalia P. 2016. *Temperate Fruits and Nuts- Way Forward for Enhancing Production and Quality*.Daya Publishing House, New Delhi.
Childers NF, Morris JR and Sibbett GS. 1995. *Modern Fruit Science: Orchard and Small Fruit Culture*. Horticultural Publications, USA.
Erez A. 2013. *Temperate Fruit Crops in Warm Climates*. Springer Science.
Jackson D, Thiele G, Looney NE and Morley-Bunker M. 2011. *Temperate and Subtropical Fruit Production*. CAB International.
Ryugo K. 1998. *Fruit Culture: Its Science and Art*. John Wiley & Sons, USA.
Tromp J, Webster AS and Wertheim SJ. 2005. *Fundamentals of Temperate Zone Tree Fruit Production. Backhuys Publishers,* Lieden, The Netherlands.
Westwood MN. 2009. *Temperate Zone Pomology: Physiology and Culture*. 3rdEdn. Timber Press, USA.

I. Course Title : Recent Developments in Growth Regulation

II. Course Code : FSC 603

III. Credit Hours : (3+0)

IV. Why this course ?

Technological advancements have resulted in deeper understanding of growth and developmental processes in plants. There is equal and just need to apply these in fruit crops for harnessing maximum benefits in term of yield and quality. So a course has been designed to provide latest information on physiological and biochemical aspects of growth and development.

V. Aim of the course

To develop updates on recent advances in growth regulation of fruit crops.

Structure of the course is as under:

No.	Blocks	Units
1	Introduction	Current Concepts and Principles
2	Growth Substances	Phytohormones and Growth Regulators
3	Growth and Development	Regulation of Developmental Processes

VI. Theory

Block 1: Introduction

Unit I: Current Concepts and Principles: Eco-physiological influences on growth and development of fruit crops-flowering, fruit set- Crop load and assimilate partitioning and distribution.

Block 2: Growth Substances

Unit I: Phytohormones and Growth Regulators: Root and canopy regulation, study of plant growth regulators in fruit culture- structure, biosynthesis, metabolic and morphogenetic effects of different plant growth promoters and growth retardants. Absorption, translocation and degradation of phytohormones – internal and external factors influencing hormonal synthesis, biochemical action, growth promotion and inhibition, canopy management for fertigated orchards.

Block 3: Growth and Development

Unit I: Regulation of Developmental Processes: Growth regulation aspects of propagation, embryogenesis, seed and bud dormancy, fruit bud initiation, regulation of flowering, off season production.

Flower drop and thinning, fruit-set and development, fruit drop, parthenocarpy, fruit maturity and ripening and storage, molecular approaches in crop growth regulation- current topics.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students would have

- Complete understanding of growth dynamics in various fruit crops
- Know-how on manipulation of growth and development processes.

IX. Suggested Reading

Bhatnagar P. 2017. *Physiology of Growth and Development of Horticultural Crops*. Agrobios (India).

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, US.

Fosket DE. 1994. *Plant Growth and Development: A Molecular Approach*. Academic Press, USA.

Leopold AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rd Ed. McGraw-Hill, US.

Richard N. Arteca. 1995. *Plant Growth Substances – Principles and Applications*. Chapman & Hall, USA.

Roberts J, Downs S and Parker P. 2002. *Plant Growth Development*. In: *Plants* (I. Ridge, Ed.), Oxford University Press.

Salisbury FB and Ross CW. 1992. *Plant Physiology*. 4th Ed. Wadsworth Publication.

I. Course Title : Advanced Laboratory Techniques

II. Course Code : FSC 604

III. Credit Hours : (1+2)

IV. Why this course ?

Accurate quality analysis of edible fruit commodities warrants stringent measurement protocols besides requisite instruments/ tools and laboratory facilities. Consequently, a specialised course is designed for imparting basic and applied training on physical and biochemical assessment of the horticultural produce.

V. Aim of the course

To familiarize with the laboratory techniques for analysis of fruit crops.

The organisation of the course is as under:-

No.	Blocks	Units
1	General Aspects	I Safety Measures and Laboratory Maintenance
2	Qualitative and Quantitative Analysis	I Destructive and Non-destructive Analysis Methods II Chromatographic and microscopic Analysis III Sensory Analysis

VI. Theory

Block 1: General Aspects

Unit 1: Safety Measures and Laboratory Maintenance: Safety aspects and upkeep of laboratory, sampling procedures for quantitative analysis, determination of proximate composition of horticultural produce. Standard solutions, determination of relative water content (RWC), physiological loss in weight (PLW), calibration and standardization of instruments, textural properties of harvested produce, TSS, Specific gravity, pH and acidity.

Block 2: Qualitative and Quantitative Analysis

Unit I: Destructive and Non-destructive Analysis Methods: Refractometry, spectrophotometry, non-destructive determination of colour, ascorbic acid, sugars, and starch in food crops.

Unit II: Chromatographic and Microscopic Analysis: Basic chromatographic techniques, GC, HPLC, GCMS, Electrophoresis techniques, ultra filtration. Application of nuclear techniques in harvested produce. Advanced microscopic techniques, ion leakage as an index of membrane permeability, determination of biochemical components in horticultural produce.

Unit III: Sensory Analysis: Importance of ethylene, quantitative estimation of rate of ethylene evolution, using gas chromatograph (GC). Sensory analysis techniques, control of test rooms, products and panel.

VII. Practical

- Determination of moisture, relative water content and physiological loss in weight (2)
- Determination of biochemical components in horticultural produce (3);
- Calibration and standardization of instruments (1);
- Textural properties of harvested produce (1);
- Determination of starch index (SI) (1);
- Specific gravity for determination of maturity assessment, and pH of produce (1)
- Detection of adulterations in fresh as well as processed products (2)
- Non-destructive determination of colour, ascorbic acid, vitamins, carotenoids, sugars and starch (2)
- Estimation of rate of ethylene evolution using gas chromatograph (GC) (2)
- Use of advanced microscopes (fluorescent, scanning electron microscope, phase contrast, etc.) (2)

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The students would be expected to develop skills and expertise on:

- Upkeep of laboratories and handling of research instruments
- Principles and methods of various analysis

X. Suggested Reading

AOAC International. 2003. *Official Methods of Analysis of AOAC International*. 17th Ed. Gaithersburg, MD, USA, Association of Analytical Communities, USA.
Clifton M and Pomeranz Y. 1988. *Food Analysis-Laboratory Experiments*. AVI Publication, USA.
Leo ML. 2004. *Handbook of Food Analysis*. 2nd Ed. Vols. I-III, USA.
Linskens HF and Jackson JF. 1995. *Fruit Analysis*. Springer.
Pomrenz Y and Meloan CE. 1996. *Food Analysis – Theory and Practice*. CBS, USA.
Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. 2nd Ed. Tata-McGraw-Hill, New Delhi.
Thompson AK. 1995. *Post Harvest Technology of Fruits and Vegetables*. Blackwell Sciences. USA.

I. Course Title : Arid and Dryland Fruit Production

II. Course Code : FSC 605

III. Credit Hours : (2+0)

IV. Why this course ?

Arid and dryland regions are known for growing an array of delicious and nutritious fruits (e.g. date palm, aonla, ber etc). Over the years, notable progress has been made in respect of domestication and technological advancements. Thus a course has been developed.

V. Aim of the course

To keep abreast with latest developments and trends in production technology of arid and dryland fruit crops.

The course is organised as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Current Scenario
2	Advanced Technologies	Propagation, Planting Systems and Crop Regulation
3	Management Practices	Stress Mitigation and Integrated Approaches

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Current Scenario: Characteristics features and major constraints of the arid and dryland region, distinguishing features of the fruit species trees for adaptation in adapting to the region, nutritional and pharmaceutical importance, national problems.

Block 2: Advanced Technologies

Unit I: Propagation, Planting Systems and Crop Regulation: Recent advances in propagation – root stocks, planting systems, High density planting, crop modelling, Precision farming, decision support systems – aspects of crop regulation- physical and chemical regulation, effects on physiology and development, influence of stress factors.

Block 3: Management Practices

Unit I: Stress Mitigation and Integrated Approaches: Strategies to overcome stress effects, integrated and modern approaches in water and nutrient management, total quality management (TQM) – Current topics.

Crops

Aonla, Annonas, ber, bael, jamun, date palm, cactus pear, khejri, kair, pilu, lasoda, manila, tamarind, monkey jack, mahua, khirni, amra, seabuckthorn, chilgoza, cafel, rhododendron, box myrtle, chironji, phalsa, karonda,woodapple, paniala and other minor fruits of regional importance

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

Consequent upon successful completion of the course, the students are expected to learnt about

- Fruit crops adopting to arid and drylands and their features
- Specific cultivation and management practices

IX. Suggested Reading

Hiwale S. 2015. *Sustainable Horticulture in Semiarid Drylands*. Springer.

Krishna H and Sharma RR. 2017. *Fruit Production – Minor Fruits*.Daya Publishing House, Delhi.

More T A, Singh RS, Bhargava R and Sharma BD. 2012. *Arid Horticulture for Nutrition and Livelihood*. Agrotech Publishing Academy, Udaipur (Rajasthan).

Pareek OP, Sharma S and Arora RK. 2007. *Underutilised Edible Fruits and Nuts,* IPGRI, Rome.

Peter K.V. 2010. *Underutilized and Underexploited Horticultural Crops*. NIPA, New Delhi.

Saroj PL, Dhandar DG and Vashishta BB. 2004. *Advances in Arid Horticulture*, Vol.-1 *Present Status*. IBDC, Lucknow.

Saroj P L and Awasthi OP. 2005. *Advances in Arid Horticulture*, Vol: II: *Production Technology of Arid and Semiarid Fruits*. IBDC, Lucknow.

Sontakke MB. 2014. *Production and Management of Fruit crops in Arid/ Drylands*. Agrotech Publishing Academy, Udaipur (Rajasthan).

I. Course Title : Abiotic Stress Management in Fruit Crops

II. Course Code : FSC 606

III. Credit Hours : (2+1)

IV. Why this course ?

Low soil fertility coupled with unpredictable and unfavourable environments often result in stress conditions. Non-availability of optimum level of inputs and congenial weather necessitates the development of suitable management practices to overcome various abiotic stresses. Hence a course is customized.

V. Aim of the course

To updates knowledge on recent trends in management of abiotic stresses in fruit crops.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	Basic Aspects and Principles
2	Stress Impact	Assessment, Physiology and Performance
3	Stress Management	Mitigation Measures and Conservation Practices

VI. Theory

Block 1: Introduction

Unit I: Basic Aspects and Principles: Stress – definition, classification, stresses due to water (high and low), temperature (high and low), radiation, wind, soil conditions (salinity, alkalinity, ion toxicity, fertilizer toxicity, etc.). Pollution – increased level of CO_2, industrial wastes, impact of stress in fruit crop production, stress indices, physiological and biochemical factors associated with stress, fruit crops suitable for different stress situations.

Block 2: Stress Impact

Unit I: Assessment, Physiology and Performance: Crop modeling for stress situations, cropping systems, assessing the stress through remote sensing, understanding adaptive features of crops for survival under stress, interaction among different stresses and their impact on crop growth and productivity.

Block 3: Stress Management

Unit I: Mitigation Measures and Conservation Practices: Greenhouse effect and methane emission and its relevance to abiotic stresses, use of anti transpirants and PGRs in stress management, mode of action and practical use, HSP inducers in stress management techniques of soil moisture conservation, mulching, hydrophilic polymers. Rain water harvesting, increasing water use efficiency, skimming technology, contingency planning to mitigate different stress situations, stability and sustainability indices.

VII. Practical

- Seed treatment/ hardening practices (2);
- Container seedling production (2);
- Analysis of soil moisture estimates (FC, ASM, PWP) (1);
- Analysis of plant stress factors, RWC, chlorophyll flourosence, chlorophyll stability index, ABA content, plant waxes, stomatal diffusive resistance, transpiration, photosynthetic rate, etc. under varied stress situations (5);
- Biological efficiencies, WUE, solar energy conversion and efficiency (2);
- Crop growth sustainability indices and economics of stress management (2);
- Visit to orchards and watershed locations (2);

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

XI. Learning outcome

On successful completion of the course, the students are expected to generate know-how on

- Various types of abiotic stresses and their effects
- Physiological processes underlying abiotic stresses
- Management and conservation practices to overcome stress

X. Suggested Reading

Blumm A. 1988. *Plant Breeding for Stress Environments*. CRC Publication, USA. Christiansen, MN and Lewis CF. 1982. *Breeding Plants for Less Favourable Environments*. Wiley International Science, USA.

Kanayama Y and Kochetor. 2015. *Abiotic Stress Biology in Horticultural Plants*. Springer.

Kramer PJ. 1980. *Drought Stress and the Origin of Adaptation*. In: *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons, USA.

Maloo SR. 2003. *Abiotic Stress and Crop Productivity*. Agrotech Publ. Academy, India.

Nickell LG. 1983. *Plant Growth Regulating Chemicals*. CRC Publication, USA.

Rao NKS, Shivashankar KS and Laxman RH. 2016. *Abiotic Stress Physiology of Horticultural Crops*. Springer.

Turner NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons, USA.

I. Course Title : Biodiversity and Conservation of Fruit Crops

II. Course Code : FSC 607

III. Credit Hours : (2+1)

IV. Why this course ?

The availability of pertinent gene pool is of utmost importance to mitigate adverse climate and to counter diseases and pests. In addition, specific gene sources (germplasm) would always be a necessity to develop superior genotypes. Considering the importance of conserving biodiversity in fruit crops for future use, the course has been designed.

V. Aim of the course

To understand the status and magnitude of biodiversity and strategies in germplasm conservation of fruit crops.

The course is organised as follows:-

No.	Blocks	Units
1	General Aspects	Issues, Goals and Current Status
2	Germplasm Conservation	Collection, Maintenance and Characterization
3	Regulatory Horticulture Intellectual Property Rights	Germplasm Exchange, Quarantine and

VI. Theory

Block 1: General Aspects

Unit I: Issues, Goals and Current Status: Biodiversity and conservation; issues and goals- needs and challenges; present status of gene centres; world's major centres of fruit crop domestication; current status of germplasm availability/ database of fruit crops in India.

Block 2: Germplasm Conservation

Unit I: Collection, Maintenance and Characterization: Exploration and collection of germplasm; sampling frequencies; size and forms of fruit and nut germplasm collections; active and base collections.Germplasm conservation- *in situ* and *ex situ* strategies, on farm conservation; problem of recalcitrancy- cold storage of scions, tissue culture, cryopreservation, pollen and seed storage.

Block 3: Regulatory Horticulture

Unit I: Germplasm Exchange, Quarantine and Intellectual Property Rights: Regulatory horticulture, inventory and exchange of fruit and nut germplasm, plant quarantine, phyto-sanitary certification, detection of genetic constitution of germplasm and maintenance of core collection. IPRs, Breeder's rights, Farmer's rights, PPV and FR Act.

GIS and documentation of local biodiversity, Geographical indications, GIS application in horticultural mapping and spatial analyses of field data; benefits of GI protection; GI tagged fruit varieties in India.

VII. Practical

- Documentation of germplasm- maintenance of passport data and other records of accessions (2);
- Field exploration trips and sampling procedures (2);
- Exercise on *ex situ* conservation – cold storage, pollen/ seed storage (2);
- Cryopreservation (2);
- Visits to National Gene Bank and other centers of PGR activities (2);
- Detection of genetic constitution of germplasm (2);
- Germplasm characterization using a standardised DUS test protocol (2);
- Special tests with biochemical and molecular markers (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The student would be expected to learn about the significance of germplasm and various strategies to conserve it in the present context.

X. Suggested Reading

Dhillon BS, Tyagi RK, Lal A and Saxena S. 2004. *Plant Genetic Resource Management. – Horticultural Crops.*Narosa Publishing House, New Delhi.

Engles JM, Ramanath RV, Brown AHD and Jackson MT. 2002. *Managing Plant Genetic Resources,* CABI, Wallingford, UK.
Frankel OH and Hawkes JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press, USA.
Hancock J. 2012. *Plant Evolution and the Origin of Crops Species*. CAB International.
Jackson M, Ford-Lloyd B and Parry M. 2014. *Plant Genetic Resources and Climate Change.* CABI, Wallingford, UK.
Moore JN and Ballington Jr, JR. 1991. *Genetic Resources of Temperate Fruit and Nut Crops.* ISHS, Belgium.
Peter KV. 2008. *Biodiversity of Horticultural Crops*. Vol. II. Daya Publ. House, Delhi.
Peter KV. 2011. *Biodiversity in HorticulturalCrops*.Vol.III. Daya Publ. House, Delhi.
Rana JC and Verma VD. 2011. *Genetic Resources of Temperate Minor Fruits (Indigenous and Exotic).* NBPGR, New Delhi.
Rajasekharan PE, Rao V and Ramanatha V. 2019. *Conservation and Utilization of Horticultural Genetic Resources*. Springer.
Sthapit B, *et al*. 2016. *Tropical Fruit Tree Diversity (Good Practices for in situ and ex situ conservation*). Bioversity International. Routledge, Taylor and Francis Group.
Virchow D. 2012. *Conservation of Genetic Resources*, Springer Verlag, Berlin.

I. Course Title : Smart Fruit Production

II. Course Code : FSC 608

III. Credit Hours : (2+0)

IV. Why this course ?

In the era of automation and mechanization, several recent innovations have direct applications in fruit growing. Thus a need is felt to have course on smart innovations.

V. Aim of the course

To acquire knowledge on hi-tech innovations useful in fruit crops.

The course is structure is as under:

No.	Blocks	Units
1	Introduction	Importance and Overview
2	Crop Modelling and Forecasting	GIS, Sensors and Wireless System
3	Nanotechnology	Concepts and Methods
4	Innovative Approaches	Mechanization, Automation and Robotics

VI. Theory

Block 1: Introduction

Unit I: Importance and Overview: Introduction and importance; concepts and applications of artificial intelligence systems; case studies in horticulture

Block 2: Crop Modelling and Forecasting

Unit I: GIS, Sensors and Wireless Systems: Application of sensors in fruit production, crop monitoring – crop load and stress incidence forecast modules, remote sensing, Geographical Information System (GIS), Differential Geo-Positioning System (DGPS) hi-tech nursery production of fruit crops under protected conditions, ultra modern wireless based drip irrigation network.

Block 3: Nanotechnology

Unit I: Concepts and Methods: Nanotechnology for smart nutrient delivery in fruit farming, concepts and methods, practical utility, nano-fertilizers, nano-herbicides; nano-pesticides

Block 4: Innovative Approaches

Unit I: Mechanization, Automation and Robotics: Production systems amenable to automation and mechanization; automated protected structures (turn-key systems); hydroponics, aeroponics, bioreactors for large scale plant multiplication; Use of drones and robotics in fruit growing – robotic planters, sprayers, shakers, harvesters, stackers, etc. Visit to Hi-tech facilities.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After successful completion of the course, the students are expected to learn about latest innovations in automation, nanotechnology and robotics for realising smart fruit production.

IX. Suggested Reading

Chadha *et al.* 2017. *Doubling Farmers Incomes through Horticulture*. Daya Publishing House, New Delhi.

Chadha *et al.* 2019.*Shaping the Future of Horticulture*. Kruger Brentt Publishers, UK.

Hewett EW. 2013. *Automation, Mechanization and Robotics in Horticulture. In:* Workshop on Emerging Postharvest Technologies. UC, Davis, USA.

Peter KV. 2016. *Innovations in Horticulture*. NIPA, New Delhi.

Prasad S, Singh D and Bhardwaj RL. 2012. *Hi-Tech Horticulture.*Agrobios (India).

Tyagi, S. 2019. *Hi- Tech Horticulture*. Vols. 1 to 7. NIPA, New Delhi.

Zhang Q. 2017. *Automation in Tree Fruit production – Principles and Practice*. CABI.

http://horticulture.ucdavis.edu- Innovative Technology for Horticultural Department.

Selected Journals

Sr. No.	Name of the Journal	ISSN No.
1.	*Advances in Horticultural Science*	0394-6169
2.	*Acta Horticulturae*	0567-7572
3.	*American Journal of Enology and Viticulture*	0002-9254
4.	*Annals of Arid Zone*	0570-1791
5.	*Annals of Horticulture*	0974-8784
6.	*Biodiversity and Conservation*	0960-3115
7.	*Current Horticulture*	2347-7377
8.	*European Journal of Horticultural Science (Gartenbauwissenschaft)*	1611-4426
9.	*Fruits*	0248-1294
10.	*Genetic Resources and Crop Evolution*	0925-9864
11.	*Horticultural Plant Journal*	2488-0141
12.	*Horticulture Environment and Biotechnology*	2211-3452
13.	*HortScience*	0018-5345
14.	*Indian Horticulture Journal*	2249-6823
15.	*Indian Journal of Arid Horticulture*	Naas-1234
16.	*Indian Journal of Dryland Agricultural Research and Development*	0971-2062

Sr. No.	Name of the Journal	ISSN No.
17.	*Indian Journal of Horticulture*	0972-8538
18.	*International Journal of Fruit Science*	1553-8621
19.	*International Journal of Horticulture*	1927-5803
20.	*International Journal of Innovative Horticulture*	2320-0286
21.	*Journal of Applied Horticulture*	0972-1045
22.	*Journal of Horticultural Research*	2300-5009
23.	*Journal of Horticultural Science and Biotechnology (Journal of Horticultural Science, England)*	1462-0316
24.	*Journal of Horticultural Sciences*	0973-354X
25.	*Journal of Horticulture*	2376-0354
26.	*Journal of The American Society for Horticultural Science*	0003-1062
27.	*Journal of Tree Fruit Production*	1055-1387
28.	*New Zealand Journal of Crop and Horticultural Science*	0114-0671
29.	*Progressive Horticulture*	0970-3020
30.	*Scientia Horticulturae*	0304-4238
31.	*The Asian Journal of Horticulture*	0973-4767
32.	*The Journal of American Pomological Society*	1527-3741

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Vegetable Science

Preamble

(Vegetable Science)

Vegetables are important constituents of Indian diet and play an important role ensuring nutritional security. They are generally of short duration, high yielding, nutraceuitically rich, economically viable and generating substancial on-farm and off-farm employment. Vegetables have aprestine place in Indian agricultural economy. The country is being blessed with diverse agro-climatic conditions ranged from the tempearate to arid more than 60 cultivated and 30 lesser known vegetables are being grown.

The country has witnessed a tremendous growth in vegetable production and productivity as a result of improved varieties/ F1 hybrids/ technologies through systematic research coupled with their large scale adoption by the farmers and developmental policies of government compared to area (2.84 m ha), production (16.5 mt) and productivity (5.8 t/ha) in 1950–51 there had been phenomenal increase in area (>3 folds; 10.1 m ha), production (>10 folds; 185 mt) and productivity (>3 folds; 18.0 t/ha) during 2017–18. Increasing per capita income, health conciousness, urbanisation, shifting of farmers to high value vegetables due to higher income, favourable income elasticity of demand and annual growth rate of domestic demand for vegetables are also important factors fueling its growth in the country.

During 2016–17, the total exports including potato and onion accounted for ₹ 5,922 crores sharing 35% of total horticultural exports. With the current level of vegetable production in the country (171 mt), population (1.3 billion) and considering 25% post harvest losses and 5% export and processing, the per capita availability of vegetable production in our country is 250 g as against 300 g recommended dietary allowance (RDA). With projected population of 1.45 billion by 2030, India has to produce 210 mt of vegetables. The targeted production needs to be achieved through utilizing scientific technological and traditional strength in a sustainable manner without much increasing area under vegetables.

Looking in to the above scenario in vegetable production, there is a need to update the knowledge among the post-graduates of Vegetable Science. An effort is therefore made to encompass the adavances made in the vegetable production by revisting the post-graduate curriculum for delivering and assuring quality education. The proposed curriculum aims to develop a competent human resource equipped with holistic and updated knowledge and skill in the field of Vegetable Science.

The course curriculum has been restructured to cover the current requirement of vegetable production and post harvest management to increase capabilities of students. In order to accomplish the task, either new courses have been formulated or existing course contents are upgraded to include latest developments in vegetables production.

In line with national policies, the existing course contents have been upgraded and five new courses, viz., Principles of vegetable breeding, Breeding for special triats in Vegetable crops, Biodiversity and conservation of Vegetable crops, Biotechnological approaches in Vegetable crops and Advanced laboratotory techniques for vegetable crops have been added. A course on Vegetable Breeding has been divided into two courses one for self-pollinated crops and another for cross pollinated vegetable crops. New components, viz., hydroponics, aeroponics, grafting technique and precision farming have been added in appropriate courses. The overall upgradation of course contents as well as addition of courses are in line with national policy priorities like doubling of farmer's income, more crop per drop, jaivik krishi, soil health, skill development, entrepreneurship development, startup initiatives, etc.

Course Title with Credit Load
M.Sc. (Hort.) in Vegetable Science

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
VSC 501*	Production of Cool Season Vegetable Crops	2+1
VSC 502*	Production of Warm Season Vegetable Crops	2+1
VSC 503*	Growth and Development of Vegetable Crops	2+1
VSC 504*	Principles of Vegetable Breeding	3+0
VSC 505	Breeding of Self Pollinated Vegetable Crops	2+1
VSC 506	Breeding of Cross Pollinated Vegetable Crops	2+1
VSC 507	Protected Cultivation of Vegetable Crops	1+1
VSC 508	Seed Production of Vegetable Crops	2+1
VSC 509	Production of Underutilized Vegetable Crops	2+1
VSC 510	Systematics of Vegetable Crops	1+1
VSC 511	Organic Vegetable Production	1+1
VSC 512	Production of Spice Crops	2+1
VSC 513	Processing of Vegetable	1+1
VSC 514	Postharvest Management of Vegetable Crops	2+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
VSC 591	Seminar	0+1
VSC 599	Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Vegetable Science

I. Course Title : Production of Cool Season Vegetable Crops

II. Course Code : VSC 501

III. Credit Hours : (2+1)

IV. Why this course ?

Cool season vegetables are a major source of dietary fibres, minerals and vitamins. Some of these vegetables also contribute protein, fat and carbohydrate. Most of the leafy and root vegetables are rich in minerals, especially in micro-elements such as copper, manganese and zinc. Vegetables differ in their temperature requirement for proper growth and development. Most of the winter vegetable crops are cultivated in cool season when the monthly mean temperature does not exceed 21°C. Even in temperate climate, these vegetables are cultivated in spring summer in hilly tracks where the daytime temperature in summer is less than 21°C. The students of vegetable science need to have an understanding of production technology of important cool season vegetable crops and their management.

V. Aim of the course

To impart knowledge and skills on advancement in production technology of cool season vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of cool season vegetable crops	I Bulb and tuber crops II Cole crops III Root crops IV Peas and beans V Leafy vegetables

VI. Theory

Introduction, commercial and nutritional importance, origin and distribution, botany and taxonomy, area, production, productivity and constraints, soil requirements, climatic factors for yield and quality, commercial varieties/ hybrids, seed rate and seed treatment, raising of nursery, sowing/ planting time and methods,hrydroponics and aeroponics, precision farming, cropping system, nutritional including micronutrients and irrigation requirements, intercultural operations, special horticultural practices, weed control, mulching, role of plant growth regulators, physiological disorders, maturity indices, harvesting, yield, post-harvest management (grading, packaging and marketing), pest and disease management and production economics of crops.

Unit I

Bulb and tuber crops—Onion, garlic and potato.

Unit II

Cole crops—Cabbage, cauliflower, kohlrabi, broccoli, Brussels sprouts and kale.

Unit III

Root crops—Carrot, radish, turnip and beetroot.

Unit IV

Peas and beans—Garden peas and broad bean.

Unit V

Leafy vegetables—Beet leaf, fenugreek, coriander and lettuce.

VII. Practical

- Scientific raising of nursery and seed treatment;
- Sowing and transplanting;
- Description of commercial varieties and hybrids;
- Demonstration on methods of irrigation, fertilizers and micronutrients application;
- Mulching practices, weed management;
- Use of plant growth substances in cool season vegetable crops;
- Study of nutritional and physiological disorders;
- Studies on hydroponics, aeroponics and other soilless culture;
- Identification of important pest and diseases and their control;
- Preparation of cropping scheme for commercial farms;
- Visit to commercial farm, greenhouse/ polyhouses;
- Visit to vegetable market;
- Analysis of benefit to cost ratio.

VIII. Teaching Methods/ Activities

- Classroom lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of cool season vegetable crops in India
- Acquire knowledge about the production technology and post-harvest handling of cool season vegetable crops
- Calculate the economics of vegetable production in India

X. Suggested Reading

Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. *Vegetable crops*. Vols. I-III. Naya udyog.

Bose TK, Som MG and Kabir J. (Eds.). 1993. *Vegetable crops*. Naya prokash.

Chadha KL and Kalloo G. (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra publ. house.

Chadha KL. (Ed.). 2002. *Hand book of horticulture*. ICAR.

Chauhan DVS. (Ed.). 1986. *Vegetable production in India*. Ram prasad and sons.

Fageria MS, Choudhary BR and Dhaka RS. 2000. *Vegetable crops: production technology*. Vol. II. Kalyani publishers.

Gopalakrishanan TR. 2007. *Vegetable crops*. New India publ. agency.

Hazra P and Banerjee MK and Chattopadhyay A. 2012. *Varieties of vegetable crops in India*, (Second edition), Kalyani publishers, Ludhiana, 199 p.
Hazra P. 2016. *Vegetable Science*. 2nd edn, Kalyani publishers, Ludhiana.
Hazra P. 2019. *Vegetable production and technology*. New India publishing agency, New Delhi.
Hazra P, Chattopadhyay A, Karmakar K and Dutta S. 2011. *Modern technology for vegetable production*, New India publishing agency, New Delhi, 413p
Rana MK. 2008. *Olericulture in India*. Kalyani publishers, New Delhi.
Rana MK. 2008. *Scientific cultivation of vegetables*. Kalyani publishers, New Delhi.
Rana MK. 2014. *Technology for vegetable production*. Kalyani publishers, New Delhi.
Rubatzky VE and Yamaguchi M. (Eds.). 1997. *World vegetables: principles, production and nutritive values*. Chapman and Hall.
Saini GS. 2001. *A text book of oleri and flori culture*. Aman publishing house.
Salunkhe DK and Kadam SS. (Ed.). 1998. Hand book of vegetable science and technology: production, composition, storage and processing. Marcel dekker.
Shanmugavelu KG. 1989. *Production technology of vegetable crops*. Oxford and IBH.
Singh DK. 2007. *Modern vegetable varieties and production technology*. International book distributing Co.
Singh SP. (Ed.). 1989. *Production technology of vegetable crops*. Agril. comm. res. centre.
Thamburaj S and Singh N. (Eds.), 2004. *Vegetables, tuber crops and spices*. ICAR.
Thompson HC and Kelly WC. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

I. Course Title : Production of Warm Season Vegetable Crops

II. Course Code : VSC 502

III. Credit Hours : (2+1)

IV. Why this course ?

Unlike cool-season vegetables, warm-season vegetable crops require higher soil and air temperature, thus, they are always planted after the last frost date ranging from late spring after the last frost date to late summer. Daytime temperature may still be warm enough but drop so much at night-time that the weather is not suitable for warm-season crops any longer. In general summer vegetables require a little higher temperature than winter vegetables for optimum growth. In summer vegetables, the edible portion is mostly botanical fruit. The students of vegetable science need to have an understanding of production technology of important warm season vegetable crops and thereafter their management.

V. Aim of the course

To impart knowledge and skills on advancement in production technology of warm season vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of warm season vegetable crops	1. Fruit vegetables 2. Beans 3. Cucurbits 4. Tuber crops 5. Leafy vegetables

VI. Theory

Introduction, commercial and nutritional importance, origin and distribution, botany and taxonomy, area, production, productivity and constraints, soil requirements, climatic factors for yield and quality, commercial varieties/ hybrids, seed rate and seed treatment, raising of nursery including grafting technique, sowing/ planting time and methods, precision farming, cropping system, nutritional including micronutrients and irrigation requirements, intercultural operations, special horticultural practices namely hydroponics, aeroponics, weed control, mulching, role of plant growth regulators, physiological disorders, maturity indices, harvesting, yield, post-harvest management (grading, packaging and marking), pest and disease management and economics of crops.

Unit I

Fruit vegetables—Tomato, brinjal, hot pepper, sweet pepper and okra.

Unit II

Beans—French bean, Indian bean (Sem), cluster bean and cowpea.

Unit III

Cucurbits—Cucumber, melons, gourds, pumpkin and squashes.

Unit IV

Tuber crops—Sweet potato, elephant foot yam, tapioca, taro and yam.

Unit V

Leafy vegetables—Amaranth and drumstick.

VII. Practical

- Scientific raising of nursery and seed treatment;
- Sowing, transplanting, vegetable grafting;
- Description of commercial varieties and hybrids;
- Demonstration on methods of irrigation, fertilizers and micronutrients application;
- Mulching practices, weed management;
- Use of plant growth substances in warm season vegetable crops;
- Study of nutritional and physiological disorders;
- Studies on hydroponics, aeroponics and other soilless culture;
- Identification of important pest and diseases and their control;
- Preparation of cropping scheme for commercial farms;
- Visit to commercial farm, greenhouse/ polyhouses;
- Visit to vegetable market;
- Analysis of benefit to cost ratio.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of warm season vegetable crops in India
- Acquire knowledge about the production technology and post-harvest handling of warm season vegetable crops
- Calculate the economics of vegetable production in India

Suggested Reading

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Thompson HC and Kelly WC. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

I. Course Title : Growth and Development of Vegetable Crops
II. Course Code : VSC 503
III. Credit Hours : (2+1)

IV. Why this course ?

In agriculture, the term plant growth and development is often substituted with crop growth and yield since agriculture is mainly concerned with crops and their economic products. Growth, which is irreversible quantitative increase in size, mass, and/ or volume of a plant or its parts, occurs with an expenditure of metabolic energy. Plant development is an overall term, which refers to various changes that occur during its life cycle. In vegetable crops, development is a series of processes from the initiation of growth to death of a plant or its parts. Growth and development are sometimes used interchangeably in conversation, but in a botanical sense, they describe separate events in the organization of the mature plant body. The students of vegetable science need to have an understanding of growth and development of vegetable crops.

V. Aim of the course

To teach the physiology of growth and development of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Growth and development of vegetable crops	1. Introduction and phytohormones 2. Physiology of dormancy and germination 3. Abiotic factors 4. Fruit physiology 5. Morphogenesis and tissue culture

VI. Theory

Unit I

Introduction and phytohormones—Definition of growth and development; Cellular structures and their functions; Physiology of phyto-hormones functioning/ biosynthesis and mode of action; Growth analysis and its importance in vegetable production.

Unit II

Physiology of dormancy and germination—Physiology of dormancy and germination of vegetable seeds, tubers and bulbs; Role of auxins, gibberellilns, cyktokinins and abscissic acid; Application of synthetic PGRs including plant growth retardants and inhibitors for various purposes in vegetable crops; Role and mode of action of morphactins, antitranspirants, anti-auxin, ripening retardant and plant stimulants in vegetable crop production.

Unit III

Abiotic factors—Impact of light, temperature, photoperiod, carbon dioxide, oxygen and other gases on growth, development of underground parts, flowering and sex expression in vegetable crops; Apical dominance.

Unit IV

Fruit physiology—Physiology of fruit set, fruit development, fruit growth, flower and fruit drop; parthenocarpy in vegetable crops; phototropism, ethylene inhibitors, senescence and abscission; fruit ripening and physiological changes associated with ripening.

Unit V

Morphogenesis and tissue culture—Morphogenesis and tissue culture techniques in vegetable crops; Grafting techniques in different vegetable crops.

VII. Practical

- Preparation of plant growth regulator's solutions and their application;
- Experiments in breaking and induction of dormancy by chemicals;
- Induction of parthenocarpy and fruit ripening;
- Application of plant growth substances for improving flower initiation, changing sex expression in cucurbits and checking flower and fruit drops and improving fruit set in solanaceous vegetables;
- Growth analysis techniques in vegetable crops;
- Grafting techniques in tomato, brinjal, cucumber and sweet pepper.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)

- Student presentation
- Hands on training of different procedure
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge about the growth and development of plants in vegetable crops
- Distinguish between primary and secondary growth in plant stems
- Understand how hormones affect the growth and development of vegetable crops

X. Suggested Reading

Bleasdale JKA. 1984. *Plant physiology in relation to horticulture* (2^{nd} Edition) MacMillan.

Gupta US. Eds. 1978. *Crop physiology*. Oxford and IBH, New Delhi.

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Krishnamoorti HN. 1981. *Application growth substances and their uses in agriculture*. Tata McGraw Hill, New Delhi.

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Rana MK. 2011. *Physio-biochemistry and Biotechnology of Vegetables*. New India Publishing Agency, Pritam Pura, New Delhi.

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Wien HC. (Eds.). 1997. *The physiology of vegetable crops*. CAB International.

I. Course Title : Principles of Vegetable Breeding

II. Course Code : VSC 504

III. Credit Hours : (2+1)

IV. Why this course ?

Plant breeding has been practiced for thousands of years, since beginning of human civilization. Vegetable breeding, which is an art and science of changing the traits of plants in order to produce desired traits, has been used to improve the quality of nutrition in products for human beings. A breeding programme, which is needed if current varieties are not producing up to the capacity of the environment, can be accomplished through many different techniques ranging from simply selecting plants with desirable characteristics, make use of knowledge of genetics and chromosomes to more complex molecular techniques. When different genotypes exhibit differential responses to different sets of environmental conditions, a genotype x environment (GxE) interaction is said to occur. Breeding high yielding open pollinated varieties and hybrids, and exploitation of location specific component of genotypic performance are the only options left to reduce this increasing gap between the production and requirements in view of decreasing land resources. Noevertheless, vegetable breeding is an integral part of plant breeding but this will be re-modeled to suit to breeding of different vegetables crops. The students of vegetable science who are having breeding as major subject need to have an understanding of vegetable breeding principles.

V. Aim of the course

To teach basic principles and practices of vegetable breeding

The course is constructed given as under:

No.	Block	Unit
1.	Principles of vegetable breeding	I. Importance and history II. Selection procedures III. Heterosis breeding IV. Mutation breeding V. Polyploid breeding VI. Ideotype breeding

VI. Theory

Unit I

Importance and history- Importance, history and evolutionary aspects of vegetable breeding and its variation from cereal crop breeding.

Unit II

Selection procedures- Techniques of selfing and crossing; Breeding systems and methods; Selection procedures and hybridization; Genetic architecture; Breeding for biotic stress (diseases, insect pests and nematode), abiotic stress (temperature, moisture and salt) resistance and quality improvement; Breeding for water use efficiency (WUE) and nutrients use efficiency (NUE).

Unit III

Heterosis breeding- Types, mechanisms and basis of heterosis, facilitating mechanisms like male sterility, self-incompatibility and sex forms.

Unit IV

Mutation and Polyploidy breeding; Improvement of asexually propagated vegetable crops and vegetables suitable for protected environment.

Unit V

Ideotype breeding- Ideotype breeding; varietal release procedure; DUS testing in vegetable crops; Application of *In-vitro* and molecular techniques in vegetable improvement.

VII. Practical

- Floral biology and pollination behaviour of different vegetables;
- Techniques of selfing and crossing of different vegetables, viz., Cole crops, okra, cucurbits, tomato, eggplant, hot pepper, etc.;
- Breeding system and handling of filial generations of different vegetables;
- Exposure to biotechnological lab practices;
- Visit to breeding farms.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:
- Acquire knowledge about the principles of vegetable breeding
- Improve yield, quality, abiotic and biotic resistance, other important traits of vegetable crops
- Understand how the basic principles are important to start breeding of vegetable crops

X. Suggested Reading

Allard RW. 1960. *Principle of plant breeding*. John Willey and Sons, USA.
Kalloo G. 1988. *Vegetable breeding* (Vol. I, II, III). CRC Press, Fl, USA.
Kole CR. 2007. *Genome mapping and molecular breeding in plants-vegetables*. Springer, USA.
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Prohens J and Nuez F. 2007. *Handbook of plant breeding-vegetables* (Vol I and II). Springer, USA.
Singh BD. 2007. *Plant breeding- principles and methods* (8th edn.). Kalyani Publishers, New Delhi.
Singh Ram J. 2007. *Genetic resources, chromosome engineering, and crop improvement-vegetable crops* (Vol. 3). CRC Press, Fl, USA.

I. Course Title : Breeding of Self Pollinated Vegetable Crops
II. Course Code : VSC 505
III. Credit Hours : (2+1)

IV. Why this course ?

Self-pollination, which is considered the highest degree of inbreeding a plant can achieve, promotes homozygosity of all gene loci and traits of the sporophyte and restricts the creation of new gene combinations (no introgression of new genes through hybridization). The progeny of a single plant is homogeneous due to self pollination. A population of self-pollinated species comprises a mixture of homozygous lines. New genes may arise through mutation but such change is restricted to individual lines or the progenies of the mutant plant. Since a self-pollinated cultivar is generally one single genotype reproducing itself, breeding of self-pollinated species usually entails identifying one superior genotype (or a few) and its multiplication. Specific breeding methods commonly used for self-pollinated species are pure-line selection, pedigree breeding, bulk populations and backcross breeding. The students of vegetable science who take breeding as a minor subject need to have an understanding of breeding of self pollinated vegetable crops.

V. Aim of the course

To impart comprehensive knowledge about principles and practices of breeding of self pollinated vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Breeding of self pollinated vegetable crops	I. Potato II. Fruit vegetables III. Garden peas and cowpea IV. Beans V. Leafy vegetables

VI. Theory

Origin, botany, taxonomy, wild relatives, cytogenetics and genetics, types of pollination and fertilization mechanism, sterility, breeding objectives, breeding methods (introduction, selection, hybridization, mutation and polyploidy), varieties and varietal characterization, resistance breeding for biotic and abiotic stresses, breeding for protected environment and quality improvement, molecular markers and marker's assisted breeding; QTLs, PPV and FR Act.

Unit I

Tuber crops: Potato.

Unit II

Fruit vegetables- Tomato, eggplant, hot pepper, sweet pepper and okra.

Unit III

Leguminous vegetables- Garden peas and cowpea.

Unit IV

Leguminous vegetables: French bean, Indian bean, cluster bean and broad bean.

Unit V

Leafy vegetables- Lettuce and fenugreek.

VII. Practical

- Floral mechanisms favouring self and often cross pollination;
- Progeny testing and development of inbred lines;
- Selection of desirable plants from breeding population, observations and analysis of various qualitative and quantitative traits in germplasm, hybrids and segregating generations;
- Palynological studies, selfing and crossing techniques;
- Hybrid seed production of vegetable crops in bulk;
- Screening techniques for biotic and abiotic stress resistance in above mentioned crops;
- Molecular marker techniques to identify useful traits in the vegetable crops and special breeding techniques;
- Visit to breeding farms;

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge about the breeding of self pollinated vegetable crops
- Improve yield, quality, abiotic and biotic resistance and other important traits of vegetable crops
- Understand how to start the breeding of self pollinated vegetable crops

X. Suggested Reading

Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.

Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.
Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005, Plant genetic resources: horticultural crops. Narosa Publ. House.
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Peter KV and Hazra P (Eds). 2015. *Hand book of vegetables* Volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509 p.
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Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Breeding of Cross Pollinated Vegetable Crops
II. Course Code : VSC 506
III. Credit Hours : (2+1)

IV. Why this course ?

The important methods of breeding in cross-pollinated vegetable species are (i) mass selection, (ii) development of hybrid varieties and (ii) development of synthetic varieties. Since cross-pollinated vegetable crops are naturally hybrid (heterozygous) for many traits and lose vigour as they become purebred (homozygous), a goal of each of these breeding methods is to preserve or restore heterozygosity in cross pollinated vegetable crops. The students of vegetable science who take breeding as a minor subject need to have an understanding of breeding of cross pollinated vegetable crops.

V. Aim of the course

To impart comprehensive knowledge about principles and practices of cross pollinated vegetable crops breeding.

The course is constructed given as under:

No.	Block	Unit
1.	Breeding of cross pollinated vegetable crops	I. Cucurbitaceous crops II. Cole crops III. Root and bulb crops IV. Tuber crops V. Leafy vegetables

VI. Theory

Origin, botany, taxonomy, cytogenetics, genetics, types of pollination and fertilization, mechanism, sterility and incompatibility, breeding objectives, breeding methods (introduction, selection, hybridization, mutation, polyploidy), varieties and varietal characterization, resistance breeding for biotic and abiotic stresses, quality improvement, molecular markers and marker assisted breeding, and QTLs, PPV and FR act

Unit I

Cucurbitaceous crops—Gourds, melons, cucumber, pumpkin and squashes.

Unit II

Cole crops—Cauliflower, cabbage, kohlrabi, broccoli and brussels sprouts.

Unit III

Root and bulb crops—Carrot, radish, turnip, beet root and onion.

Unit IV

Tuber crops—Sweet potato, tapioca, taro and yam.

Unit V

Leafy vegetables—Beet leaf, spinach, amaranth and coriander.

VII. Practical

- Floral mechanisms favouring cross pollination;
- Development of inbred lines;
- Selection of desirable plants from breeding population;
- Observations and analysis of various quantitative and qualitative traits in germplasm, hybrids and segregating generations;
- Induction of flowering, palynological studies, selfing and crossing techniques;
- Hybrid seed production of vegetable crops in bulk; Screening techniques for biotic and abiotic stress resistance in above mentioned crops;
- Demonstration of sib-mating and mixed population;
- Molecular marker techniques to identify useful traits in vegetable crops and special breeding techniques;
- Visit to breeding blocks.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation individual or in group
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge about the breeding of cross pollinated vegetable crops
- Improve yield, quality, abiotic and biotic resistance, and important traits of cross pollinated vegetable crops
- Understand how to start the breeding of cross pollinated vegetable crops

X. Suggested Reading

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Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa publ. house.

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Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.

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I. Course Title : Protected Cultivation of Vegetable CropS

II. Course Code : VSC 507

III. Credit Hours : (2+1)

IV. Why this course ?

India is the second largest producer of vegetable crops in the world. However, its vegetable production is much less than the requirement, if a balanced diet is provided to every individual. There are different ways and means to achieve this target. Protected cultivation, which is the modification of the natural environment to achieve optimum plant growth. Is the most intensive form of crop production with a yield per unit area up to ten times superior to that of a field crop. During winter under north-east Indian conditions, it is difficult to grow tomato, capsicum, cucurbits, french bean, amaranth, etc. in open field. However, various types of protected structure have been developed for growing some high value crops by providing protection from the excessive cold. Production of off-season vegetable nurseries under protected structure has become a profitable business. The main purpose of raising nursery plants in protected structure is to get higher profit and disease free seedlings in off-season to raise early crop in protected and open field condition. The low cost polyhouse is economical for small and marginal farmers, who cannot afford huge cost of high-tech polyhouse. Besides supplying the local markets, the production of polyhouse vegetables is greatly valued for its export potential and plays an important role in the foreign trade balance of several national economies. The students of vegetable science need to have an understanding of protected cultivation of vegetable crops.

V. Aim of the course

To impart latest knowledge about growing of vegetable crops under protected environmental conditions

The course is constructed given as under:

No.	Block	Unit
1.	Protected cultivation of vegetable crops	I. Scope and importance II. Types of protected structure III. Abiotic factors IV. Nursery raising V. Cultivation of crops VI. Solutions to problems

VI. Theory

Unit I

Scope and importance- Concept, scope and importance of protected cultivation of vegetable crops; Principles, design, orientation of structure, low and high cost polyhouses/ greenhouse structures.

Unit II

Types of protected structure- Classification and types of protected structures-greenhouse/ polyhouses, plastic-non plastic low tunnels, plastic walk in tunnels, high roof tunnels with ventilation, insect proof net houses, shed net houses, rain shelters, NVP, climate control greenhouses, hydroponics and aeroponics; Soil and soilless media for bed preparation; Design and installation of drip irrigation and fertigation system.

Unit III

Abiotic factors- Effect of environmental factors and manipulation of temperature, light, carbon dioxide, humidity, etc. on growth and yield of different vegetables.

Unit IV

Nursery raising- High tech vegetable nursery raising in protected structures using plugs and portrays, different media for growing nursery under protected cultivation; Nursery problems and management technologies including fertigation.

Unit V

Cultivation of crops- Regulation of flowering and fruiting in vegetable crops; Technology for raising tomato, sweet pepper, cucumber and other vegetables in protected structures, including varieties and hybrids, training, pruning and staking in growing vegetables under protected structures.

Unit VI

Solutions to problems- Problems of growing vegetables in protected structures and their remedies, physiological disorders, insect and disease management in protected structures; Use of protected structures for seed production; Economics of greenhouse crop production.

VII. Practical

- Study of various types of protected structure;
- Study of different methods to control temperature, carbon dioxide and light;
- Study of different types of growing media, training and pruning systems in greenhouse crops;
- Study of fertigation and nutrient management under protected structures;
- Study of insect pests and diseases in greenhouse and its control;
- Use of protected structures in hybrid seed production of vegetables;
- Economics of protected cultivation (Any one crop);
- Visit to established green/ polyhouses/ shade net houses in the region.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of protected cultivation of vegetable crops in India
- Acquire knowledge about the effect of abiotic factors on growth, flowering and production of vegetable crops
- Gaining knowledge about the designing of various low cost protected structures
- Adopting the raising of vegetable seedlings in low cost protected structures as entrepreneur

X. Suggested Reading

Chadha KL and Kalloo G. (Eds.). 1993-94. *Advances in horticulture*. Malhotra Pub. House.

Chandra S and Som V. 2000. *Cultivating vegetables in green house*. Indian horticulture 45:17-18.

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I. Course Title : Seed Production of Vegetable Crops
II. Course Code : VSC 508
III. Credit Hours : (2+1)

IV. Why this course ?

Enhancing yield and quality of vegetable crops depends upon a number of factors. The inputs like fertilizers, irrigation and plant protection measures and suitable agronomic practices contribute greatly towards improving yield and quality of the vegetable produce. If good quality seed is not used, the full benefits of such inputs and agronomic practices can not be realized. The use of high quality seed thus, plays a pivotal role in the production of vegetable crops. It is, therefore, important to use the seed conforming to the prescribed standards. A good quality seed should have high genetic and physical purity, proper moisture content and good germination. It should also be free from seed borne diseases and weed seeds. The quality of the produce will deteriorate if these factors are overlooked. Out crossing, physical admixtures and mutations are the prime factors responsible for the deterioration of seed quality. A variety could be saved from deterioration if proper checks are made at different stages of seed multiplication. It is also extremely important to maintain high genetic purity of a variety. The students of vegetable science need to have an understanding of seed production technology of vegetable crops and their essential processing before supplying them to the market or further use.

V. Aim of the course

To impart a comprehensive knowledge and skills on quality seed production of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Seed production of vegetable crops	I. Introduction, history, propagation and reproduction II. Agro-climate and methods of seed production III. Seed multiplication and its quality maintenance IV. Seed harvesting, extraction and its processing V. Improved agro-techniques and field and seed standards

VI. Theory

Unit I

Introduction, history, propagation and reproduction—Introduction, definition of seed and its quality, seed morphology, development and maturation; Apomixis and fertilization; Modes of propagation and reproductive behaviour; Pollination mechanisms and sex forms in vegetables; History of vegetable seed production; Status and share of vegetable seeds in seed industry

Unit II

Agro-climate and methods of seed production—Agro-climate and its influence on quality seed production; Deterioration of crop varieties, genetical and agronomic principles of vegetable seed production; Methods of seed production, hybrid seeds and techniques of large scale hybrid seed production; Seed village concept

Unit III

Seed multiplication and its quality maintenance—Seed multiplication ratios and replacement rates in vegetables; Generation system of seed multiplication; Maintenance and production of nucleus, breeder, foundation, certified/ truthful label seeds; Seed quality and mechanisms of genetic purity testing

Unit IV

Seed harvesting, extraction and its processing—Maturity standards; Seed harvesting, curing and extraction; Seed processing, viz., cleaning, drying and treatment of seeds, seed health and quality enhancement, packaging and marketing; Principles of seed storage; Orthodox and recalcitrant seeds; Seed dormancy

Unit V

Improved agro-techniques and field and seed standards—Improved agro-techniques; Field and seed standards in important solanaceous, leguminous and cucurbitaceous vegetables, cole crops, leafy vegetables, bulbous and root crops and okra; clonal propagation and multiplication in vegetative propagated crops; Seed plot technique and true potato seed production in potato

VII. Practical

- Study of floral biology and pollination mechanisms in vegetables;
- Determination of modes of pollination;
- Field and seed standards;
- Use of pollination control mechanisms in hybrid seed production of important vegetables;
- Maturity standards and seed extraction methods;
- Seed sampling and testing;
- Visit to commercial seed production areas;
- Visit to seed processing plant;
- Visit to seed testing laboratories.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of seed production of vegetable crops in India
- Acquire knowledge about the complete seed production technology, extraction and post-extraction processing of vegetable seeds
- Adoption of seed production of vegetable crops as entrepreneur

X. Suggested Reading

Agarwaal PK and Anuradha V. 2018. *Fundamentals of seed science and technology*. Brilliant publications, New Delhi.

Agrawal PK and Dadlani M. (Eds.). 1992. *Techniques in seed science and technology*. South asian Publ.

Agrawal RL. (Ed.). 1997. *Seed technology*. Oxford and IBH.

Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.

Bench ALR and Sanchez RA. 2004. *Handbook of seed physiology*. Food products press, NY/ London.

Bendell PE. (Eds.). 1998. *Seed science and technology: Indian forestry species*. Allied Publ.

Chakraborty SK, Prakash S, Sharma SP and Dadlani M. 2002. *Testing of distinctiveness, uniformity and stability for plant variety protection*. IARI, New Delhi

Copland LO and McDonald MB. 2004. *Seed science and technology*, Kluwer Academic Press.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: breeding and seed production*. Vol. I. Kalyani Publishers, New Delhi.

George RAT. 1999. *Vegetable seed production* (2nd Edition). CAB International.

Kalloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated publishing company, New Delhi.

Hazra P and Som HG. 2015. *Seed production and hybrid technology of vegetable crops*. Kalyani publishers, Ludhiana.

Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro botanical publ.

More TA, Kale PB and Khule BW. 1996. *Vegetable seed production technology*. Maharashtra state seed corp.

Rajan S and Markose BL. 2007. *Propagation of horticultural crops*. New India publ. agency.

Singh NP, Singh DK, Singh YK and Kumar V. 2006. *Vegetable seed production technology*. International book distributing Co.

Singh SP. 2001. *Seed production of commercial vegetables*. Agrotech publ. academy.

Singhal NC. 2003. *Hybrid seed production*. Kalyani publishers, New Delhi

I. Course Title : Production of Underutilized Vegetable Crops

II. Course Code : VSC 509

III. Credit Hours : (2+1)

IV. Why this course ?

With increasing population and fast depletion of natural resources, it has become essential to explore the possibilities of using newer indigenous plant resources. Underutilized crops are plant species that are used traditionally by the country people for their food, fibre, fodder, oil, or medicinal properties but have yet to be adopted by large scale agriculturalists. In general, underutilized plants constitute those plant species that occur as life support species in extreme environmental conditions and threatened habitats, having genetic tolerance to survive under harsh conditions and possess qualities of nutritional and/ or industrial importance for a variety of purposes. Underutilized crops are those plant species with under-exploited potential for contributing to food security, health (nutritional or medicinal), income generation and environmental services. Once the underutilized food crops are properly utilized, they may help to contribute in food security, nutrition, health, income generation and environmental services. The underutilized crops can be defined as the crops, which being region specific are less available, less utilized or rarely used. These underutilized crop species have also been described as *rare*, *minor*, *orphan*, *promising* and little-used vegetable crops. The students of vegetable science need to have an understanding of production technology of underutilized vegetable crops.

V. Aim of the course

To impart knowledge about production technology of lesser utilized vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of underutilized vegetable crops	I. Stem and bulb crops II. Cole and salad crops III. Gourds and melons IV. Leafy vegetables V. Yams and beans

VI. Theory

Importance and scope, botany and taxonomy, climate and soil requirement, commercial varieties/ hybrids, improved cultural practices, physiological disorders, harvesting and yield, plant protection measures and post harvest management of:

Unit I

Stem and bulb crops—Asparagus, leek and chinese chive

Unit II

Cole and salad crops—Red cabbage, chinese cabbage, kale, sweet corn and baby corn

Unit III

Leafy vegetables—Celery, parsley, indian spinach (poi), spinach, chenopods, chekurmanis and indigenous vegetables of regional importance

Unit IV

Gourds and melons—Sweet gourd, spine gourd, teasle gourd, round gourd, and little/ Ivy gourd, snake gourd, pointed gourd, kachri, long melon, snap melon and gherkin

Unit V

Yam and beans—Elephant foot yam, yam, yam bean, lima bean and winged bean

VII. Practical

- Identification and botanical description of plants and varieties;
- Seed/ planting material;
- Production, lay out and method of planting;
- Important cultural operations;
- Identification of important pests and diseases and their control;
- Maturity standards and harvesting;
- Visit to local farms.

Teaching Methods/ Activities

- Delivering of lectures by power point presentation
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of production of underutilized vegetable crops in India
- Acquire knowledge about the production technology of underutilized vegetable crops
- Adopting production of lesser utilised crops as entrepreneur

Suggested Reading

Bhat KL. 2001. *Minor vegetables-untapped potential*. Kalyani publishers, New Delhi.

Indira P and Peter KV. 1984. *Unexploited tropical vegetables*. Kerala agricultural university, Kerala.

Pandey AK. 2011. *Aquatic vegetables*. Agrotech publisher academy, New Delhi.

Peter KV. (Eds.). 2007-08. *Underutilized and underexploited horticultural crops*. Vol.1-4, New India publishing agency, Lucknow.

Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II and III. Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509 p.

Rana MK. 2018. *Vegetable crop science*. CRC Press Taylor and Francis Group 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742 ISBN: 978-1-1380-3521-8

Rubatzky VE and Yamaguchi M. 1997. *World vegetables: vegetable crops*. NBPGR, New Delhi.

I. Course Title : Systematics of Vegetable Crops

II. Course Code : VSC 510

III. Credit Hours : (1+1)

IV. Why this course ?

Systematics is fundamental to our understanding of the world around us as it provides basis for understanding the patterns of diversity on earth. Vegetable systematics is the science of botanical diversity of vegetable crops on earth, including variation from the level of genes within an individual to individuals, populations and species. The primary aim of systematics is to discover all the branches of the tree of life, document evolutionary changes occurring along those branches, and describe all the species on earth (the tips of the branches). The secondary aim of systematic is to analyze and synthesize information into a classification that reflects evolutionary relationships, to organize this information into a useful, retrievable form to gain insight into evolutionary processes that lead to diversity.

V. Aim of the course

To impart knowledge on morphological, cytological and molecular taxonomy of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Systematics of vegetable crops	I. Significance of systematics II. Origin and evolution III. Botanical and morphological description IV. Cytology V. Molecular markers

VI. Theory

Unit I

Significance of systematic—Significance of systematics and crop diversity in vegetable crops; Principles of classification; different methods of classification; Salient features of international code of nomenclature of vegetable crops

Unit II

Origin and evolution—Origin, history, evolution and distribution of vegetable crops

Unit III

Botanical and morphological description—Botanical description of families, genera and species covering various tropical, subtropical and temperate vegetables; Morphological keys to identify important families, floral biology, floral formula and diagram; Morphological description of all parts of vegetables

Unit IV

Cytology—Cytological level of various vegetable crops with descriptive keys

Unit V

Molecular markers—Importance of molecular markers in evolution of vegetable crops; Molecular markers as an aid in characterization and taxonomy of vegetable crops

VII. Practical

- Identification, description, classification and maintenance of vegetable species and varieties;
- Survey, collection of allied species and genera locally available;
- Preparation of keys to the species and varieties;
- Methods of preparation of herbarium and specimens.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge on identification, description, classification and maintenance of vegetable species and varieties
- Collecting locally available allied species of vegetable crops
- Preparing herbarium and specimens

X. Suggested Reading

Chopra GL. 1968. *Angiosperms- systematics and life cycle*. S. Nagin

Dutta AC. 1986. *A class book of botany*. Oxford Univ. Press.

Pandey BP. 1999. *Taxonomy of angiosperm*. S. Chand and Co

Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables*. (Revised), ICAR.

Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II.Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume III.Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 634p.

Simmonds NW and Smartt J. 1995. *Evolution of crop plants*. Wiley-Blackwell.

Soule J. 1985. *Glossary for Horticultural Crops*. John Wiley and Sons.

Srivastava U, Mahajan RK, Gangopadyay KK, Singh M and Dhillon BS. 2001. *Minimal descriptors of agri-horticultural crops*. Part-II: Vegetable Crops. NBPGR, New Delhi.

Vasistha. 1998. *Taxonomy of angiosperm*. Kalyani Publishers, New Delhi.

Vincent ER and Yamaguchi M. 1997. *World vegetables*. 2nd Ed. Chapman and Hall.

I. Course Title : Organic Vegetable Production

II. Course Code : VSC 511

III. Credit Hours : (1+1)

IV. Why this course ?

Organic vegetable farming is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. Organic farming has been simply defined as a production system working in partnership with nature to produce vegetable crops. The current trend towards increasing popularity of organically produced vegetables is relatively new. The objective of organic farming is to produce safer food and to keep the environment healthy. During the decade of nineties, the interest in organic farming began to creep into the mainstream consumer purchases. Currently, it appears to be an influx of business oriented producers into the organic production field. The increasing popularity of organic food among the elite societies is due to the belief that food produced with this system is free of pesticides and has greater nutritive value than conventionally produced food. The students of vegetable science need to have an understanding of organic vegetable farming technology.

V. Aim of the course

To elucidate principles, concepts and their applications in organic farming of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Organic vegetable production	1. Importance and principles 2. Organic production of vegetables 3. Managing soil fertility 4. Composting methods 5. Certification and export

VI. Theory

Unit I

Importance and principles—Importance, principles, perspective, concepts and components of organic farming in vegetable crops

Unit II

Organic production of vegetables—Organic production of vegetable crops, viz., Solanaceous, Cucurbitaceous, Cole, root and tuber crops

Unit III

Managing soil fertility—Managing soil fertility, mulching, raising green manure crops, weed management in organic farming system; Crop rotation in organic production; Processing and quality control of organic vegetable produce

Unit IV

Composting methods—Indigenous methods of composting, Panchyagavvya, Biodynamics preparations and their application; ITKs in organic vegetable farming; Role of botanicals and bio-control agents in the management of pests and diseases in vegetable crops

Unit V

Certification and export—Techniques of natural vegetable farming, GAP and GMP-certification of organic products; Export- opportunity and challenges

VII. Practical

- Methods of preparation and use of compost, vermicompost, biofertilizers and biopesticides;
- Soil solarisation;
- Use of green manures;
- Waste management; Organic soil amendments in organic production of vegetable crops;
- Weed, pest and disease management in organic vegetable production;
- Visit to organic fields and marketing centres.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of organic vegetable production in India
- Acquire knowledge about the organic vegetable production technology
- Adopting production of organic vegetable crops a s entrepreneur

X. Suggested Reading

Dahama AK. 2005. *Organic farming for sustainable agriculture*. 2nd Ed. Agrobios.

Gehlot G. 2005. *Organic farming; standards, accreditation certification and inspection*. Agrobios.

Palaniappan SP and Annadorai K. 2003. *Organic farming, theory and practice*. Scientific publ.

Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2008. *Management of horticultural crops*. New India Publ. Agency.

Shivashankar K. 1997. *Food security in harmony with nature. 3rd IFOAMASIA,* Scientific Conf. 1- 4 December, UAS, Bangalore.

I. Course Title : Production of Spice Crops

II. Course Code : VSC 512

III. Credit Hours : (2+1)

IV. Why this course ?

Spices are an important part of human history and played an important role in the development of most cultures around the world. Spice may be a seed, fruit, root, bark, or any other plant substance primarily used for flavouring, colouring, or preserving food. Spices are distinguished from herbs, which are the leaves, flowers, or stems of plants used for flavouring or as a garnish. Many spices have antimicrobial properties, because of which why spices are more commonly used in warmer climates, which have more infectious diseases, and use of spices is prominent in meat, which is predominantly susceptible to spoiling. The students of vegetable science need to have an understanding of production technology of spices and their processing before supplying them to the market or further use.

V. Aim of the course

To impart basic knowledge about the importance and production technology of spices grown in India

The course is constructed given as under:

No.	Block	Unit
1.	Production of spice crops	1. Fruit spices 2. Bud and kernel spices 3. Underground spice crops 4. Seed spices 5. Tree spices

VI. Theory

Introduction and importance of spice crops- historical accent, present status (national and international), future prospects, botany and taxonomy, climatic and soil requirement, commercial cultivars/ hybrids, site selection, layout, sowing/ planting time and methods, seed rate and seed treatment, nutritional and irrigation requirement, intercropping, mixed cropping, intercultural operations, weed control, mulching, physiological disorders, harvesting, post-harvest management, plant protection measures, quality control and pharmaceutical significance of crops mentioned below:

Unit I

Fruit spices- Black pepper, small cardamom, large cardamom and allspice

Unit II

Bud and kernel- Clove and nutmeg

Unit III

Underground spices- Turmeric, ginger and garlic

Unit IV

Seed spices- Coriander, fenugreek, cumin, fennel, ajowain, dill and celery

Unit V

Tree spices- Cinnamon, tamarind, garcinia and vanilla

VII. Practical

- Identification of seeds and plants;
- Botanical description of plant;
- Preparation of spice herbarium;
- Propagation;
- Nursery raising;

- Field layout and method of planting;
- Cultural practices;
- Harvesting, drying, storage, packaging and processing;
- Value addition;
- Short term experiments on spice crops.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of production of spice crops in India
- Acquire knowledge about the production technology and processing of spice crops
- Adopting production of spice crops as entrepreneur

X. Suggested Reading

Agarwal S, Sastry EVD and Sharma RK. 2001. *Seed spices: production, quality, export*. Pointer Publication.

Arya PS. 2003. *Spice crops of India*. Kalyani.

Bhattacharjee SK. 2000. *Hand book of aromatic plants*. Pointer publications.

Bose TK, Mitra SK, Farooqi SK and Sadhu MK. (Eds.). 1999. *Tropical horticulture*.Vol.I. Naya Prokash.

Chadha KL and Rethinam P. (Eds.). 1993. *Advances in horticulture*. Vols. IX-X. *Plantation crops and spices*. Malhotra Publ. House.

Gupta S. (Ed.). *Hand book of spices and packaging with formulae*. engineers India research institute, New Delhi.

Kumar NA, Khader P, Rangaswami and Irulappan I. 2000. *Introduction to spices, plantation crops, medicinal and aromatic plants*. Oxford and IBH.

Nybe EV, Miniraj N and Peter KV. 2007. *Spices*. New India Publ. Agency.

Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic spices*. New India Publ. Agency.

Peter KV. 2001. *Hand book of herbs and spices*. Vols. I-III. Woodhead Publ. Co. UK and CRC USA.

Pruthi JS. (Ed.). 1998. *Spices and condiments*. National Book Trust

Pruthi JS. 2001. *Minor spices and condiments- crop management and post harvest technology*. ICAR.

Purseglove JW, Brown EG, Green CL and Robbins SRJ. (Eds.). 1981. *Spices*. Vols. I, II. Longman.

Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production technology of spices and plantation crops*. Agrobios.

Thamburaj S and Singh N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR.

Tiwari RS and Agarwal A. 2004. *Production technology of spices*. International Book Distr. Co.

Varmudy V. 2001. *Marketing of spices*. Daya Publ. House.

I. Course Title : Processing of Vegetable Crops

II. Course Code : VSC 513

III. Credit Hours : (1+1)

IV. Why this course ?

In India, agriculture is the basis of economy. Agricultural industries and related activities, which can be termed as agriculturally based vegetable processing, can account for a considerable proportion of their output. Both established and planned vegetable processing projects aim at solving a very clearly identified developmental problems. The growers sustain substantial losses due to insufficient demand in the market, weak infrastructure, poor transportation and perishable nature of the vegetable crops. During the postharvest glut, the loss is considerable and often some of the produce are fed to the animals or allowed to decay. Even the established vegetable canning industries or small/ medium scale processing centres suffer huge loss due to erratic supplies since the growers like to sell their produce in the open market directly to the consumers, or the produce may not be of enough high quality to process but it might be good enough for the table use, meaning that processing is seriously underexploited. The main objective of vegetable processing is to supply wholesome, safe, nutritious and acceptable food to the consumers throughout the year. Vegetable processing also aims to replace imported products like squash, jams, tomato sauces, pickles, etc., besides earning foreign exchange by exporting finished or semi-processed products. The students of vegetable science need to have an understanding of vegetable processing.

V. Aim of the course

To educate the students about the principles and practices of processing in vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Processing of vegetable crops	I Present status II Spoilage and biochemical changes III Processing equipments IV Quality control V Value addition

VI. Theory

Unit I

Present status—Present status and future prospects of vegetable preservation industry in India

Unit II

Spoilage and biochemical changes—Spoilage of fresh and processed vegetable produce; biochemical changes and enzymes associated with spoilage of vegetable produce; Principal spoilage organisms, food poisoning and their control measures; Role of microorganisms in food preservation

Unit III

Processing equipments—Raw material for processing; Primary and minimal processing; Processing equipments; Layout and establishment of processing industry; FPO licence; Importance of hygiene; Plant sanitation

Unit IV

Quality control—Quality assurance and quality control, TQM, GMP; Food standards-FPO, PFA, etc.; Food laws and regulations; Food safety- hazard analysis and critical control points (HACCP); Labeling and labeling act and nutrition labeling

Unit V

Value addition—Major value added vegetable products; Utilization of byproducts of vegetable processing industry; Management of processing industry waste; Investment analysis; Principles and methods of sensory evaluation of fresh and processed vegetables

VII. Practical

- Study of machinery and equipments used in processing of vegetable produce;
- Chemical analysis for nutritive value of fresh and processed vegetable;
- Study of different types of spoilage in fresh as well as processed vegetable produce;
- Classification and identification of spoilage organisms;
- Study of biochemical changes and enzymes associated with spoilage;
- Laboratory examination of vegetable products;
- Sensory evaluation of fresh and processed vegetables;
- Study of food standards- National, international, CODEX Alimentarius;
- Visit to processing units to study the layout, hygiene, sanitation and waste management.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of vegetable processing in India
- Acquire knowledge about the processing technology of vegetable crops
- Adopting processing products of vegetable crops at small or medium scale
- Adopt processing of vegetable crops as entrepreneur

X. Suggested Reading

Arthey D and Dennis C. 1996. *Vegetable processing*. Blackie/ Springer-Verlag.

Chadha DS. 2006. *The Prevention of food adulteration act*. Confed. of Indian Industry.

Desrosier NW. 1977. *Elements and technology*. AVI Publ. Co.

FAO. 1997. *Fruit and Vegetable processing*. FAO.

FAO. *CODEX Alimentarius: Joint FAO/ WHO food standards programme*. 2nd Ed. Vol. VB. *tropical fresh fruits and vegetables*. FAO.

FAO. *Food quality and safety systems- training manual on food hygiene and haccp*. FAO.

Fellow's P. 1988. Food processing technology. Ellis Horwood International.

Frazier WC and Westhoff DC. 1995. *Food microbiology*. 4th Ed. Tata McGraw Hill.

Giridharilal GS Siddappa and Tandon GL. 1986, *Preservation of fruits and vegetables*. ICAR.

Gisela J. 1985. *Sensory evaluation of food- theory and practices*. Ellis Horwood.

Graham HD. 1980. *Safety of foods*. AVI Publ. Co.

Hildegrade H and Lawless HT. 1997. *Sensory evaluation of food*. CBS.

Joslyn M and Heid *Food processing operations*.AVI Publ. Co.

Mahindru SN. 2004. *Food safety: concepts and reality*. APH Publ. Corp.

Ranganna S. 1986. *Handbook of analysis and quality control for fruit and vegetable products*. 2nd Ed. Tata-McGraw Hill.

Shapiro R. 1995. *Nutrition labeling handbook*. Marcel Dekker.

Srivastava RP and Kumar S. 2003. *Fruit and vegetable preservation: principles and practices*. 3rd Ed. International Book Distri. Co.

Tressler and Joslyn MA. 1971. *Fruit and vegetable juice processing technology*. AVI Publ. Co.
Verma LR and Joshi VK. 2000. *Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management*. Indus Publ. Co.

I. Course Title : Postharvest Management of Vegetable Crops

II. Course Code : VSC 514

III. Credit Hours : (2+1)

IV. Why this course ?

Vegetables are highly perishable crops as they have great quantity and quality loss after harvest. Hence, they require integrated approach to arrest their spoilage, which causes tonnes of vegetable produce annually. Lack of postharvest awareness and inadequacy of equipments are the major problems in postharvest chain, which lead to a serious post-harvest loss in the developing countries every year. A comprehensive understanding of postharvest factors causing deterioration is necessary to overcome these challenges. Pre and postharvest management such as use of improved varieties, good cultural practices, good pre and postharvest handling practices, management of temperature, relative humidity and storage atmosphere according to crop requirement, use of permitted chemicals, design of appropriate packaging material and storage structures are some of the control measures used in reducing postharvest losses, therefore, this course was customized.

V. Aim of the course

To facilitate deeper understanding of principles and to acquaint the student with proper handling and management technologies of vegetable crops for minimizing the post-harvest losses

The course is organized as follows:

No.	Blocks	Units
1.	Post-harvest management of vegetable crops	I Importance and scope
		II Maturity indices and biochemistry
		III Harvesting and losses factors
		IV Packinghouse operations
		V Methods of storage

VI. Theory

Unit I

Importance and scope—Importance and scope of post-harvest management of vegetables

Unit II

Maturity indices and biochemistry—Maturity indices and standards for different vegetables; Methods of maturity determination; Biochemistry of maturity and ripening; Enzymatic and textural changes; Ethylene evolution and ethylene management; Respiration and transpiration along with their regulation methods

Unit III

Harvesting and losses factors—Harvesting tools and practices for specific market requirement; Postharvest physical and biochemical changes; Preharvest practices and other factors affecting postharvest losses

Unit IV

Packing house operations—Packing house operations; Commodity pretreatments chemicals, wax coating, precooling and irradiation; Packaging of vegetables, prevention from infestation, management of postharvest diseases and principles of transportation

Unit V

Methods of storage—Ventilated, refrigerated, modified atmosphere and controlled atmosphere storage, hypobaric storage and cold storage; Zero-energy cool chamber, storage disorders like chilling injury in vegetables

VII. Practical

- Studies on stages and maturing indices;
- Ripening of commercially important vegetable crops;
- Studies of harvesting, pre-cooling, pre-treatments, physiological disorders- chilling injury;
- Improved packaging;
- Use of chemicals for ripening and enhancing shelf life of vegetables;
- Physiological loss in weight, estimation of transpiration, respiration rate and ethylene release;
- Storage of important vegetables;
- Cold chain management;
- Visit to commercial packinghouse, cold storage and control atmosphere storage.

VIII. Teaching Methods/ Activities

- Classroom lectures including ppt.
- Students group discussion
- Individual or group assignments (writing and speaking)
- Presentation of practical handwork

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Regulation of postharvest losses by using chemicals and growth regulators
- Pre and postharvest treatments for extending shelf life of vegetable crops
- Packinghouse operations for extending the shelf life of vegetable crops
- Successful storage of vegetable crops

X. Suggested Reading

Chadha KL and Pareek OP. 1996. *Advances in horticulture*. Vol. IV. Malhotra Publ. House.

Chattopadhyay SK. 2007. *Handling, transportation and storage of fruit and vegetables*. Gene-Tech books, New Delhi.

Haid NF and Salunkhe SK. 1997. *Postharvest physiology and handling of fruits and vegetables*. Grenada Publ.

Mitra SK. 1997. *Postharvest physiology and storage of tropical and sub-tropical fruits*. CABI.

Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest biology and technology of Fruits, vegetables and flowers*. Wiley-Blackwell, ISBN: 9780813804088.

Ranganna S. 1997. *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill.

Stawley JK. 1998. *Postharvest physiology of perishable plant products*. CBS publishers.

Sudheer KP and Indira V. 2007. *Postharvest technology of horticultural crops*. New India Publ. Agency.

Thompson AK. (Ed.). 2014. *Fruit and vegetables: harvesting, handling and storage* (Vol. 1 and 2) Blackwell Publishing Ltd, Oxford, UK. ISBN: 9781118654040.

Verma LR and Joshi VK. 2000. *Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.

Willis R, McGlassen WB, Graham D and Joyce D. 1998. *Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals*. CABI.

Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.

Wills RBH and Golding J. 2017. *Advances in postharvest fruit and vegetable technology*, CRC Press, ISBN 9781138894051.

Course Title with Credit Load
Ph.D. (Hort.) in Vegetable Science

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
VSC 601*	Recent Trends in Vegetable Production	3+0
VSC 602*	Advances in Breeding of Vegetable Crops	3+0
VSC 603	Abiotic Stress Management in Vegetable Crops	2+1
VSC 604	Seed Certification, Processing and Storage of Vegetable Crops	2+1
VSC 605	Breeding for Special Traits in Vegetable Crops	2+0
VSC 606	Biodiversity and Conservation of Vegetable Crops	2+1
VSC 607	Biotechnological Approaches in Vegetable Crops	2+1
VSC 608	Advanced Laboratory Techniques for Vegetable Crops	1+2
	Minor courses	06
	Supporting courses	05
VSC 691	Seminar I	0+1
VSC 692	Seminar II	0+1
VSC 699	Research	0+75
	Total Credits	100

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Vegetable Science

I. Course Title : Recent Trends in Vegetable Production

II. Course Code : VSC 601

III. Credit Hours : (3+0)

IV. Why this course ?

India is the second largest producer of vegetables in the world, next only to China. Most challenging task is to ensure for continuous and enough supply of vegetables to growing population. Urban areas are experiencing substantial increase in population; this growth is accompanied with change in food habits and rising concerns for food quality. Here, food quality refers to the optimum levels of the nutrition in the food along with the minimized amount of the chemical (pesticides/ fertilizers) residues used in the production of the vegetables. Vegetables are being highly seasonal, perishable are also capital and labour intensive and need care in handling and transportation. Environmental stress (climate change) and shortage of water and land resources are major constraints haunting the production. Though the advances in science and information technology has resulted in more comfortable world with global linkages, these advances has led to changes in production practices. Thus, the students of vegetable science need to have an understanding of recent trends in production technology of vegetable crops and their management.

V. Aim of the course

To keep abreast with latest developments and trends in production technology of vegetable crops.

The course is constructed given as under:

No.	Block	Unit
1	Recent trends in vegetable production	1. Solanaceous crops 2. Cole crops 3. Okra, onion, peas and beans, amaranth and drumstick. 4. Root crops and cucurbits 5. Tuber crops

VI. Theory

Present status and prospects of vegetable cultivation; nutritional, antioxidant and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; Hi-tech nursery management; modern concepts in water and weed management; physiological basis of growth, yield and quality as influenced by chemicals and growth regulators; role of organic manures, inorganic fertilizers, micronutrients and biofertilizers; response of genotypes to low and high nutrient management, nutritional deficiencies/ disorders and correction methods; different cropping systems; mulching; Protected cultivation of vegetables, containerized culture for year round vegetable production; low cost polyhouse; nethouse production; crop modelling, organic gardening; vegetable production for pigments, export and processing of:

Unit I

Solanaceous crops: Tomato, brinjal, chilli, sweet pepper and potato.

Unit II

Cole crops: Cabbage, cauliflower and knol-khol, sprouting broccoli.

Unit III

Okra, onion, peas and beans, amaranth and drumstick.

Unit IV

Root crops and cucurbits: Carrot, beet root, turnip and radish and cucurbits

Unit V

Tuber crops: Sweet potato, Cassava, elephant foot yam, Dioscorea and taro.

VII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Group discussion

VIII. Learning outcome

After successful completion of this course, the students are exposed to:

- Acquire the knowledge about recent trends in production technology of vegetable crops

IX. Suggested Reading

Bose TK and Som NG. 1986. *Vegetable crops of India*. Naya prokash.

Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. *Vegetable crops*. Vols. I-III. Naya Udyog.

Brewster JL. 1994. *Onions and other vegetable alliums*. CABI.

Chadha KL and Kalloo G (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra Publ. House.

Chadha KL (Ed.). 2002. *Hand book of horticulture*. ICAR.

Chauhan DVS (Ed.). 1986. *Vegetable production in India*. Ram prasad and Sons.

Fageria MS, Choudhary BR and Dhaka RS. 2000. *Vegetable crops: production technology*. Vol. II. Kalyani.

FFTC. *Improved vegetable production in Asia*. Book Series No. 36.

Ghosh SP, Ramanujam T, Jos JS, Moorthy SN and Nair RG. 1988. *Tuber crops*. Oxford and IBH.

Gopalakrishanan TR. 2007. *Vegetable crops*. New India Publ. Agency.

Hazra P and Som MG. 2015. *Seed production and hybrid technology of vegetable crops*. Kalyani publishers, Ludhiana.

Hazra P. 2016. *Vegetable science*. 2ndedn, Kalyani publishers, Ludhiana.

Hazra P. 2019. *Vegetable production and technology*. New India publishing agency, New Delhi.

Kallo G and Singh K. (Ed.). 2001. *Emerging scenario in vegetable research and development*. Research periodicals and Book Publ. House.

Kurup GT, Palanisami MS, Potty VP, Padmaja G, Kabeerathuma S and Pallai SV. 1996. *Tropical tuber crops, problems, prospects and future strategies*. Oxford and IBH.

Rana MK. 2008. *Olericulture in India*. Kalyani Publishers, New Delhi.

Rana MK. 2008. *Scientific cultivation of vegetables*. Kalyani Publishers, New Delhi.

Rubatzky VE and Yamaguchi M. (Eds.). 1997. *World vegetables: principles, production and nutritive values*. Chapman and Hall.
Saini GS. 2001. *A Text Book of oleri and flori culture*. Aman Publishing House.
Salunkhe DK and Kadam SS. (Ed.). 1998. *Hand book of vegetable science and technology: production, composition, storage and processing*. Marcel Dekker.
Shanmugavelu KG. 1989. *Production technology of vegetable crops*. Oxford and IBH.
Sin MT and Onwueme IC. 1978. *The tropical tuber crops*. John Wiley and Sons.
Singh DK. 2007. *Modern vegetable varieties and production technology*. International book distributing Co.
Singh NP, Bhardwaj AK, Kumar A and Singh KM. 2004. *Modern technology on Vegetable production*. International book distr. Co.
Singh PK, Dasgupta SK and Tripathi SK. 2006. *Hybrid vegetable development*. International book distr. Co.
Singh SP. (Ed.). 1989. *Production technology of vegetable crops*. Agril. Comm. Res. Centre.
Thamburaj S and Singh N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR.
Thompson HC and Kelly WC. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

I. Course Title : Advances in Breeding of Vegetable Crops
II. Course Code : VSC 602
III. Credit Hours : (3 +0)

IV. Why this course ?

The improvement of vegetable crops has until recently, been largely confined to conventional breeding approaches and such programmes rely on hybridization of plants which have desirable heritable characteristics and on naturally or artificially induced random mutations. The introduction of new genetic information can result in increased resistance to insect pest, diseases tolerance to environmental condition, improved quality, etc. The modern biotechnological tools like molecular assisted selection, double haploidy, genetic engineering, etc. can be of immense importance for rapid development of superior varieties with desirable qualitative and quantitative traits. Therefore, conventional breeding in conjunction with molecular biology has bright prospects of developing high yielding vegetable varieties with high nutraceuticals and bio active compounds suitable for fresh as well as processed market. The students of vegetable science who are having breeding as major subject need to have an understanding of recent technologies in vegetable crops.

V. Aim of the course

To impart knowledge on the recent research trends and advances in breeding of vegetable crops.

The course is constructed given as under:

No.	Block	Unit
1	Advances in Breeding of vegetable crops	I. Solanaceous crops and okra II. Cucurbits and Cole crops III. Legumes and leafy vegetables IV. Root crops and onion V. Tuber crops

VI. Theory

Evolution, distribution, cytogenetics, Genetics and genetic resources, wild relatives, genetic divergence, hybridization, inheritance of qualitative and quantitative traits, heterosis breeding, plant idotype concept and selection indices, breeding mechanisms, pre breeding, mutation breeding, ploidy breeding, breeding for biotic and abiotic stresses, breeding techniques for improving quality and processing characters, bio-fortification, *in-vitro* breeding, marker assisted breeding, haploidy, development of transgenic.

Unit I

Solanaceous crops—Tomato, Brinjal, Hot Peeper, Sweet Pepper, Okra and Potato

Unit II

Cucurbits and Cole crops

Unit III

Legumes and leafy vegetables—Peas and Beans, Amaranth, Palak, Chenopods and Lettuce.

Unit IV

Root crops and onion—Carrot, Beetroot, Radish, Turnip, Onion

Unit V

Tuber crops—Sweet potato, Tapioca, Elephant foot yam, Colocasia, Dioscorea

VII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Group discussion

VIII. Learning outcome

After successful completion of this course, the students are exposed to:

- Breeding objectives and trends
- Recent Adavnces in vegetable breeding

IX. Suggested Reading

Allard RW. 1999. *Principle of plant breeding*. John Willey and Sons, USA.

Basset MJ. (Ed.). 1986. Breeding vegetable crops. AVI Publ.

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*. Vol. I. Kalyani.

Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.

Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.

Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles and prospects*. Chapman and Hall.

Hazra P and Som MG. 2015. *Vegetable science* (Second revised edition), Kalyani publishers, Ludhiana, 598 p

Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani Publishers, Ludhiana, 459 p

Kalloo G. 1988. *Vegetable breeding* (Vol. I, II, III). CRC Press, Fl, USA.

Kalloo G. 1998. *Vegetable breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency.

Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro Botanical Publ.

Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybrid technology in Asia-Pacific Region*. FAO.

Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables*. Revised, ICAR.

Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.
Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.
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Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.
Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.
Singh BD. 1983. *Plant breeding*. Kalyani Publishers, New Delhi.
Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.
Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Abiotic Stress Management in Vegetable Crops

II. Course Code : VSC 603

III. Credit Hours : (2+1)

IV. Why this course ?

Improvement of vegetable crops has traditionally focused on enhancing a plant's ability to resist diseases or insects. That is evidenced by the large number of disease- or insect-resistant cultivars or germplasm released and used. Research on crop resistance or tolerance to abiotic stresses (heat, cold, drought, flood, salt, pH, etc.) has not received much attention. However, that is changing as a result of the research and publicity of global warming. The changing environments pose serious and imminent threats to vegetable production and place unprecedented pressures on the sustainability of vegetable production. The challenges and opportunities coexist for our dynamic and resilient industry. In addition to conserving resources, we should mitigate abiotic stresses and adapt to the warming planet. The student of vegetable science need to know the different methods involved to mitigate the abiotic stress in vegetable crops.

V. Aim of the course

To update knowledge on the recent research trends in the field of abiotic stress management in vegetables.

- To teach management practices to mitigate abiotic stress in vegetable crops

The course is constructed given as under:

No.	Block	Unit
1	Abiotic stress management in vegetable crops	I Environmental stress II Mechanism and measurements of tolerance III Soil-plant-water relations IV Techniques of vegetable growing under high stress condition V Use of chemicals

VI. Theory

Unit I

Environmental stress—its types, soil parameters including pH, classification of vegetable crops based on susceptibility and tolerance to various types of stress.

Unit II

Mechanism and measurements—tolerance to drought, water logging, soil salinity, frost and heat stress in vegetable crops.

Unit III

Soil-plant-water relations—under different stress conditions in vegetable crops production and their management practices.

Unit IV

Techniques of vegetable growing under water deficit, water logging, salinity and sodicity.

Unit V

Use of chemicals—techniques of vegetable growing under high and low temperature conditions, use of chemicals and antitranspirants in alleviation of different stresses.

VII. Practical

- Identification of susceptibility and tolerance symptoms to various types of stress in vegetable crops;
- Measurement of tolerance to various stresses in vegetable crops;
- Short term experiments on growing vegetable under water deficit, water logging, salinity and sodicity, high and low temperature conditions;
- Use of chemicals for alleviation of different stresses.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedure
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire the knowledge about effect of different abiotic stresses on vegetables
- Methods to mitigate abiotic stress in vegetables

X. Suggested Reading

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.

Dwivedi P and Dwivedi RS. 2005. *Physiology of abiotic stress in plants*. Agrobios.

Janick JJ. 1986. *Horticultural science*. 4th Ed. WH Freeman and Co.

Kaloo G and Singh K. 2001. *Emerging scenario in vegetable research and development*. Research periodicals and book publ. house.

Kaloo G. 1994.*Vegetable breeding*. Vols. I-III. Vedams eBooks.

Lerner HR. (Eds.). 1999. *Plant responses to environmental stresses*. Marcel Decker.

Maloo SR. 2003. *Abiotic stresses and crop productivity*.Agrotech Publ. Academy.

Narendra T. *et al.* 2012. *Improving crops resistance to abiotic stress*. Wiley and Sons.US.

Peter KV and Pradeep Kumar T. 2008. *Genetics and breeding of vegetables*. (Revised Ed.). ICAR.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* volume III. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 634p.

Ram HH. 2001. *Vegetable breeding*. Kalyani.

Rao NK. (Eds.). 2016. *Abiotic stress physiology of horticultural crops*. Springer publication.

I. Course Title : Seed Certification, Processing and Storage of Vegetable Seeds

II. Course Code : VSC 604

III. Credit Hours : (2+1)

IV. Why this course ?

Every farmer should able to access healthy seeds which are genetically pure, with high seed vigour and good germination percentage. Timely availability of good quality seeds at reasonable price ensures good yield and profit to the farmers. The seeds plays a vital role in agriculture and acts as a carrier of the genetic potential of varieties. Quality seed production which follows efficient certification procedures plays a major role in the increase of food production of our country. To ensure this, the Government has prescribed standards and has brought in seed production techniques, testing, certification and marketing procedures through the Seeds Act, 1966. In the current scenario, the demand for good quality certified seeds far exceed the availability in the market. This manual provides details about production and procurement of good quality seeds.

V. Aim of the course

To impart the knowledge on seed certification, processing and storage of vegetable seeds

VI. Theory

Unit I

Seed certification, history, concepts and objectives, seed certification agency, phases of seed certification, Indian Minimum seed Certification standards, Planning and management of seed certification programmes.

Unit II

Principles and procedures of field inspection, seed sampling, testing and granting certification, OECD certification Schemes.

Unit III

Principles of seed processing, Methods of seed drying and cleaning, seed processing plant- Layout and design, seed treatment, seed quality enhancement, packaging and marketing.

Unit IV

Principles of Seed Storage, orthodox/ recalcitrant seeds, types of storage (open, bulk, controlled, germplasm, cryopreservation), factors affecting seed longevity in storage (Pre and post harvest factors).

Unit V

Seed aging and deterioration, maintenance of seed viability and vigor during storage, storage methods, storage structures, transportation and marketing of seeds.

VII. Practical

- General procedures of seed certification;
- Field inspection and standards;
- Isolation and rouging;
- Inspection and sampling at harvesting, threshing and processing;
- Testing physical purity, germination and moisture, grow-out test;

- Visit to regulatory seed testing and plant quarantine laboratories;
- Seed processing plants and commercial seed stores.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation individual or in group
- Hands on training of different procedure
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire the knowledge on seed certification
- Acquire the knowledge on seed processing and storage

X. Suggested Reading

Agarwaal PK and Anuradha V. 2018. *Fundamentals of seed science and technology*. Brilliant publications, New Delhi.

Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.

Bench ALR and Sanchez RA. 2004. *Handbook of seed physiology*. Food products press, NY/ London.

Chakraborty SK, Prakash S, Sharma SP and Dadlani M. 2002. *Testing of distinctiveness, uniformity and stability for plant variety protection*. IARI, New Delhi

Copland LO and McDonald MB. 2004. *Seed science and technology*, Kluwer academic press.

Fageria MS, Arya PS and Choudhry AK. 2000. *Vegetable crops: breeding and seed production* Vol 1. Kalyani publishers, New Delhi.

George RAT. 1999. *Vegetable seed production* (2nd Edition). CAB International.

Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani publishers, Ludhiana, 459p

Kalloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated publishing company, New Delhi.

Singhal NC. 2003. *Hybrid seed production*. Kalyani publishers, New Delhi.

I. Course Title : Breeding for Special Traits in Vegetable Crops

II. Course Code : VSC 605

III. Credit Hours : (2+0)

IV. Why this course ?

Many epidemiological studies reveal that people having a high level of consumption of vegetables presents a better health and lower risk of chronic diseases, including cardiovascular diseases and different types of cancer. Vegetables contain many bioactive compounds and represent a major source of antioxidants and other compounds that are beneficial to human health. Consumers are increasingly demanding vegetables with bioactive properties that contribute to maintaining a good health and preventing diseases. In consequence, breeding programmes in vegetables are increasingly considering the content in bioactive compounds as a major breeding objective. In this way, there is an increasing number of breeding programmes and scientific studied aimed at improving the content in bioactive compounds of vegetables, and the trend seems that will continuing in the coming years. In this respect, the particular course has been designed for students of Vegetable Science department.

V. Aim of the course

To impart knowledge on recent developments in breeding for improved nutritional quality in important vegetable crops

VI. Theory

Important nutrient constituents in vegetables and their role in human diet. Genetics of nutrients. Genetic and genomic resources for improving quality traits in vegetables, breeding strategies for developing varieties with improved nutrition for market and industrial purposes. Molecular and biotechnological approaches in breeding suitable cultivars of different crops for micronutrients and color content.

Unit I

Brassica group, carrot and beetroot.

Unit II

Tomato, brinjal, peppers and potato.

Unit III

Green leafy vegetables, Legume crops and okra.

Unit IV

Cucurbitaceous vegetable crops and edible Alliums.

Unit V

Biofortification in vegetable crops, genetic engineering for improvement of quality traits in vegetable crops, bioavailability of dietary nutrients from improved vegetable crops and impact on micronutrient malnutrition, achievements and future prospects in breeding for quality traits in vegetables.

VII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedure
- Group discussion

VIII. Learning outcome

After successful completion of this course, the students are expected to:
- Know about various special characters of vegetables
- The recent breeding methods to achieve special characters in vegetables

IX. Suggested Reading

Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.

Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*. Vol. I. Kalyani.

Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.

Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.

Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles and prospects*. Chapman and Hall.

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Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro Botanical Publ.

Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybrid technology in Asia-Pacific Region*. FAO.

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Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.

Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.

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Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.

Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.

Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Biodiversity and Conservation of Vegetable Crops

II. Course Code : VSC 606

III. Credit Hours : (2+1)

IV. Why this course ?

The availability of pertinent gene pool is of utmost importance to mitigate adverse climate and to counter diseases and pests. In addition, specific gene sources (germplasm) would always be necessary to develop superior genotypes. Considering the importance of conserving biodiversity in vegetable crops for future use, the course has been designed.

V. Aim of the course

To understand the status and magnitude of biodiversity and strategies in germplasm conservation of vegetable crops.

The course is organised as follows:

No.	Blocks	Units
1	Biodiversity and conservation of vegetable crops	I General Aspects: Issues, Goals and Current Status II. Germplasm Conservation: Collection, Maintenance and Characterization III. Regulatory Horticulture: Germplasm Exchange, Quarantine and Intellectual Property Rights

VI. Theory

Unit I

General aspects: issues, goals and current status: Biodiversity and conservation; issues and goals- needs and challenges; present status of gene centres; world's major centres of fruit crop domestication; current status of germplasm availability/ database of fruit crops in India

Unit II

Germplasm conservation: collection, maintenance and characterization: Exploration and collection of germplasm; sampling frequencies; size and forms of fruit and nut germplasm collections; active and base collections. Germplasm conservation- in situ and ex situ strategies, on farm conservation; problem of recalcitrance- cold storage of scions, tissue culture, cryopreservation, pollen and seed storage.

Unit III

Regulatory horticulture: Germplasm exchange, quarantine and intellectual property rights germplasm exchange, quarantine and intellectual property rights regulatory horticulture, inventory and exchange of fruit and nut germplasm, plant quarantine, phytosanitary certification, detection of genetic constitution of germplasm and maintenance of core collection. IPRs, Breeder's rights, Farmer's rights, PPVandFR Act. GIS and documentation of local biodiversity, Geographical indications, GIS application in horticultural mapping and spatial analyses of field data; benefits of GI protection; GI tagged fruit varieties in India.

VII. Practical

- Documentation of germplasm- maintenance of passport data and other records of accessions;
- Field exploration trips and sampling procedures;
- Exercise on *ex situ* conservation – cold storage, pollen/ seed storage
- Cryopreservation;
- Visits to national gene bank and other centers of PGR activities;
- Detection of genetic constitution of germplasm;
- Germplasm characterization using a standardised DUS test protocol;
- Special tests with biochemical and molecular markers.

VIII. Teaching Methods/ Activities

- Class room lectures
- Laboratory/ field practicals
- Student seminars/ presentations
- Field tours/ demonstrations
- Assignments

IX. Learning outcome

- The student would be expected to learn about the significance of germplasm
- Various strategies to conserve it in the present context.

X. Suggested Reading

Dhillon BS, Tyagi RK, Lal A and Saxena S. 2004. *Plant genetic resource management. – horticultural crops*. Narosa publishing house, New Delhi.

Engles JM, Ramanath RV, Brown AHD and Jackson MT. 2002. *Managing plant genetic resources*, CABI, Wallingford, UK.

Frankel OH and Hawkes JG. 1975. *Crop genetic resources for today and tomorrow*. Cambridge University Press, USA.
Hancock J. 2012. *Plant evolution and the origin of crops species.* CAB International.
Jackson M, Ford-Lloyd B and Parry M. 2014, *Plant genetic resources and climate change*. CABI, Wallingford, UK
Moore JN and Ballington JR. 1991. *Genetic resources of temperate Fruit and nut crops*. ISHS, Belgium.
Peter KV. 2008. *Biodiversity of horticultural crops*. Vol. II. Daya Publ. House, Delhi.
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Rajasekharan PE, Rao V and Ramanatha V. 2019. *Conservation and utilization of horticultural genetic resources*. Springer.
Rana JC and Verma VD. 2011. *Genetic resources of temperate minor fruits (indigenous andexotic)*. NBPGR, New Delhi.
Sthapit *et al.* 2016. *Tropical fruit tree diversity (good practices for in situ and ex situ conservation)*. Bioversity international. routledge, Taylor and Francis Group.
Virchow D. 2012. *Conservation of genetic resources*, Springer Verlag, Berlin

I. Course Title : Biotechnological Approaches in Vegetable Crops
II. Course Code : VSC 607
III. Credit Hours : (2+1)

IV. Why this course ?

Biotechnology is a rapidly developing area of contemporary science. It can bring new ideas, improved tools and novel approaches to the solution of some persistent, seemingly intractable problems in vegetable production. Given the pressing need to enhance and stabilize the vegetable production in response to mounting population pressures and increasing awareness, there is an urgent need to explore novel technologies that will break traditional barriers.

V. Aim of the course

To impart latest knowledge in biotechnical advancement in vegetable crops

The course is organised as follows:-

No.	Blocks	Units
1	Biotechnological approaches in vegetable crops	I Importance and scope of Biotechnology II Somatic embryogenesis III Blotting techniques, DNA finger printing, IV Plant genetic engineering V Concepts and methods of next generation sequencing (NGS)

VI. Theory

Unit I

Importance and scope of biotechnology – in vegetable crop improvement. *In-vitro* culture, micropropagation, anther culture, pollen culture, ovule culture, embryo culture, endosperm culture.

Unit II

Somatic embryogenesis – somaclonal variation and synthetic seed production, protoplast isolation, culture, manipulation and fusion. Somatic hybrids and cybrids and their application in vegetable improvement programme.

Unit III

Blotting techniques, DNA finger printing – Molecular markers/ DNA based markers and role. RFLP, AFLP, RAPD, SSR, SNPs, DNA probes. QTL mapping. MAS and its application in vegetable crop improvement. Allele mining by TILLING and Eco-TILLING.

Unit IV

Plant genetic engineering – Scope and importance, Concepts of cisgenesis, intragenesis and transgenesis. Gene cloning, direct and indirect methods of gene transfer. Role of RNAi based gene silencing in vegetable crop improvement. Bio-safety issue, regulatory issues for commercial approval.

Unit V

Concepts and methods of next generation sequencing (NGS)- Genome sequencing, transcriptomics, proteomics, metabolomics. Genome editing (ZFN, TALENS and CRISPER)

Crops

Solanaceous crops, cole crops, cucurbitaceous crops, root vegetables, garden pea, onion, potato and leafy vegetables

VII. Practical

- Micropropagation, Pollen- Ovule and Embryo culture- Synthetic seed production (2);
- *In-vitro* mutation induction, *in-vitro* rooting – hardening at primary and secondary nurseries (3);
- DNA isolation from economic vegetable crop varieties – Quantification and amplification (2);
- DNA and Protein profiling – molecular markers, PCR Handling (2);
- Vectors for cloning and particle bombardment (3);
- DNA fingerprinting of flower crop varieties (3);
- Project preparation for establishment of low, medium and high cost tissue culture laboratories (1).

VIII. Teaching Methods/ Activities

- Class room lectures
- Laboratory/ field practicals
- Student seminars/ presentations
- Field tours/ demonstrations
- Assignments

IX. Learning outcome

The student would be expected to learn

- Different biotechnological tools
- NGS, genetic engineering

X. Suggested Reading

Bajaj YPS. (Ed.). 1987. *Biotechnology in agriculture and forestry*. Vol. XIX. Hitech and Micropropagation. Springer.

Chadha KL, Ravindran PN and Sahijram L. (Eds.). 2000. *Biotechnology of horticulture and plantation crops*. Malhotra Publ. House.

Debnath M. 2005. *Tools and techniques of biotechnology*. Pointer publication, New Delhi.

Glover MD. 1984. *Gene cloning: the mechanics of DNA manipulation*. Chapman and Hall.
Gorden H and Rubsell S. 1960. *Hormones and cell culture*. AB Book Publ.
Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New India Publ. Agency.
Keshavachandran R and Peter KV. 2008. *Plant biotechnology; tissue culture and gene transfer*. Orient and Longman, USA.
Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New-India Publication Agency, New Delhi.
Panopoulas NJ. (Ed.). 1981. *Genetic engineering in plant sciences*. Praeger Publ.
Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of horticultural crops*. Vols. I-III. Naya Prokash.
Pierik RLM. 1987. *In-vitro culture of higher plants*. Martinus Nijhoff Publ.
Prasad S. 1999. *Impact of plant biotechnology on horticulture*. 2nd Ed. Agro Botanica.
Rout GR and Peter KV. 2018. *Genetic engineering of horticultural crops*. Academic Press Elsveer, USA.
Sharma R. 2000. *Plant tissue culture*. Campus Books.
Singh BD. 2010. *Biotechnology- expanding horizons*. Kalyani Publishers, New Delhi.
Skoog Y and Miller CO. 1957. *Chemical regulation of growth and formation in plant tissue cultured in-vitro*. Attidel. II Symp. On biotechnology action of growth substance.
Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic hybridization and genetic manipulation in plants, plant regulation and world agriculture*. Planum Press.

I. Course Title : Advanced Laboratory Techniques for Vegetable Crops

II. Course Code : VSC 608

III. Credit Hours : (1+2)

IV. Why this course ?

Accurate quality analysis of vegetables warrants stringent measurement protocols besides requisite instruments/ tools and laboratory facilities. Consequently, a specialized course is designed for imparting basic and applied training on physical and biochemical assessment of the vegetable produce.

V. Aim of the course

To familiarize with the laboratory techniques for analysis of vegetable crops.

The organisation of the course is as under:

No.	Blocks	Units
1	Advanced laboratory techniques for vegetable crops	I Safety measures and laboratory maintenance II Qualitative and quantitative analysis destructive and non-destructive analysis methods III Chromatographic and microscopic analysis IV Sensory analysis

VI. Theory

Unit I

Safety measures and laboratory maintenance – Safety aspects and upkeep of laboratory, sampling procedures for quantitative analysis, determination of proximate composition of horticultural produce. Standard solutions, determination of relative water content (RWC), physiological loss in weight (PLW), calibration and standardization of instruments, textural properties of harvested produce, TSS, Specific gravity, pH and acidity.

Unit II

Destructive and non-destructive analysis methods – Refractometry, spectrophotometry, non-destructive determination of colour, ascorbic acid, sugars, and starch in food crops.

Unit III

Chromatographic and microscopic analysis- basic chromatographic techniques, GC, HPLC, GCMS, Electrophoresis techniques, ultra filtration. Application of nuclear techniques in harvested produce. Advanced microscopic techniques, ion leakage as an index of membrane permeability, determination of biochemical components in horticultural produce.

Unit IV

Sensory analysis – Importance of ethylene, quantitative estimation of rate of ethylene evolution, using gas chromatograph (GC). Sensory analysis techniques, control of test rooms, products and panel.

VII. Practical

- Determination of moisture, relative water content and physiological loss in weight;
- Determination of biochemical components in horticultural produce;
- Calibration and standardization of instruments;
- Textural properties of harvested produce;
- Determination of starch index (SI);
- Specific gravity for determination of maturity assessment, and pH of produce;
- Detection of adulterations in fresh as well as processed products;
- Non-destructive determination of colour, ascorbic acid, vitamins, carotenoids, sugars and starch;
- Estimation of rate of ethylene evolution using gas chromatograph (GC);
- Use of advanced microscopes (fluorescent, scanning electron microscope, phase contrast, etc.).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The students would be expected to develop skills and expertise on

- Upkeep of laboratories and handling of research instruments
- Principles and methods of various analysis

X. Suggested Reading

AOAC International. 2003. *Official methods of analysis of AOAC international*. 17th Ed. Gaithersburg, MD, USA, association of analytical communities, USA.

Clifton M and Pomeranz Y. 1988. *Food analysis – laboratory experiments*. AVI publication, USA.

Linskens HF and Jackson JF. 1995. *Fruit analysis*. Springer.

Leo ML. 2004. *Handbook of food analysis*, 2nd Ed. Vols. I-III, USA.
Pomrenz Y and Meloan CE. 1996. *Food analysis – theory and practice*. CBS, USA.
Ranganna S. 2001. *Handbook of analysis and quality control for fruit and vegetable products*. 2nd Ed. Tata-McGraw-Hill, New Delhi.
Thompson AK. 1995, *Postharvest technology of fruits and vegetables*. Blackwell sciences. USA.

Selected Journals

Sr. No.	Name of the Journal	ISSN No.
1.	*American Journal of Horticultural Sciences*	0003-1062
2.	*American Potato Growers*	
3.	*American Scientst*	1545-2786
4.	*Annals of Agricultural Research*	9703179
5.	*Annual Review of Plant Physiology*	0066-4294
6.	*California Agriculture*	1097-0967
7.	*Haryana Journal of Horticultural Sciences*	0970-2873
8.	*HAU Journal of Research*	0379-4008
9.	*Horticulture Research*	2052-7276
10.	*HortScience*	2327-9834
11.	*IIVR Bulletins*	1462-0316
12.	*Indian Horticulture*	0019-4875
13.	*Indian Journal of Agricultural Sciences*	0019-5022
14.	*Indian Journal of Horticulture*	0974-0112
15.	*Indian Journal of Plant Physiology*	2662-2548
16.	*Journal of American Society for Horticutural Sciences*	0003-1062
17.	*Journal of Arecanut and Spice Crops*	
18.	*Journal of Food Science and Technology*	0975-8402
19.	*Journal of Plant Physiology*	0176-1617
20.	*Journal of Biology and Technology*	0925-5214
21.	*Postharvest Biology and Technology*	0925-5214
22.	*Scientia Horticulturae*	0304-4238
23.	*Seed Research*	2151-6146
24.	*Seed Science*	23171537
25.	*South Indian Horticulture*	0038-3473
26.	*Vegetable Grower*	2330-2321
27.	*Vegetable Science*	2455-7552

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Floriculture and Landscaping

Preamble
(Floriculture and Landscaping)

Indian floriculture which remained homestead farming till late 80's assumed commercial significance during 90's owing to the favourable environment created by a series of reforms in economy and seed sector. This has paved the way for the import of new plant material, introduction of protected cultivation technology in the country. The area under flower crops got almost tripled from 1,06,000 ha during 2001–02 to 3,39,000 ha during 2018–19. Similar trend was also noticed in production of flowers in India with an overall production of 19.91 lakh tonnes. India's total export of floriculture was ₹ 571.38 Crores/ 81.94 USD Millions in 2018–19. The major importing countries were United States, Netherlands, United Kingdom, Germany and United Arab Emirates.

Contrary to belief, floriculture encompasses a large number of sub sectors that include loose flowers, cut flowers, cut foliage, specialty flowers, cut greens and fillers, pot plants, bedding plants, landscaping and interiorscaping, vertical gardening, dry flowers, lawns, arboriculture, essential oils, nutraceutical pigments, dyes, value addition, etc., Keeping in pace with the latest developments in these sectors, there is a need to update the knowledge among the students. An effort is therefore made to encompass the advances made in the sector by revising the post-graduate curriculum.

New courses like Systematics of ornamental plants; Indoor plants and Interioscaping, Nursery Management of ornamental plants; Turf grass management; Seed production in flower crops; Crop regulation in ornamental crops; Speciality flowers, fillers and cut greens; Vertical gardening; Modern approaches in breeding of floricultural crops; Current trends in production of floricultural crops; Recent developments in protected cultivation of floricultural crops are introduced in the new syllabus while retaining some of the old courses.

Keeping in view of the National Initiatives and priorities like Skill India and emphasis on StartUps to encourage students to become job creators rather than job seekers, new courses are added in different avenues of floriculture like Indoor plants and Interioscaping, Nursery management, Turfgrass management, Vertical gardening. These courses will help and encourage students to develop their skills and would pave way for different StartUps in these areas.

New courses like seed production in flower crops, Crop regulation in ornamental crops, Specialty flowers, fillers and cut greens are introduced in line with requirement to improve profitability of farmers/ growers. Seed production in flowers which is a high value, low volume segment was focussed upon which will boost our exports and help in improving profitability and improving farmers income. Crop regulation is an important aspect and need of the hour to avoid market glut, improve profitability and income of growers.

Rapid changes and development have occurred in global arena particularly in the field of biochemistry, molecular biology and biotechnology. Many advances took place in the area of application of biotechnology approaches in flower crops. A segment on genome editing systems/ tools like CRISPR-CAS is introduced into the syllabus keeping in view of the recent developments. Several new developments in the area of protected cultivation like automation, sensors, lighting, AI, robotics, retractable greenhouses, IPR, flower labels, etc. are given due emphasis in the new syllabus.

Flowers are highly perishable and fluctuation of prices is very high and marketing is a very crucial step where growers and entrepreneurs face problems. Topics on marketing, Agri export Zones, value chain and cold chain management and crop insurance were given importance. Government of India has introduced a number of schemes and mechanisms to support the farming community. To make the students aware about the recent steps taken by Government, topic on Institutional support is introduced. Farming community is rapidly diversifying in to areas like FPO's and contract farming and these areas are introduced.

Course Title with Credit Load
M.Sc. (Hort.) in Floriculture and Landscaping

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FLS 501*	Systematics of Ornamental Plants	2+1
FLS 502*	Breeding of Ornamental Plants	2+1
FLS 503*	Commercial Production of Cut Flowers	2+1
FLS 504*	Commercial Production of Loose Flowers	2+1
FLS 505*	Ornamental Gardening and Landscaping	2+1
FLS 506	Indoor Plants and Interiorscaping	1+1
FLS 507	Nursery Management in Ornamental Plants	2+1
FLS 508	Turf Grass Management	2+1
FLS 509	Value Addition in Floriculture	2+1
FLS 510	Protected Cultivation of Flower Crops	2+1
FLS 511	CAD for Landscaping	1+2
FLS 512	Seed Production in Flower Crops	1+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
FLS 591	Seminar	0+1
FLS 599	Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Floriculture and Landscaping

I. Course Title : Systematics of Ornamental Plants
II. Course Code : FLS 501
III. Credit Hours : (1+1)

IV. Why this course ?

Systematics of ornamental plants will give an in depth knowledge on nomenclature, description of genera, floral biology and use of molecular techniques in systematics of flower crops and ornamental crops.

V. Aim of the course

To familiarize students about the taxonomy, classification, nomenclature and descriptors of different ornamental crops.

The course is organized as follows

No	Blocks	Units
1	Nomenclature	Unit 1: History, origin, hotspots, classification and nomenclature systems Unit 2: International Code, Identification features, descriptors. Unit 3: Red Book, Registration with NBPGR, PPVFRA
2	Families	Unit 1: Rosaceae, Asteraceae, Caryophyllaceae, Orchidaceae, Aracaeae, Liliacaeae, Unit 2: Acanthaceae, Palmaceae, Asparagaceae, Malvaceae, Musaceae, Oleaceae, Iridaceae.
3	Molecular techniques systematics.	Unit 1: Molecular techniques in modern

VI. Theory

Block I: **Nomenclature**

Unit I: Nomenclature: History, origin, hotspots, classification and nomenclature systems.

Unit II: International systems: International Code, Treaties, International and National Organisations, Biodiversity Act, Identification features, descriptors.

Unit III: Red Book, Registration (NBPGR, PPVFRA, NBA).

Block 2: **Families**

Unit I: Families: Description and families and important genera Rosaceae, Asteraceae, Caryophyllaceae, Orchidaceae, Aracaceae, Liliacae.

Unit II: Acanthaceae, Palmaceae, Asparagaceae, Malvaceae, Musaceae, Oleaceae, Iridaceae.

Block 3: Molecular techniques

Unit I: Molecular techniques in modern systematics.

VII. Practical

- Different nomenclature systems of plants (2);
- Floral biology and taxonomic description of rose, chrysanthemum, orchids, carnation, gerbera, anthurium, marigold, tuberose, Jasmine, China aster, lilium, gypsophila (6);
- Cyropreservation and tissue culture repository (4);
- Molecular techniques (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures

IX. Learning outcome

After successful completion of this course,

- The students will have an in depth knowledge of nomenclature, description of important genera and use of molecular techniques in systematics of flower crop

X. Suggested Reading

Bhattacharya B and Johri BM. 2004. *Flowering Plants: Taxonomy and Phylogeny*. Narosa Publ. House, New Delhi, India. pp.753.

Dutta AC. 1986. *A Class Book of Botany*. Oxford Univ. Press, Kolkata, India.

Pandey BP. 2013. *Taxonomy of Angiosperms*. S. Chand & Co. pp. 608.

Rajput CBS and Haribabu RS. 2014. *Citriculture*, Kalyani Publishers, New Delhi, India.

Spencer RR, Cross R and Lumley P. 2007. *Plant Names*. 3rd Ed. *A Guide to Botanical Nomenclature*. CSIRO Publ., Australia., 176 p.

Vasistha BB. 1998. *Taxonomy of Angiosperms*. Kalyani Publishers, New Delhi, India.

I. Course Title : Breeding of Ornamental Crops

II. Course Code : FLS 502

III. Credit Hours : (2+1)

IV. Why this course ?

Breeding novel and desired varieties is very important for growth of floriculture Industry. Students should have a thorough understanding of principles of plant breeding, genetic mechanisms and breeding methods in ornamental crops for making improvement in these crops.

V. Aim of the course

To impart comprehensive knowledge about the principles and practices of breeding of ornamental plants.

The course is organized as follows

No	Blocks	Units
1	Principles of Plant Breeding	I. Principles of plant breeding II. Intellectual Property and Plant Breeders Rights III. Genetic mechanisms and inheritance
2	Breeding methods	I. Breeding methods II. Role of biotechnology

VI. Theory

Block 1: Principles of Plant Breeding

Unit I: Principles of plant breeding: Principles of plant breeding; Origin, evolution, distribution, introduction, domestication and conservation of ornamental crops.

Unit II: Intellectual Property and Plant Breeders Rights: Introduction and initiatives in IPR and PBR of ornamental crops.

Unit III: Genetic mechanisms and inheritance: Breeding objectives, reproductive barriers (Male sterility, incompatibility) in major ornamental crops. Inheritance of important traits, Genetic mechanisms associated with flower colour, size, form, doubleness, fragrance, plant architecture, post-harvest life, abiotic and biotic stress tolerance/ resistance.

Block 2: Breeding methods

Unit I: Breeding methods: Breeding methods suitable for sexually, asexually propagated flower crops, self and cross pollinated crops- pedigree selection, backcross, clonal selection, polyploidy and mutation breeding, heterosis and F1 hybrids.

Unit II: Role of biotechnology: Role of biotechnology in improvement of flower crops including somaclonal variation, *in-vitro* mutagenesis, *in-vitro* selection, genetic engineering, molecular markers, etc.

Crops

Rose, chrysanthemum, carnation, gerbera, gladiolus, orchids, anthurium, lilium, marigold, jasmine, tuberose, dahlia, gaillardia, crossandra, aster, etc., Flowering annuals: petunia, zinnia, snapdragon, stock, pansy, calendula, balsam, dianthus, etc. Important ornamental crops like aglaonema, diffenbachia, hibiscus, bougainvillea, kalanchoe, etc.

VII. Practical

- Floral biology of important ornamental crops (2);
- Cytology and cytogenetics (2);
- Selfing and crossing procedures for important ornamental crops (2);
- Evaluation of hybrid progenies (2);
- Induction of mutants through physical and chemical mutagens (2);
- *In-vitro* selection, genetic engineering (2);
- Induction of polyploidy (2);
- DUS testing (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures

IX. Learning outcome

After successful completion of course, the students are expected to have

- Thorough understanding of principles of plant breeding and genetic mechanisms in different ornamental plants and flowers.
- Application of different breeding methods for improvement of ornamental crops
- Develop the required skills in conventional and advanced breeding

X Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Pointer Publ., Reprint, 6 vols, pp. 2065.

Bose TK and Yadav LP. 1989. *Commercial flowers*. Naya Prokash, Kolkata, India.

Callaway DJ and Callaway MB. 2009. *Breeding Ornamental Plants*. Timber Press. Revised edition, pp. 359.

Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.

Chadha KL and Choudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

Chaudhary RC. 1993. *Introduction to Plant Breeding*. Oxford & IBH Publ.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Cut Flowers*. Kruger Brentt Publisher UK Ltd. pp.584.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.

Singh BD. 2016. *Plant Breeding Principles and Methods*. Kalyani Publishers, New Delhi-Ludhiana, India.

Vainstein A. (Ed). 2002. *Breeding for ornamental crops: Classical and Molecular Approaches*. Springer-Science-Business Media, B.V. Edition 1. pp. 392.

Watts L. 1980. *Flower and Vegetable Plant Breeding*. Unilever Research, Sharnbrook, Bedford, UK. pp 182. Grower Books, London, UK.

I. Course Title : Commercial Production of Cut Flowers

II. Course Code : FLS 503

III. Credit Hours : (2+1)

IV. Why this course ?

Cut flowers are grown in a wide variety of environments and agroclimatic regions. The students of floriculture need to have an understanding of production and post harvest management of important cut flower crops on a commercial scale.

V. Aim of the course

To impart basic knowledge about the importance and production dynamics of cut flowers grown in India.

The course is organized as follows

No	Blocks	Units
1	Production management	I. Scope and scenario II. Growing environment

No	Blocks	Units
		III. Crop Management IV. Flower regulation
2	Post harvest management and marketing	I. Post harvest management II. Marketing

VI. Theory

Block 1: Production management

Unit I: Scope and scenario: National and International scenario, importance and scope of cut flower trade, constraints for cut flower production in India.

Unit II: Growing environment: Soli analysis, soil health card, Growing environment, open cultivation, protected cultivation, soil/ media requirements, land preparation, planting methods, influence of light, temperature, moisture, humidity and microclimate management on growth and flowering.

Unit III: Crop management: Commercial Flower production – Commercial varieties, water and nutrient management, fertigation, weed management, crop specific practices, ratooning, training and pruning, pinching, deshooting, bending, desuckering, disbudding. Use of growth regulators, physiological disorders and remedies, IPM and IDM.

Unit IV: Flower regulation: Flower forcing and year round/ offseason flower production through physiological interventions, chemical regulation, environmental manipulation.

Block 2: Post-harvest management and marketing

Unit I: Post harvest management: Cut flower standards and grades, harvest indices, harvesting techniques, post-harvest handling, Methods of delaying flower opening, Pre-cooling, pulsing, packing, storage and transportation.

Unit II: Marketing: Marketing, export potential, institutional support, Agri Export Zones, 100% Export Oriented units, Crop Insurance.

Crops

Rose, chrysanthemum, gladiolus, tuberose, carnation, gerbera, orchids, lilium, anthurium, china aster, alstroemeria, bird of paradise, heliconia, alpinia, ornamental ginger, dahlia, gypsophila, solidago, limonium, stock, cut greens and fillers.

VII. Practical

- Identification of varieties (1);
- Propagation (2);
- Microclimate management (2);
- Training and pruning techniques (1);
- Pinching, deshooting, disbudding, desuckering (1);
- Practices in manuring, drip and fertigation, foliar nutrition, growth regulator application (2);

- Harvesting techniques, post-harvest handling, cold chain (2);
- Economics, Project preparation for regionally important cut flowers, crop specific guidelines for project financing (NHB guidelines) (2);
- Visit to commercial cut flower units (2);
- Case studies (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to–

- Understand the scope and scenario of floriculture
- A thorough understanding of production and post harvest management of flower crops.
- Acquire the required skills to prepare project reports on different crops for financing.

X. Suggested Reading

Arora JS. 2010. *Introductory Ornamental Horticulture*. Kalyani Publishers. 6th edition, pp. 230.

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Bose TK, Maiti, RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Prokash, Kolkata, India.

Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.

Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.

Chadha KL and Chaudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

Dole JM and Wilkins HF. 2004. *Floriculture-Principles and Species*. Prentice Hall. 2nd edition, pp. 1048.

Larson RA. 1980. *Introduction to Floriculture*. New York Academic Press. pp. 628.

Laurie A and Rees VH. 2001. *Floriculture-Fundamentals and Practices*. Agrobios Publications, Jodhpur. pp.534.

Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publications, Jodhpur.

Randhawa GS and Mukhopadhyay A. 2001. *Floriculture in India*. Allied Publ. pp 660.

Reddy S, Janakiram T, Balaji Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.

Singh AK. 2006. *Flower Crops: Cultivation and Management*. New India Publ. Agency, New Delhi, India. pp. 475.

I. Course Title : Commercial Production of Loose Flowers

II. Course Code : FLS 504

III. Credit Hours : (2+1)

IV. Why this course ?

Loose flowers are grown in a wide range of agroclimatic regions. The students of floriculture need to have an understanding of production and post harvest management of important loose flower crops.

V. Aim of the course

To impart basic knowledge about the importance and management of loose flowers grown in India.

The course is organized as follows

No	Blocks	Units
1	Production management	I. Scope and scenario II. Growing environment III. Crop management IV. Flower regulation
2	Post harvest management and marketing	I. Post harvest management II. Marketing

VI. Theory

Block 1: Production management

Unit I: Scope and scenario: Scope, scenario and importance of loose flowers, constraints and opportunities in loose flower production.

Unit II: Growing environment: Nursery management, pro-tray nursery under shade nets, soil and climate requirement, Field preparation, systems of planting.

Unit III: Crop management: Soli analysis, soil health card, water and nutrient management, weed management, training and pruning, special horticultural practices such as pinching and disbudding, use of growth regulators, physiological disorders and remedies, INM, IPM and IDM.

Unit IV: Crop regulation: Flower forcing and year round flowering, production for special occasions through physiological interventions, chemical regulation.

Block 2: Post harvest management and marketing

Unit I: Post harvest management: Harvest indices, harvesting techniques, post-harvest handling and grading, pre-cooling, packaging and storage.

Unit II: Marketing: Important local markets, Export potential, transportation and marketing, APMC and online trading, institutional support, Crop Insurance.

Crops

Rose, jasmine, chrysanthemum, marigold, tuberose, china aster, crossandra, gaillardia, spider lily, hibiscus, nerium, barleria, celosia, gomphrena, Madar (*Calotropis gigantea*), nyctanthes (Harsingar), tabernaemontana (Chandni), lotus, water lily, michelia (Champa), gardenia, ixora and balsam.

VII. Practical

- Identification of species and varieties (1);
- Propagation and nursery management (1);
- Training and pruning techniques (1);
- Fertigation, foliar nutrition, growth regulator application (2);

- Crop protection (2);
- Pinching, disbudding, staking, harvesting techniques (1);
- Post-harvest handling, storage and cold chain (2);
- Project preparation for regionally important commercial loose flowers. crop specific guidelines for project financing (NHB guidelines) (2);
- Cost Economics (2);
- Exposure Visits to fields (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students would have

- A thorough understanding of production and post harvest management of loose flowers.
- Develop the required skills on commercial production management

X. Suggested Reading

Arora JS. 2010. *Introductory Ornamental Horticulture*. Kalyani Publi. 6th Edition, pp. 230.

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Bose T K, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and landscaping*. Naya Prokash, Kolkata, India.

Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.

Chadha KL and Bhattacharjee S K. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.

Chadha KL and Chaudhury B.1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

Laurie A and Rees VH. 2001. *Floriculture-Fundamentals and Practices*. Agrobios Publ., Jodhpur. pp.534.

Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.

Randhawa GS and Mukhopadhyay A. 2001. *Floriculture in India*. Allied Publ. pp 660.

Sheela VL. 2008. *Flowers for Trade*. Horticulture Science Series, vol.10, pp. 392. New India Publ. Agency, New Delhi, India.

I. Course Title : Ornamental Gardening And Landscaping

II. Course Code : FLS 505

III. Credit Hours : (2+1)

IV. Why this course ?

Ornamental gardening and landscaping is an important course which gives a thorough understanding of different types of gardens and their components. The students need to imbibe the principles of landscaping and should develop skills for planning under different situations.

V. Aim of the course

Familiarization with principles and practices of landscaping

The course is organized as follows

No	Blocks	Units
1	Gardens and components	I. Styles and types of gardens II. Garden components III. Specialized gardens
2	Landscape planning	I. Principles and elements of landscaping II. Landscaping for different situations

VI. Theory

Block 1: Gardens and components

Unit I: Styles and types of gardens: Historical background of gardening, Importance and scope of ornamental gardening, styles and types of gardens, formal and informal style gardens. English, Mughal, Japanese, Persian, Spanish, Italian, French, Hindu and Buddhist gardens.

Unit II: Garden components: Garden components (living and non-living): arboretum, shrubbery, fernery, palmatum, arches and pergolas, edges and hedges, climbers and creepers, cacti and succulents, herbs, annuals, flower borders and beds, ground covers, carpet beds, colour wheels, clock garden, bamboo groves, bonsai; Non -living components like-path, garden gate, fencing, paving and garden features like fountains, garden seating, swings, lanterns, basins, bird baths, sculptures, waterfalls, bridge, steps, ramps, Lawn -genera and species, establishment and maintenance.

Unit III: Specialized gardens: Specialised gardens such as vertical garden, roof garden, terrace garden, water garden, sunken garden, rock garden, shade garden, temple garden, sacred gardens (with emphasis on native plants), Zen garden.

Block 2: Landscape planning

Unit I: Principles and elements of landscaping: Basic drawing skills, use of drawing instruments garden symbols, steps in preparation of garden design, programmes phase, design, phase, etc.

Elements and principles of landscape design. Organization of spaces, visual aspects of plan arrangement- view, vista and axis. Principles of circulation, site analysis and landscape, water requirement, use of recycled water.

Unit II: Landscaping for different situations: Urban landscaping, Landscaping for specific situations such as residential, farm houses, institutions, corporate sector, industries, hospitals, roadsides, traffic islands, Children parks, public parks, xeriscaping, airports, railway station and tracks, river banks and dam sites and IT/ SEZ parks. Bio-aesthetic planning, eco-tourism, theme parks, indoor gardening, therapeutic gardening.

VII. Practical

- Graphic language and symbols in landscaping, study of drawing instruments, viz., 'T' square, setsquare, drawing board, etc. (1);
- Identification of various types of ornamental plants for different gardens and occasions (1);
- Preparation of land, planning, layout and planting, deviations from landscape principles (1);
- Case study (1);
- Site analysis, interpretation of map of different sites, use of GIS for selection (1);
- Enlargement from blue print. Landscape design layout and drafting on paper as per the scale (2);
- Preparation of garden models for home gardens, farm houses, industrial gardens, institutional gardens, corporate, avenue planting, practices in planning and planting of special types of gardens.(3);
- Burlapping, lawn making, planting of edges, hedges, topiary, herbaceous and shrubbery borders (2);
- Project preparation on landscaping for different situations, creation of formal and informal gardens (2);
- Visit to parks and botanical gardens (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training on different models of landscaping
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to be

- The students will be apprised of different types of gardens and have a thorough understanding of principles of landscape gardening
- Develop skills for landscaping under different situations and layout of garden components.

X. Suggested Reading

Bose TK, Chowdhury B and Sharma SP. 2011. *Tropical Garden Plants in Colour*. Hort. and Allied Publ.

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Grewal HS and Singh P. 2014. *Landscape Designing and Ornamental Plants*. Kalyani Publishers, New Delhi.

Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices*.Agrobios Publ., Jodhpur.

Misra RL and Misra S. 2012. *Landscape Gardening*. Westville Publ. House, New Delhi, India.

Nambisan KMP. 1992. *Design Elements of Landscape Gardening*. Oxford & IBH Publ. Co., New Delhi, India.

Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.

Sabina GT and Peter KV. 2008. *Ornamental Plants for Gardens*. New India Publ. Agency, New Delhi, India.

Singh A and Dhaduk BK. 2015. *A Colour Handbook: Landscape Gardening*. New India Publ. Agency, New Delhi, India.

Valsalakumari PK, Rajeevan PK, Sudhadevi PK and Geetha CK. 2008. *Flowering Trees*. New India Publ. Agency, New Delhi, India.
Woodrow MG.1999. *Gardening in India*. Biotech Books, New Delhi, India.

I. Course Title : Indoor Plants and Interiorscaping
II. Course Code : FLS 506
III. Credit Hours : (1+1)

IV. Why this course ?

Indoor plants are an important component of floriculture. They not only improve the aesthetic environment of indoors but are also known to improve indoor air quality. The students in floriculture need up to date knowledge on factors affecting indoor growing, types, cultural operations and different principles of interiorscaping.

V. Aim of the course

To facilitate deeper understanding of the benefits of indoor plants, selection, designing and their management.

The course is organized as follows

No	Blocks	Units
1	Scope, principles and operations	I. Importance and scope II. Classification and principles III. Cultural operations
2	Presentations and marketing	I. Special gardens II. Vertical gardens III. Marketing

VI. Theory

Block 1: Scope, principles and operations

Unit I: Importance and scope: Importance and scope of indoor plants and Interiorscaping, Indoor plants and Indoor air quality.

Unit II: Classification and principles: Factors affecting growth, development and flowering of Indoor plants. Classification of indoor plants based on light, temperature, humidity and pollution tolerance, Description and cultivation of various indoor plants. Principles of Interiorscaping, Role in pollution mitigation.

Unit III: Cultural operations: Containers and substrates, preparation of growing media, propagation, training, grooming, nutrition, management of disease, pests and weeds. Maintenance of plants including repotting, foliar nutrition, light exposure and plant rotation. Media standards, Nursery and Export standards for potted plants, Nursery standards.

Block 2: Presentations and marketing

Unit I: Special gardens: Special gardens including miniature gardens and plant stand. Presentations like dish, terrarium, bottle gardens, hanging baskets, window boxes and Bonsai.

Unit II: Vertical gardens: Vertical gardens- History, planting material, structures, containers, substrate, water and nutrient management, supplemental lighting.

Unit III: Marketing: Marketing channels, Business models including plant rentals.

VII. Practical

- Identification of important house plants (2);
- Media and containers (1);
- Propagation (1);
- Cultural operations, maintenance and economics of indoor plants (2);
- Models for Interiorscaping (2);
- Familiarization with different indoor gardens (2);
- Making of terrariums, bottle garden, dish garden and their economics (2);
- Making of vertical gardens and economics (2);
- Exposure visits (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to develop

- Deep understanding and knowledge of principles affecting indoor cultivation including vertical gardens
- Develop required skills in interiorscaping
- Develop required entrepreneurial acumen

X. Suggested Reading

Barbara P. 2005. *The Complete Houseplant Survival Manual*. Storey Publ., New Adams.
Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.
Wallach C. 1995. *Interior Decorating with Plants*. McMillan Seed Production Co. Inc., New York.

I. Course Title : Nursery Management for Ornamental Plants

II. Course Code : FLS 507

III. Credit Hours : (2+1)

IV. Why this course ?

Nursery management is very essential for production of quality planting material in ornamental plants. The course gives a thorough understanding of propagation of different ornamental plants, nursery management, standards, law and certification.

V. Aim of the course

Familiarization with principles and practices of propagation and nursery management for Ornamental plants.

The course is organized as follows:

No	Blocks	Units
1	Nursery Industry and Propagation	I Scenario of nursery industry and sexual propagation II Asexual propagation III Micropropgation
2	Nursery Management	I Growing structures II Sanitary and phytosanitary issues III Standards

VI. Theory

Block 1: Nursery Industry and Propagation

Unit I: Scenario of nursery industry and sexual propagation: Importance and present scenario and status of nursery industry in India and in the world, life cycles in plants, Propagation methods, Factors influencing seed germination of flower crops, dormancy, seed quality, packing, storage, certification, testing. Hormonal regulation of germination and seedling growth.

Unit II: Asexual propagation: Methods of asexual propagation, rooting of soft and hard wood cutting under mist. Role of Plant growth regulators. Physiological, anatomical and biochemical aspects of root induction in cuttings. Layering – principles and methods, budding and grafting – selection of elite mother plants. Stock, scion and inter stock, relationship – Incompatibility.

Unit III: Micropropagation: Micro-propagation – principles and concepts, commercial exploitation in flower crops. Techniques – *in-vitro* clonal propagation, direct organogenesis, embryogenesis, micrografting, meristem culture. Hardening, packing and transport of micro-propagules.

Block 2: Nursery Management

Unit I: Growing structures: Growing structures like mist chambers, tunnels, lath house, net house, growing media types, soil less culture and containers. Automation in nursery management.

Unit II: Sanitary and phyto-sanitary issues: Nursery – types, components, planning and layout. Nursery management practices for healthy propagule production. Nursery Act, PPV&FR act and Quarantine system in India. Important quarantine pests and diseases, sanitary and phyto-sanitary issues threats to nursery Industry.

Unit III: Standards: Nursery standards, Hi-tech nurseries, garden centers.

VII. Practical

- Anatomical studies in rooting of cutting and graft union (2);
- Identification and production of plug plants, seedlings and saplings (2);
- Preparation of growing media and use of PGRs (2);
- Practice of propagation through specialized structures cuttings, layering, budding and grafting (2);
- Case studies (2);

- Micropropagation of ornamental crops and hardening (3);
- Visit to tissue culture labs and nurseries (2);
- Economics (1).

VIII. Teaching Methods/ Activities
- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,
- The students will develop thorough understanding of nursery management in flower crops.
- Empower the students with the knowledge to start an enterprise
- Hone adequate skill in propagation and management

X. Suggested Reading

Adriance GW and Brison FR. 2000. *Propagation of Horticultural Plants*. Biotech Books, New Delhi, India.

Bose TK, Mitra SK and Sadhu M K. 1991. *Propagation of Tropical and Subtropical Horticultural Crops*. Naya Prokash, Kolkata, India.

Chadha KL, Ravindran PL and Leela Sahijram. 2000. *Biotechnology in Horticulture and Plantation Crops*. Malhotra Publ. House, New Delhi, India.

Davies Fred T Jr., Geneve RL, Wilson SB, Hartmann HT and Kester DL. 2018. *Hartmann and Kester's Plant Propagation: Principles and Practices*. Pearson Publ. 9th Edition.

Peter KV. 2008. *Basics of Horticulture*. New India Publ. Agency, New Delhi, India.

Rajan S and Baby LM. 2007. *Propagation of Horticultural Crops*. New India Publ. Agency, New Delhi, India. pp. 251.

Singh SP. 1989. *Mist Propagation*. Metropolitan Book Co., New Delhi, India.

I. Course Title : Turfgrass Management

II. Course Code : FLS 508

III. Credit Hours : (2+1)

IV. Why this course ?

Turf grass management deals with establishment and maintenance of different turf grasses for aesthetic, recreational and sports purposes. The course deals with basic types, requirement of turf grasses, management and development of turf for different purposes.

V. Aim of the course

To understand the science, principles and management of turf grasses.
The course is organized as follows:

No	Blocks	Units
1	Turf Industry and turf management	I Prospects and basic requirement
		II Types of turf grasses
		III Operations and management
2	Turf for different ground	I Making of different sports arenas
		II Automation in turf management

VI. Theory

Block 1: Turf industry and turf grasses

Unit I: Prospects and basic requirement: History, present status and prospects of turf industry; basic requirements, site selection and evaluation, concepts of quality of soil pertaining to turf grass establishment, criteria for evaluation of turf quality.

Unit II: Types of turf grasses: Types, species, varieties, important breeders, grasses for different locations and conditions and their compatible groupings as per climatic conditions; Turfing for roof gardens.

Unit III: Operations and management: Preparatory operations; Turf establishment methods such as seeding, sprigging/ dibbling, plugging, sodding/ turfing, turf plastering, instant turfing (portable), hydro-seeding, synthetic turfing. Turf management – Irrigation, drainage, nutrition, special practices like aerating, rolling, coring, dethatching, verticutting, soil top dressing, use of plant growth regulators and micronutrients, Turf mowing – mowing equipments, techniques to minimize wear and compaction, weed control, biotic and abiotic stress management in turfs, standards for turf, use of recycled water, etc.

Block 2: Turf for different grounds

Unit I: Making of different sports arenas: Establishment and maintenance of turfs for playgrounds, viz., golf, football, hockey, cricket, tennis, rugby, residential and public parks, turfing of Govt. and Corporate office gardens, event specific preparation, turf colourants.

Unit II: Automation: Exposure to different tools, gadgets, machinery used in turf industry.

VII. Practical

- Identification of turf grasses and turf machinery (1);
- Soil preparation, turf establishment methods, provision of drainage (2);
- Layout of macro and micro irrigation systems (1);
- Water and nutrient management (2);
- Special practices – mowing, raking, rolling, soil top dressing, weed management (2);
- Biotic and abiotic stress management (2);
- Project preparation for turf establishment (2);
- Visit to parks, model cricket grounds and golf courses, airports, corporates, Govt. organizations (2);
- Rejuvenation of lawns (1);
- Turf economics (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to

- Deep understanding and knowledge of different types of grasses and their management
- Developing skills for turfing of different arenas
- Develop required entrepreneurial acumen

X. Suggested Reading

Aldous D.1999. *International Turf Management Handbook*. CRC Press. pp.368.

Beard JB. 1972. *Turf Grass Science and Culture*. Pearson. 1st edition, pp. 672.

Chawla SL, Patil S, Patel MA, Patel RB and Patel RM. 2013. *Turf grass Management*. Publised by NAU, Navsari.

Emmons R. 2007. *Turf grass Science and Management*. Cengage Learning Publ. 4th edition, pp. 592.

Nick-Christians. 2011. *Fundamentals of Turf grass Management*. Wiley; 4th Edition, pp. 424.

Turgeon AJ. 1980. *Turf grass Management*. Reston Publ. Inc.

I. Course Title : Value Addition in Floriculture

II. Course Code : FLS 509

III. Credit Hours : (2+1)

IV. Why this course ?

Value addition is done to increase the economic value of any floriculture commodity. Students need to develop thorough understanding of scope, scenario and different methods of value addition so that they can improve the income of the stakeholders by value addition.

V. Aim of the course

To understand the avenues for value addition in floriculture

The course is organized as follows:

No	Blocks	Units
1	Value added products	I Scope and scenario II Value addition of loose flowers III Floral Arrangements IV Dry flowers
2	Extraction of value added products	I Essential oils II Pigments and nutraceuticals

VI. Theory

Block 1: Value added products

Unit I: Scope and scenario: Scope and prospects of value addition, National and global scenario, production and exports. Types of value added products, techniques of value addition including tinting.

Unit II: Value addition in loose flowers: Value addition in loose flowers and product development- Gulkhand, floral tea, rose oil, rose water, Pankhuri, floral dyes, rose sherbet, floral ice creams, sweets, etc.

Unit III: Floral Arrangements: Selection of containers and accessories for floral products and decorations. Flower arrangement, styles, ikebana schools (*ikenobo, ohara, sogetsu,* etc.), Ikebana- moribana, nagiere, contemporary style.

Unit IV: Dry flowers: Dry flowers– Identification and selection of flowers and plant parts; Raw material procurement, preservation and storage; tips for collecting dry flower making, selection of stages for picking of flowers for drying, Techniques in dry flower making – Drying, glycerising, bleaching, dyeing, embedding, pressing; Accessories; Designing and arrangement – dry flower baskets, bouquets, pot-pourri, wall hangings, button holes, greeting cards, wreaths; petal embedded handmade papers, Packaging and storage. Post drying management including moisture, pests and molds.

Block 2: Extraction of value added products

Unit I: Essential oils: Essential oils; Selection of species and varieties (including non-conventional species), extraction methods, Packing and storage, Aromatherapy.

Unit II: Pigments and nutraceuticals: Types of pigments, carotenoids, anthocyanins, chlorophyll, betalains; Significance of natural pigments as nutraceuticals, Extraction methods and applications in food, pharmaceutical and poultry industries.

Unit III: Dying: Synthetic and Natural dyes, dying techniques, colour retention,

VII. Practical

- Practices in preparation of different type of flower arrangements including bouquets, button-holes, flower baskets, corsages, floral wreaths, garlands with fresh flowers (4);
- Techniques in flower arrangement and floral decoration (2);
- Identification of plants for dry flower making (2);
- Practices in dry flower making; Preparation of dry flower baskets, bouquets, pot-pourri, wall hangings, button holes, greeting cards, wreaths, etc. (2);
- Essential oil extraction units (1);
- Extraction of pigments (2);
- Visit to dry flower units (2);
- Economics of value added products (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to

- Understand and prepare different value added products from flowers
- Develop entrepreneurial acumen
- Imbibe the skills for making various value added products

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants.* Vol. XII, Parts 1 & 2. pp.533 and pp.574. Malhotra Publ. House, New Delhi, India.

Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices.*Agrobios Publ., Jodhpur.

Nowak J and Rudnicki RM. 1990. *Postharvest handling and storage of cut flowers, florist greens, and potted plants*. Timber Press, USA. pp. 210.

Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.

Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.

I. Course Title : Protected Cultivation of Flower Crops

II. Course Code : FLS 510

III. Credit Hours : (2+1)

IV. Why this course ?

Protected cultivation is more rewarding in production of high value cut flowers. With appropriate structures and plant environment control measures, the constraints of environment prevalent in the region can be overcome allowing almost year-round cultivation. The students need a thorough understanding of principles, types, designs, crops for different environments and management of environment in protected cultivation.

V. Aim of the course

Understanding the principles, theoretical aspects and developing skills in protected cultivation of flower crops.

The course is organized as follows

No	Blocks	Units
1	Principles and types	I Prospects and types of protected structures
		II Principles and designs
2	Growing Environment	I Control of environment
		II Crop management and crop regulation
		III Automation and standards

VI. Theory

Block 1: Principles and types

Unit I: Prospects and types of protected structures: Prospects of protected floriculture in India; Types of protected structures – Glasshouse/ polyhouse, shadenet houses, mist chambers, lath houses, orchidarium, fernery, rain shelters, etc.

Unit II: Principles and design: Principles of designing and erection of protected structures; Low cost/ Medium cost/ High cost structures; Location specific designs; Structural components; Suitable flower and foliage plants for protected cultivation.

Block 2: Growing environment

Unit I: Control of environment: Microclimate management and manipulation of temperature, light, humidity, air and CO_2; Heating and cooling systems, ventilation, naturally ventilated greenhouses, fan and pad cooled greenhouses, light regulation, water harvesting.

Unit II: Intercultural operations and crop regulation: Containers and substrates, media, soil decontamination, layout of drip and fertigation system, water and nutrient management, IPM and IDM, Crop regulation by chemical methods and special horticultural practices (pinching, disbudding, deshooting, deblossoming, etc.); Staking and netting, Photoperiod regulation.

Unit III: Automation and standards: Automation in greenhouses, sensors, solar greenhouses and retractable greenhouses, GAP/ Flower labels, Export standards, EXIM policy, APEDA regulations for export, Non-tariff barriers.

Crops

Rose, Chrysanthemum, Carnation, Gerbera, Orchids, Anthuriums, Lilium, Limonium, Lisianthus, heliconia, Cala lily, Alstromeria, etc.

VII. Practical

- Study of various protected structures (1);
- Design, layout and erection of different types of structures (2);
- Practices in preparatory operations, growing media, soil decontamination techniques (2);
- Microclimate management (2);
- Practices in drip and fertigation techniques, special horticultural practices (2);
- Determination of harvest indices and harvesting methods (1);
- Postharvest handling, packing methods (1);
- Economics of cultivation, Project preparation (2);
- Project Financing guidelines (1);
- Visit to commercial greenhouses (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to be acquire

- Knowledge on types, design and principles of protected structures
- Thorough understanding of principles of microclimate management and crop management.
- Develop the required skills for designing a greenhouse
- Acquire skills on microclimate management, production management

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash,

Kolkata, India.
Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.
Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp.533 and pp.574. Malhotra Publ. House, New Delhi, India.
Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices*.Agrobios Publ., Jodhpur.
Nelson PV. 2011. *Green House Operation and Management*. Pearson Publ. 7th edition, pp. 624.
Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.
Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.
Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India

I. Course Title : CAD for Landscaping

II. Course Code : FLS 511

III. Credit Hours : (1+2)

IV. Why this course ?

CAD is widely used in landscaping planning and design. The students need to develop in depth knowledge of CAD software so that they can modify raw data into plans, drawing and models for landscape planning.

V. Aim of the course

To impart basic knowledge about the Computer Aided Designing (CAD) of landscape.

The course is organized as follows

No	Blocks	Units
1	CAD	I CAD basics and applications
		II 2D drawing
2	ARCHICAD	I 3D drawing
		II Dimensioning and visualization

VI. Theory

Block 1: CAD

Unit II: CAD basics and applications: Principles of integrating the architecture and landscaping, Exposure to CAD (Computer Aided Designing) – Applications of CAD in landscape garden designing, 2D drawing by AUTOCAD, Creating legends for plant and non-plant components, Basics of Photoshop software in garden designing.

Unit II: 2D drawing: 2D drawing methods, AUTOCAD Basics, Coordinate systems in AUTOCAD LT 2007, Point picking methods, Toolbars and Icons, File handling functions, Modifying tools, Modifying comments, Isometric drawings, Drafting objects. Using patterns in AUTOCAD drawing, Dimension concepts, Hyperlinking, Script making, Using productivity tools, e-transmit file, making sample drawing for outdoor and indoor garden by AUTOCAD 2D Drawing techniques, Drawing web format design, Making layout.

Block 2: ARCHICAD

Unit I: 3D drawing: 3D drawing methods, 3D drawing by ARCHICAD, 3D drawing by 3D MAX software, ARCHICAD file system, Tools and Infobox, modification tools, structural elements, GDL objects (Grid Dimensional Linking), Creation of garden components through ARCHICAD.

Unit II: Dimensioning and visualization: ARCHICAD organization tools, Dimensioning and detailing of designs, Landscape designing softwares and CD ROM for ornamental plant material (TRES, HIMFLORA, CAPSSA, etc), Attribute settings of components, Visualization tools for landscape preview, Data management, plotting and accessories for designing, Inserting picture using photoshop, Making sample drawing for outdoor and indoor gardens.

VII. Practical

- Practices in point picking methods, Using tool bars and icons, Using modifying tools and modifying comments (4);
- Isometric drawings, Using productivity tools (2);
- Drawing designs by AUTOCAD for home garden, institutional garden and special types of garden (4);
- Using tools and info-box for 3D drawing, Creation of garden components with ARCHICAD (4);
- Organization, dimensioning, detailing and visualization tools with ARCHICAD (4);
- Using Photoshop package for 3D picture insertion (2);
- Drawing designs with ARCHICAD for home garden, interior garden designing, IT parks, Corporates, Theme parks and Ecotourism spots (6);
- Exposure visits (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to develop

- The students will be able to use CAD and ARCHICAD for landscape planning and designing.
- Develop the adequate skills to create 3 D model to showcase interaction of different factors in landscape gardening.
- Develop the entrepreneurial acumen

X. Suggested Reading

Christine, Wein-Ping Yu. 1987. *Computer-aided Design: Application to Conceptual Thinking in Landscape Architecture*. amazon.com.

Misra RL and Misra S. 2012. *Landscape Gardening*. Westville Publ. House, New Delhi, India.

I. Course Title : Seed Production in Flower Crops

II. Course Code : FLS: 512

III. Credit Hours : (1+1)

IV. Why this course ?

Seed production of flowers is a highly remunerative enterprise. The students need to have knowledge of seed industry, seed production methods and seed certification. This course provides hands on training on seed production of important flower crops.

V. Aim of the course

To impart basic knowledge about the importance of seed production in important flower crops.

The course is organized as follows

No	Blocks	Units
1	Seed Industry	I Scenario of Seed industry
2	Hybrid Seed Production	I Seed Production methods
		II Population improvement
		III F1 Hybrid production
3	Regulations	I Seed certification and standards

VI. Theory

Block 1: Seed Industry

Unit I: Scenario of Seed Industry: Scope, scenario and importance of seed production in flower crops. Constraints in flower seed production. Marketing and economics of flower seeds.

Block 2: Hybrid Seed Production

Unit I: Seed production-Methods: Methods of seed production, agrotechniques for production of nucleus, breeder and certified seeds. Harvesting, seed processing, seed priming, seed chain, packaging and storage.

Unit II: Population improvement: Mass selection, progeny selection.Use of incompatibility and male sterility, maintenance of variety and seed production in flower crops.

Unit III: F1 hybrids: F1 hybrid seed production advantages, steps involved in hybrid seed production, pollination behaviour and isolation, pollination management methods in production of F1/ hybrids in different flower crops.

Block 3: Regulations

Unit I: Seed certification and standards: Seed certification, Seed standards, seed act, plant breeders rights and farmers' rights, Bio safety, handling of transgenic seed crops, importing of seeds and OGL, trade barriers in seed business, sanitary and phytosanitaty issues, custom clearance and quarantine.

Crops

Marigold, petunia, antirrhinum, zinnia, pansy, lupin, calendula, phlox, vinca, dianthus, sunflower, annual chrysanthemum, poppy, corn flower, rice flower.

VII. Practical

- Seed production of open pollinated varieties (2);
- Seed production of cross pollinated varieties (2);
- Steps involved in hybrid seed production (2);
- Hybrid seed production in different flower crops like marigold, petunia, antirrhinum, zinnia, pansy, lupin, calendula, phlox, vinca, dianthus, sunflower, annual chrysanthemum, etc. (6);
- Visit to seed industry (3);
- Visit to quarantine facility (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will get a thorough knowledge on seed industry, principles and methods of seed production in flower crops.
- Students will get awareness on seed standards, certification and law in flower crops.

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Bose TK, Yadav LP, Pal P, Parthasarathy VA and Das,P. 2003. *Commercial Flowers*. Vol. I & II. Naya Udyog, Kolkata, India.

Davies, Fred T Jr., Geneve RL, Wilson SB, Hartmann HT. Kester DL. 2018. *Hartmann and Kester's Plant Propagation: Principles and Practices*. Pearson Publ.9th Edition.

Larson RA and Armitage AM. 1992. *Introduction of Floriculture*. International Book Distributing Co., Lucknow, India.

Course Title with Credit Load
Ph.D. (Hort.) in Floriculture and Lanscaping

Course Code	Course Title	Credit Hours
	Major Courses(12 Credits)	
FLS 601*	Crop Regulation in Ornamental Crops	1+1
FLS 602*	Postharvest Biology of Floricultural Crops	2+1
FLS 603	Specialty Flowers, Fillers and Cut Greens	1+1
FLS 604	Biotechnological Approaches in Floricultural Crops	2+1
FLS 605*	Advances in Landscaping	1+1
FLS 606	Vertical Gardening	1+2
FLS 607	Modern Approaches in Breeding of Floricultural crops	2+1
FLS 608	Current Trends in Production Technology of Floricultural Crops	2+1
FLS 609	Recent Developments in Protected Cultivation of Floricultural Crops	2+1
	Minor courses	06
	Supporting courses	05
FLS 691	Seminar-I	0+1
FLS 692	Seminar-II	0+1
FLS 699	Research*	0+75
	Total Credits	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Floriculture and Lanscaping

I. Course Title : Crop Regulation in Ornamental Crops

II. Course Code : FLS 601

III. Credit Hours : (2+1)

IV. Why this course ?

The course deals with the physiological and biochemical basis of crop regulation and programmed production of flower crops. The students need a thorough understanding on crop regulation to improve the profitability of growers.

V. Aim of the course

Appraise on advances in programmed production of flower crops

The course is organized as follows:

No	Blocks	Units
1	Basis of crop regulation	I Basis of flowering II Growth regulators
2	Programming	I Growth regulation II Programmed production

VI. Theory

Block 1: Basis of crop regulation

Unit I: Basis of flowering: Ecophysiological influences on growth and development of flower crops for flowering, Crop load and assimilate partitioning and distribution.Root and canopy regulation.

Unit II: Growth regulators: Study of plant growth regulators including biostimulants and polyamines in floriculture- structure, biosynthesis, metabolic and morphogenetic effects of different plant growth promoters and growth retardants. Absorption, translocation and degradation of phytohormones – internal and external factors influencing hormonal synthesis, biochemical action, growth promotion and inhibition, Plant architecture management for flower crops and ornamental plants, molecular approaches in crop growth regulation.

Block 2: Programming

Unit I: Growth regulation: Growth regulation aspects of propagation, embryogenesis, seed and bud dormancy, flower bud initiation, regulation of flowering, photo and thermo periodism, off season production, bulb forcing techniques.

Unit II: Programmed production: Programmed production of important flower crops like chrysanthemum, tulips, lilium, daffodils, poinsettia, kalanchoe, gypsophila.

VII. Practical

- Plant architecture studies in important flower crops (2);
- Bioassay and isolation through chromatographic analysis for auxins, gibberellins, cytokinins, ABA (4);
- Growth regulation during propagation, dormancy, flowering (2);
- Photoperiod regulation in short day and long day crops (2);
- Off season production in important crops (2);
- Bulb forcing in bulbous ornamental crops (2);
- Exposure visits (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with physiological and biochemical basis of crop regulation in flower crops.
- The students will be able to carry out programmed production of flower crops.
- Instill the entrepreneurial acumen in the students

X. Suggested Reading

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. 2015. Wiley Blackwell Publ. 2nd Edition, pp. 1280.

De Hertagh A and Le Nard M. 1993. *The Physiology of Flower Bulbs*. Elsevier, London, UK.

Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. John Wiley & Sons.

Fosket DE. 1994. *Plant Growth and Development: A Molecular Approach*. Academic Press. pp. 580.

Leoplod AC and Kriedermann PE. 1985. *Plant Growth and Development*. McGraw-Hill, New York. 3rd Edition.

Peter KV. 2008. *Basics of Horticulture*. New India Publ. Agency, New Delhi, India.

Roberts J, Downs S and Parker P. 2002. *Plant Growth Development*: *In Plant*. Oxford University Press. pp. 221-274.

Salisbury FB. and Ross CW. 1992. *Plant Physiology, Hormones and Plant Regulators: Auxins and Gibberellins*. Wadsworth Publ., Belmont. 4th Edition, pp. 357-381.

I. Course Title : Postharvest Biology of Floricultural Crops

II. Course Code : FLS 602

III. Credit Hours : (2+1)

IV. Why this course ?

The course deals with physiological, biochemical basis of senescence of flowers and the treatments and packaging methods to mitigate these processes for improving post-harvest life.

V. Aim of the course

To facilitate deeper understanding of biochemistry and postharvest technology in flowers at molecular as well as applied level.

The course is organized as follows:

No	Blocks	Units
1	Pre-harvest and post harvest physiology and biochemistry	I Pre harvest physiology II Senescence III Pigments and secondary metabolites
2	Storage and packaging	I Treatments and storage II Packaging III Dried ornamental crops

VI. Theory

Block 1: Preharvest and post harvest physiology and biochemistry

Unit I: Pre harvest physiology: Maturity indices, harvesting practices for specific market requirements, influence of pre-harvest practices, enzymatic and other biochemical changes, respiration, transpiration in important flower crops.

Unit II: Senescence: Physiology and biochemistry of flowering, enzymatic changes, Ethylene sensitivity, ethylene evolution and management, factors leading to post-harvest loss, pre-cooling. Petal senescence at molecular level, functional gene analysis for postharvest flower quality in important flower crops, etc.

Unit III: Pigments and secondary metabolites: Biosynthetic pathways of chlorophyll, xanthophyll, carotenoids, flavonoids and anthocyanins and betalains. Chemistry and importance of secondary metabolites. Biochemistry and utilization for commercial products in important flower crops.

Block 2: Storage and packaging

Unit I: Storage of flowers: Treatments prior to shipment, viz., precooling, pulsing, impregnation, chemicals, Irradiation, biocontrol agents and natural plant products. Methods of storage: ventilated, refrigerated, Modified atmosphere, Controlled atmosphere storage, cool chain management, physical injuries and disorders in important flower crops.

Unit II: Packaging: Packing methods and transport, Smart technologies in packaging and storage, advanced tools like nanotechnology application for quality parameters and post harvest treatments for export in important flower crops, packaging standards, flower labels value chain in floriculture.

Unit III: Recent trends: Recent trends- extraction of bio-colours from flowers- conventional as well as *in-vitro* methods and their value addition uses in food and textile industries. Molecular techniques for enhancing postharvest flower quality, transgenics in ornamental plants for enhanced postharvest life.

Unit IV: Dried ornamental crops: Post harvest handling of dried ornamental crops including packing, storage and shipment. Storage pest and mould problems in dried ornamental produce, colour retention, physiological and biochemical changes, etc.

VII. Practical

- Improved packaging and storage of important flowers (2);
- Physiological loss in weight of flowers, estimation of transpiration, respiration rate, ethylene release and study of vase life (2);
- Extension in cut flower vase life using chemicals (1);
- Estimation of quality characteristics in stored flowers (1);
- Estimation of biochemical changes like enzymatic changes, lipids and electrolyte leakage (2);
- Extraction of flower pigments – Chlorophyll, xanthophylls, carotenoids and anthocyanins (4);
- Cold chain management – visit to cold storage, MA and CA storage units (2);
- Project preparation (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with physiological and biochemical basis of senescence in flower crops.
- The students would acquire the required skill sets of managing the storage and packaging methods to be followed in case of flowers.
- Prepare the students to explore the entrepreneurial options in post harvest management.

X. Suggested Reading

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. 2015. Wiley Blackwell Publ. 2nd edition, pp. 1280.
Dey PM and Harborne JB. 1997. *Plant Biochemistry*. Academic Press. 2nd Edition.
Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ.
Goodwin TW and Mercer EI. 2003. *Introduction to Plant Biochemistry*. CBS Publ.

I. Course Title : Specialty Flowers, Fillers and Cut Greens

II. Course Code : FLS 603

III. Credit Hours : (1+1)

IV. Why this course ?

This course deals with introduction to specialty flowers, cut greens and fillers, ways to cultivate them and their post harvest handling and storage. The students need to be aware of these crops so that they could improve the profitability of growers.

V. Aim of the course

To impart the knowledge on importance and cultivation of specialty flowers, fillers and cut green crops.

The course is organized as follows:

No	Blocks	Units
1	Scope	I Importance, national and international scenario
2	Avenues	I Specialty flowers
		II Fillers
		III Cut greens
3	Trade and marketing	I Post harvest management and marketing 2. Standards

VI. Theory

Block 1: Scope

Unit I: Importance, national and international scenario: Introduction, present status, scope, importance and avenues for specialty flowers and cut greens.

Block 2: **Avenues**

Unit I: Specialty flowers: Cultivation practices of specialty flower crops like heliconia, red ginger, Bird of Paradise, Ornamental banana, ornamental curcuma, gingers, wax flower, kangaroo paw, limonium, rice flower, etc.

Unit II: Fillers: Cultivation practices of fillers like gypsophila, solidago, Mollucella, lupins, etc.

Unit III: Cut greens: Cultivation practices of cut greens like anthurium, ferns, asparagus, cycas, thuja, bottle brush, ornamental palms, zanado, dracaena, eucalyptus, ruscus, dianella, alpinia, etc.

Block 3: Trade and Marketing

Unit I: Post harvest management: Pre and post harvest factors influencing the vase life of the flowers and fillers, Post harvest management including pulsing, holding, packing, storing, forward and backward linkages, value chain management.

Unit II: Standards: Quality standards, Packaging standards, marketing and trade in important flower, filler and foliage crops.

VII. Practical

- Identification of specialty flowers, fillers and cut greens (2);
- Media and bed preparation for cultivation (2);
- Propagation of important crops (2);
- Integrated disease and pest management in important crops (2);
- Post harvest handling of specialty flowers, fillers and cut greens (2);
- Preparation of value added products from important specialty flowers, fillers and foliages (2);
- Exposure visits (2);
- Economics and Project preparation (2).

VIII. Teaching Methods/ Activities

- Lectures

- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will gain knowledge on different specialty flowers, cut greens, fillers their cultivation practices and post harvest management.
- Infuse confidence to take up cultivation as an enterprise.

X. Suggested Reading

Armitage AM and Laushman JM. 2008. *Speciality Cut Flowers*. Timber Press. 2nd Edition, pp. 636.

Bhattacharjee SK. 2006. *Vistas in Floriculture*. Pointer Publ., Jaipur, India.

Bhattacharjee SK and De LC. 2003. *Advanced Commercial Floriculture* Vol.1. Aavishkar Publ. & Distributors, Jaipur India.

Bose TK, Yadav LP, Pal P, Parthasarathy VA and Das P. 2003. *Commercial Flowers*. Vol. I & II. Naya Udyog, Kolkata, India.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.

Mukherjee D. 2008. *Speciality Cut Flowers-Production Technologies*. Naya Udyog Kolkata, India. pp. 614.

Salunkhe K, Bhatt NR and Desai BB. 2004. *Post harvest Biotechnology of Flowers and Ornamental Plants*. Naya Prokash, Kolkata, India.

I. Course Title : Biotechnological Approaches in Floricultural Crops

II. Course Code : FLS 604

III. Credit Hours : (2+1)

IV. Why this course ?

This course deals with advances in biotechnology of flower crops. The student needs to be abreast with recent advances in tissue culture, genetic engineering and molecular biology of flower crops

V. Aim of the course

Equip the students with the advances in application of biotechnology in flower crops.

No	Blocks	Units	
1	Scope of biotechnology	I	Scope of biotechnology
2	Cell, Tissue and Organ culture	I	Tissue cultures
		II	Somaclonal variation and *in-vitro* conservation
3	Genetic engineering and molecular biology	I	Genetic Engineering
		II	Molecular approaches

VI. Theory

Block 1: Scope of biotechnology

Unit I: Scope of biotechnology: Present status of biotechnology, tools techniques and role in floriculture industry, physical factors and chemical factors influencing the growth and development of plant cell, tissue and organs, cyto-differentiation, organogenesis, somatic embryogenesis in important flower crops.

Block 2: Cell, tissue and organ culture

Unit I: Micropropagation: *In-vitro* lines for biotic and abiotic stress – Meristem culture for disease elimination, production of haploids through anther and pollen culture – embryo and ovule culture, micrografting, wide hybridization and embryo rescue techniques, construction of somatic hybrids and cybrids, regeneration and characterization of hybrids and cybrids, *in-vitro* pollination and fertilization, hardening media, techniques and establishment of tissue culture plants in the primary and secondary nursery in important flower crops.

Unit II: Somaclonal variation and *in-vitro* conservation: Somoclonal variation and its applications – variability induction through *in-vitro* mutation, development of cell suspension cultures, types and techniques, Synthetic Seed technology, *in-vitro* production of secondary metabolites, role of bioreactors in production of secondary metabolites, quantification and quality analysis of secondary metabolites using HPLC/ MS/ GCMS/ *in-vitro* conservation and cryo-preservation techniques in important flower crops.

Block 3: Genetic engineering and molecular biology

Unit I: Genetic engineering: Gene cloning, genetic engineering: vectors and methods of transformation – electroporation, particle bombardment, Functional gene analysis techniques like PTGS including VIGS in ornamental plants, Agrobacterium mediated, transgenic plants in flower crops, Biosafety of transgenics isolation of DNA, RNA, quantification, Polymerase Chain Reaction for amplification; AGE and PAGE techniques; identification of molecular markers in important flower crops.

Unit II: Molecular approaches: Molecular markers as a tool for analysis of genetic relatedness and selection in ornamental crops. Molecular control of flower development, light sensing with respect to plant development, flower pigmentation, fragrance, senescence, ethylene synthesis pathway in important flower crops. Molecular biology- Gene isolation, characterization, manipulation and transfer in important flower crops.

Construction of c- DNA library, DNA fingerprinting technique in economic flower crop varieties, RNAi, Genome editing basics, molecular approaches to control ethylene response, Fragrance, Plant Architecture, desirable flower traits, colour, shape, improving postharvest life, improving resistance for environmental stress, approaches to improve flower development, pigment production, secondary metabolite production, post harvest biotechnology of flowers, ornamental plants, achievements of bio-technology in flower crops.

VII. Practical

- Micropropagation, Pollen- Ovule and Embryo culture- Synthetic seed production (2);

- *In-vitro* mutation induction, *in-vitro* rooting – hardening at primary and secondary nurseries (3);
- DNA isolation from economic flower crop varieties – Quantification and amplification (2) DNA and Protein profiling – molecular markers, PCR Handling (2);
- Vectors for cloning and particle bombardment (3);
- DNA fingerprinting of flower crop varieties (3);
- Project preparation for establishment of low, medium and high cost tissue culture laboratories (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Suggested Reading

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology-Concepts, Methods and Applications*. Oxford & IBH Publ. Company, USA. pp. 200.

Debnath M. 2011. *Tools and Techniques of Biotechnology*. Pointer Publ.

Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ.

Gorden H and Rubsell S. 1960. *Hormones and Cell Culture*. AB Book Publ.

Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Horticultural Biotechnology*. Vols. I & II, 1018 p. New India Publ. Agency, New Delhi, India.

Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Methods in Tissue Culture and Gene Transfer*. Orient Blackswan. 312 p.

I. Course Title : Vertical Gardening

II. Course Code : FLS 605

III. Credit Hours : (1+2)

IV. Why this course ?

This course deals with development in vertical gardening which is expanding across the country. In view of the unprecedented pollution, advent of smart cities demand for green walls/ living walls is increasing day by day. The students therefore need to be equipped with the advancements taking place to offer solutions.

V. Aim of the course

Equip the students with the latest developments in vertical gardening.

No	Blocks	Units
1	Importance	I Scope
		II Growth
		III Making of vertical garden
2	Green roofing	I Green facades
		II Mitigation of pollution
		III Maintenance

VI. Theory

Block 1: Importance

Unit I: Scope: Present status of vertical gardening, benefits of vertical gardening, History of vertical gardens, role of indoor plants in mitigating pollution.

Unit II: Growth: Factors influencing the growth and development of the plants including light, humidity, temperature, nutrition, irrigation, growth regulation.

Unit III: Making of vertical gardens: Containers, media, frames, cost effective components, cables, wires, nets for the vertical formations, modular living walls.

Block 2: Green roofing

Unit I: Green Facades: Influence of green facades in providing thermal comfort, atmospheric cleansing and related environmental benefits, Energy saving potential of green façades, Aesthetic appeal of green structures and other relevant studies on urban greening.

Unit II: Mitigation of pollution: Plants suitable, Dust mitigation, Radiation absorption, Pollution mitigation, Acoustic attributes of urban greening.

Unit III: Maintenance: Lifecycle, maintenance, Plants with low light, medium, high intensity requirement, cost effectiveness and overall sustainability of living walls.

VII. Practical

- Identification of plants (2);
- Components of vertical gardens (2);
- Designing of vertical gardens for different locations (4);
- Maintenance of vertical gardens (2);
- Economics (1);
- Project preparation (1);
- Exposure visit (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Suggested Reading

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology-Concepts, Methods and Applications*. Oxford & IBH Publ. Company, USA. pp. 200.

Debnath M. 2011. *Tools and Techniques of Biotechnology*. Pointer Publ.

Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ.

Gorden H and Rubsell S. 1960. *Hormones and Cell Culture*. AB Book Publ.

Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Horticultural Biotechnology*. Vols. I & II, pp. 1018. New India Publ. Agency, New Delhi, India.

Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Methods in Tissue Culture and Gene Transfer*. Orient Blackswan. pp. 312.

I. Course Title : Advances in Breeding of Flower Crops

II. Course Code : FLS 606

III. Credit Hours : (2+1)

IV. Why this course ?

There have been several advances in application of biotechnology of flower crops. The students need to be aware of a wide array of *in-vitro* and molecular techniques with reference to flower crops.

V. Aim of the course

To teach students about the recent research trends in the field of breeding of ornamental crops with special emphasis on biotechnological approaches.

The course is organized as follows:

No	Blocks	Units
1	*In-vitro* techniques and biosynthetic pathways	I *In-vitro* techniques II Biosynthetic pathways
2	Molecular techniques	I Molecular breeding II Genome editing III. Advances in flower crops

VI. Theory

Block 1: *In-vitro* techniques and biosynthetic pathways

Unit I: *In-vitro* techniques: Role of biotechnology in improvement of flower crops; *in-vitro* mutagenesis, embryo culture, somaclonal variation, transformation, *in-vitro* cryopreservation, somatic hybridization, anther and ovule culture including somatic embryogenesis.

Unit II: Biosynthetic pathways: Biosynthetic pathways of pigment, fragrance and senescence, flower form; chemistry and importance of secondary metabolites, genomics, proteomics, metabolomics.

Block 2: Molecular techniques

Unit I: Molecular breeding: Molecular breeding and Marker assisted selection; molecular characterization; construction of c-DNA library; High throughput sequencing.

Unit II: Genome editing: Genome editing, CRISPER CAS, gene pyramiding, allele mining.

Unit III: Advances in flower crops: Breeding for biotic and abiotic stresses using biotechnological means; designer flower crops. Advancements in important flower crops like rose, chrysanthemum, carnation, orchids, anthuriums, lilium, gerbera, etc.

VII. Practical

- *In-vitro* mutagenesis, embryo culture, somaclonal variation (2);
- Somatic hybridization, anther and ovule culture and somatic embryogenesis (2)

- Genetic transformation (2);
- Genetic fingerprinting, Genome editing techniques (4);
- PCR, genomics, blotting techniques (2);
- Cloning, marker assisted selection (2);
- Bioinformatics (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will have in depth knowledge and hands on training in *in-vitro* and molecular approaches that can be used in flower crops.
- Equip the students with the skills for develop designer crops

X. Suggested Reading

Anderson NO. 2007. *Flower Breeding and Genetics Issues, Challenges and Opportunities for the 21st Century*. Springer Publ., The Netherlands.

Arthur ML. 2013. *Introduction to Bioinformatics*. Oxford University Press, U.K. 400 p.

Chadha KL and Chaudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

Nelson DL and Cox MM. 2000. *Principles of Biochemistry*. 4th Edition, Lehninger Publ.

Panopoulas NJ (Ed.). 1981. *Genetic Engineering in Plant Sciences*. Praeger Publ.

Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vol. I-III. Naya Prokash, Kolkata, India.

Pierik RLM. 1987. *In-vitro Culture of Higher Plants*. MartinusNijhoff Publ. Amsterdam.

Primrose SB and Twyman R. 2006. *Principles of Gene manipulation and Genomics*. Blackwell Publ., USA.

Srivastava PS, Narula A and Srivastava S. 2005. *Plant Biotechnology and Molecular Markers*. Anamaya Publ., New Delhi, India.

Vainstein A. (Ed.) 2002. *Breeding for Ornamental crops: Classical and Molecular Approaches*. Springer-Science-Business Media, B.V. 1st Edition.

Wilson K and Walker J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*. 7th Edition, Cambridge University Press, UK.

I. Course Title : Advances in Production Technology of Flower Crops

II. Course Code : FLS 607

III. Credit Hours : (2+1)

IV. Why this course ?

Production technology of flower crops is undergoing a rapid change due to advances from other sciences. The students need to keep abreast with these advances in production technology in flower crops.

V. Aim of the course

To keep abreast with latest developments and trends in production technology of flower crops.

The course is organized as follows:

No	Blocks	Units
1	Production technology	I Scope and scenario II Cultural operations III Crop regulation IV Advances in production technology of flowers
2	Mechanization and Post harvest management	I Mechanization II Post harvest management

VI. Theory

Block 1: Production technology

Unit I: Scope and scenario: Commercial flower production; Scope and importance; Global Scenario in cut flower production and trade, varietal wealth and diversity; Soil and Environment; cut flower, loose flowers, dry flowers and essential oil trade, flower seed production. Special characteristics and requirements. Essential oil industry, recent advances in extraction methods.

Unit II: Cultural operations: Propagation and multiplication; Greenhouse management; Soil/ media decontamination techniques; Microirrigation; nutrition and fertigation; slow release fertilizers and biofertilizers; influence of environmental parameters, light, temperature, moisture, humidity and CO_2 on growth and flowering.

Unit III: Crop Regulation: Flower forcing and year-round flowering through physiological interventions; Chemical regulation; Environmental manipulation, important insect pests, diseases, nematodes and their management through IPM and IDM, quarantine measures for export and other export norms.

Unit IV: Advances in production technology of crops: Advances in roses, chrysanthemum, carnation, tuberose, gladiolus, lilum, gerbera, orchids, anthuriums, etc.

Block 2: Mechanization and Post harvest management

Unit I: Mechanization: Mechanization, automation, ICT and AI in floriculture.

Unit II: Post-harvest management: Harvest indices, Harvesting techniques; Post harvest handling for local, distant and export market, Cluster production, Contract farming, FPOs, Value chain management.

VII. Practical

- Greenhouse management; Soil decontamination techniques (2);
- Microirrigation; Nutrition and fertigation (2);
- Special practices- bending, netting, pinching, disbudding, defoliation and chemical pruning, etc. (2);
- Photoperiodic and chemical induction of flowering (2);
- Assessing harvest indices; Post-harvest handling (2);
- Case studies (2);
- Visit to commercial cut flower and essential oil units (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will acquire knowledge and skills in advances in production technology, crop regulation and mechanization in flower crops.
- Develop enterprising attitude among students.

X. Suggested Reading

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Chadha KL and Choudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

George S and Peter KV. 2008. *Plants in a Garden*. New India Publ. Agency, New Delhi, India.

Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices*.Agrobios Publ., Jodhpur, India.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.

Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.

Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi India.

Singh AK. 2006. *Flower Crops: Cultivation and Management*. New India Publ. Agency, New Delhi, India.

Singh AK. 2014. *Breeding and Biotechnology of Flowers, Vol.1: Commercial Flowers*. New India Publ. Agency, New Delhi, India. pp.740.

I. Course Title : Advances in Protected Cultivation of Flower Crops

II. Course Code : FLS 608

III. Credit Hours : (2+1)

IV. Why this course ?

Protected cultivation is more rewarding in production of high value cut flowers. With appropriate structures and plant environment control measures, the constraints of environment prevalent in the region can be overcome allowing almost year-round cultivation. The students need to get updated with the recent advances in protected cultivation.

V. Aim of the course

Appraisal on the advances in protected and precision farming of flower crops.

The course is organized as follows:

No	Blocks	Units
1	Production technology	I Scope and Scenario II Microclimate management III Cultural operations

No	Blocks	Units
		IV Advances in flower crops
2	Precision floriculture and regulations	I Precision floriculture II Regulations

VI. Theory

Block 1: Production technology

Unit I: Scope and Scenario: Prospects of protected floriculture in India, growing structures, basic considerations in establishment and operation of green houses, functioning and maintenance. Global trade, forward and backward linkages for import clusters, International and national auction houses.

UNIT II: Microclimate management: Environmental control systems in greenhouse, regulation of light through LEDs containers, substrate culture, soil decontamination techniques, aeroponics, hydroponics and vertical farming.

Unit III: Cultural operations: Water and nutrient management, crop regulation, special horticultural practices under protected cultivation of rose, chrysanthemum, carnation, orchids, anthurium, gerbera, lilium, cut foliage and potted ornamental crops; plant architecture management in ornamental plants.

Unit IV: Advances in flower crops: Advances in protected cultivation of important flowering (rose, chrysanthemum,carnation, gerbera, orchids, anthurium, lilium, and foliage plants (agloenema, monstera, dracaena, syngonium, pothos, diffenbachia, etc.)

Block 2: Precision floriculture and regulations

Unit I: Precision floriculture: Precision floriculture, Principles and concepts, enabling technologies of precision floriculture, remote sensing, sensors, automation in greenhouses, solar greenhouses, retractable greenhouses. Computers and robotics, decision support systems, apps, cold chain management, use of AI for production and trade.

Unit II: Regulations: PBR/ IPR issues; Forward and backward linkages, 100% EOU, packaging and export standards, Cool chain Management, non-tariff barriers, APEDA regulations for export, marketing channels, auction houses, major markets.

VII. Practical

- Growing structures, basic considerations in establishment and operation of greenhouses;
- Environmental control systems in greenhouse;
- Containers, substrate culture, soil decontamination techniques;
- Crop regulation;
- Special horticultural practices under protected cultivation;
- Precision equipments, computers and robotics in precision farming;
- Harvest indices – harvesting, Post harvest handling, marketing;
- Export and cold chain management.

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with the recent advances in protected cultivation of flower crops
- Equip the students with skill to independently manage enterprises

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, 2065 p.

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Reddy S, Janakiram T, Balaji, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.

I. Course Title : Advances in Landscape Gardening

II. Course Code : FLS 609

III. Credit Hours : (1+2)

IV. Why this course ?

Advances in landscape gardening is a course which deals with principles of landscape design, landscape engineering and site analysis. It will also create awareness on latest developments in landscape gardening among students.

V. Aim of the course

To update knowledge on the recent trends in the field of landscape designing and developing practical skills.

The course is organized as follows:

1. Landscape design
2. Site analysis
3. Software in landscaping
4. Landscaping for different situations
5. Maintenance

VI. Theory

Unit I

Landscape design: Commercial landscape gardening- History, Plant identification and ecology, Materials of garden design, Design making by different garden styles and types. Design principles in ancient and modern landscape. Principles of designing a commercial landscape project. Role of landscaping in environment improvement, ecology conservation (birds, butterflies, animals). Plant wealth for edges, hedges, herbaceous borders, trees, floral beds, water plants, cacti, ferns, palms, etc.

Unit II

Site analysis: Assessing site and plants adaptability for different locations, Landscape engineering (Topographical survey and designing concept including GIS,GPS, Remote sensing), special techniques in garden landscaping (Burlapping, waterscaping, xeriscaping, hardscaping, lawn establishment, topiary styles specializing, bioaesthetic planning).

Unit III

Software in landscaping: Preparation and drawing of site plan, Learning the basics in computer aided design (CAD) for developing a garden landscape plan, Handling soft landscape materials (AUTOCAD and ARCHICAD), GIS as a tool for spatial designing.

Unit IV

Landscaping for different situations: Contemporary landscaping, Urban landscaping, Environmental landscaping, Industrial and institutional landscaping, Public and private garden making, play ground landscaping, Inventory management, Landscape restoration, Assessing a successful design in site.

Unit V

Maintenance: Maintenance of different types of gardens, waste water utilisation, historical and archaeological garden sites, Permissions required for bigger projects, carbon sequestration, carbon credits etc.

VII. Practical

- Plant identification (1);
- Materials of garden design, Design making by different garden styles and types (2);
- Assessing site and plants adaptability for different locations (2);
- Way of designing a commercial landscape project (4);
- Landscape engineering (Topographical survey and designing concept) (2);
- Preparation and drawing of site plan (4);
- Learning the basics in computer aided design (CAD) for developing a garden landscape plan (4);
- Handling soft landscape materials (AUTOCAD and ARCHICAD), GIS as a tool for spatial designing (4);
- Case study with the successful landscapist (4);
- Budget/ Project cost estimating (2);
- Exposure visits (3).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with the recent advances in landscape gardening
- Acquire the skills to independently handle landscape projects

X. Suggested Reading

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Nambisan KMP.1992. *Design Elements of Landscape Gardening*. Oxford & IBH Publ. Co., New Delhi, India.

Ozayuvuz M. 2013. *Advances in Landscape Architecture*. In Tech Open Publ.

Woodrow MG. 1999. *Gardening in India*. Biotech Books, New Delhi, India.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Plantation, Spices, Medicinal and Aromatic Crops

Preamble

(Plantation, Spices, Medicinal and Aromatic Crops)

Plantation Crops are high value commercial crops of greater economic importance and play a vital role in our national economy. Crops like tea, coffee, rubber, coconut, arecanut, cocoa, oil palm, cashew, etc. occupy less than two percent of the total cultivated area but have a stake of 16% of the total export earnings of all commodities or 75% of total earnings from the export of agricultural produce. Plantation industry provides direct as well as indirect employment to many millions of people and also supports other by-product industries and many rural industries. Therefore, the country has considered horticulture and plantation sector as the growth engine of agricultural economy.

Spices are important group of horticultural crops providing livelihood to millions of peoples in the country. They have tremendous importance in the way we live, as ingredients in foods, alcoholic beverages, medicine, perfumery, cosmetics, pharmaceuticals, coloring and also as garden plants. Out of the total 109 spices listed by the International Organization for Standards (ISO), 63 are grown in India. The trade in spices is one of the oldest and currently the most important form of commerce. The tropical humid regions of India grows major spices like black pepper, cardamom, ginger, turmeric, nutmeg, cinnamon, clove, etc. and the arid and semi arid parts of India are known as the seed spice bowl.

The medicinal and aromatic plant sector plays a significant role in the subsistence economy of the people. The domestic as well as export market of MAP is ever increasing. The annual turn over of the major Indian systems of medicine ie, Ayurveda, Unani, and Sidha is estimated to be more than half a million dollars. The MAP sector is also an integral part of natural resource management contributing to economic growth, environmental protection and trade.

In the present syllabus, courses have been organized to cover the current requirements of the plantation, spice and MAP sector to increase the capability of horticulture graduates. Either new courses have been formulated or existing courses upgraded to include latest developments in various sectors. In the masters programme new courses ie, systematics, growth and development, biochemistry and biodiversity conservation of PSMA crops have been included. In most of the PSMA crops quality of the produce is of paramount importance and hence a thorough understanding of the systematics, growth and developmental physiology and biochemistry is essential. To ensure sustainability aspects, biodiversity management are also added. Both national as well as global perspectives are taken care of in deciding the course content, especially in the case of doctoral programme. Tools of biotechnology have been extensively utilized in the improvement of PSMA crops and the course to this effect has been included. As the climate changes are happening globally and being crops which are greatly influenced by the change if climate, a course on abiotic stress management is included. As most of the PSMA crops are export oriented, separate courses on organic production and export are also included. All courses are designed in line with the national initiatives as well as the global scenario.

Course Title with Credit Load
M.Sc. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
PSM 501*	Production of Plantation Crops	2+1
PSM 502*	Production of Spice Crops	2+1
PSM 503*	Production of Medicinal and Aromatic Crops	2+1
PSM 504*	Breeding of Plantation and Spice Crops	2+1
PSM 505*	Breeding of Medicinal and Aromatic Crops	1+1
PSM 506	Systematics of Plantation and Spice Crops	1+1
PSM 507	Systematics of Medicinal and Aromatic Crops	1+1
PSM 508	Underexploited Plantation, Spice, Medicinal and Aromatic Plants	2+0
PSM 509	Growth and Development of Plantation, Spice, Medicinal and Aromatic Crops	2+1
PSMA 510	Biochemistry of Plantation, Spice, Medicinal and Aromatic crops	2+1
PSMA 511	Biodiversity and Conservation of Plantation, Spice, Medicinal and Aromatic Crops	2+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
PSMA 591	Seminar	0+1
PSMA 599	Research	0+30
	Total	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

I. Course Title : Production of Plantation Crops

II. Course Code : PSM 501

III. Credit Hours : (2+1)

IV. Why this course ?

Plantation crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various plantation crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on various aspects of production technology of plantation crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Plantation Crops	I Role of plantation crops II Export potential III Promotional programmes
2	Production Technology	I Varietal wealth II Propagation and nursery management III Agro techniques
3	Harvest and Post-harvest management	I Maturity indices and harvest II Post harvest management

VI. Theory

Block 1: Importance of Plantation Crops

Unit 1: Role of plantation crops: Role of plantation crops in national economy, area-production statistics at national and international level, classification, clean development mechanism and carbon sequestration potential of plantation crops.

Unit 2: Export potential: Export potential, problems and prospects and IPR issues in plantation crops.

Unit 3: Promotional programmes: Role of commodity boards and directorates in the development programmes of plantation crops.

Block 2: Production Technology

Unit 1: Varietal wealth: Botany, taxonomy, species, cultivars and improved varieties in plantation crops.

Unit 2: Propagation and nursery management: Plant multiplication including *in-vitro* multiplication, nursery techniques and nursery management in plantation crops.

Unit 3: Agro techniques: Systems of cultivation, cropping systems, multitier cropping, climate and soil requirements, systems of planting, high density planting, nutritional requirements, water requirements, fertigation, moisture conservation, role of growth regulators, macro and micro nutrients, nutrient deficiency symptoms, physiological disorders, shade regulation, weed management, training and pruning, crop regulation, plant protection, management of drought, precision farming.

Block 3: Harvest and Post harvest management

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons and mechanized harvesting in plantation crops.

Unit 2: Post harvest management: Post harvest handling including primary processing, grading, packaging, storage and benefit cost analysis of plantation crops.

Crops

Coconut, Arecanut, Oilpalm, Cashew, Coffee, Tea, Cocoa, Rubber, Palmyrah, Betel vine

VII. Practical

- Description of botanical and varietal features;
- Selection of mother palms and seedlings;
- Nursery techniques;
- Soil and water conservation measures;
- Nutrient deficiency symptoms;
- Manuring practices;
- Pruning and training methods;
- Maturity standards;
- Harvesting;
- Project preparation for establishing plantations;
- GAP in plantation crops;
- Exposure visits to commercial plantations, research institutes.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in commercial cultivation of plantation crops
- Be able to start plantation crop-based enterprises

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.
Anonymous. 1985. *Rubber and its Cultivation*. The Rubber Board of India.
Chopra VL and Peter KV. 2005. *Handbook of Industrial Crops*. Panima.
Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*.

Daya Publishing House, New Delhi
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e-manual on Advances in Cashew Production Technology. ICAR –Directorate of Cashew Research, Puttur –574 202, DK, Karnataka.
Harler CR. 1963. *The Culture and Marketing of Tea*. Oxford Univ. Press.
Joshi P. 2018. *Text Book on fruit and plantation crops*. Narendra Publishing House, New Delhi
Kurian A and Peter KV. 2007. *Commercial Crops Technology*. New India Publ. Agency.
Nair MK, Bhaskara Rao EVV, Nambia KKN and Nambiar MC. 1979. *Cashew*. CPCRI, Kasaragod.
Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
Peter KV. 2002. *Plantation Crops*. National Book Trust.
Pillay PNR. 1980. *Handbook of natural rbber production in India*. Rubber Research Institute, Kottayam. pp.668.
Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops*. Parts I, II. New India Publ. Agency.
Ramachandra *et al*. 2018. *Breeding of Spices and Plantation crops*. Narendra Publishing House, New Delhi.
Ranganathan V. 1979. *Hand Book of Tea Cultivation*. UPASI, Tea Res. Stn. Cinchona.
Sera T, Soccol CR, Pandey A, Roussos S *Coffee Biotechnology and Quality*. Springer, Dordrecht.
Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.
Srivastava HC, Vatsaya and Menon, KKG. 1986. *Plantation Crops – Opportunities and Constraints*. Oxford and IBH.
Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.

I. Course Title : Production of Spice Crops

II. Course Code : PSM 502

III. Credit Hours : (2+1)

IV. Why this course ?

Spice crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various spice crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on various aspects of production technology of spice crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Spice Crops	I Role of spice crops
		II Classification of spice crops
2	Production Technology	I Varietal wealth

No	Blocks	Units
		II Propagation and nursery management III Agro techniques
3	Harvest and Post harvest management	I Maturity indices and harvest II Post harvest management

VI. Theory

Block 1: Importance of spice crops

Unit 1: Role of Spice crops: Introduction, importance of spice crops, pharmaceutical significance, historical accent, present status – national and international, future prospects, role of Spices board and other development agencies.

Unit 2: Classification of spice crops: Major spices, minor spices, seed spices, tree spices, herbal spices.

Block 2: Production Technology

Unit 1: Varietal wealth: Botany and taxonomy, species, cultivars, commercial varieties/ hybrids in spice crops.

Unit 2: Propagation and nursery management: Seed, vegetative and micro-propagation methods, nursery techniques and nursery management practices.

Unit 3: Agro techniques: Climatic and soil requirements, site selection, layout, sowing/ planting times and methods, seed rate and seed treatment, nutritional and irrigation requirements, intercropping, mixed cropping, intercultural operations, weed control, mulching, plant protection, precision farming, physiological disorders, protected cultivation.

Block 3: Harvest and Post harvest management

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons, mechanized harvesting.

Unit 2: Post harvest management: Post harvest management including primary processing, grading, packaging and storage, GMP in major spice crops.

Crops

Black pepper, small and large Cardamom, Turmeric, Ginger, Garlic, Coriander, Fenugreek, Cumin, Fennel, Ajwain, Saffron, Vanilla, Nutmeg, Clove, Cinnamon, Allspice, Tamarind, Garcinia

VII. Practical

- Identification of seeds and plants;
- Botanical description of plant;
- Varietal features;
- Planting material production;
- Field layout and method of planting;
- Cultural practices;
- Harvest maturity, harvesting;
- Drying, storage, packaging;
- Primary processing;

- GAP in spice crops;
- GMP in spice crops;
- Short term experiments on spice crops;
- Exposure visits to spice farms, research institutes.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in commercial cultivation of spice crops
- Be able to start spice-based enterprises

X. Suggested Reading

Agarwal S, Sastry EVD and Sharma RK. 2001. *Seed Spices: Production, Quality, Export.* Pointer Publ.

Arya PS. 2003. *Spice Crops of India.* Kalyani.

Bose TK, Mitra SK, Farooqi SK and Sadhu MK. Eds. 1999. *Tropical Horticulture.* Vol.I. Naya Prokash.

Chadha KL and Rethinam P. Eds. 1993. *Advances in Horticulture.* Vols. IX-X. *Plantation Crops and Spices.* Malhotra Publ. House.

Gupta S. Ed. *Hand Book of Spices and Packaging with Formulae.* Engineers India Research Institute, New Delhi.

Kumar NA, Khader P, Rangaswami and Irulappan I. 2000. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants.* Oxford and IBH.

Nybe EV, Miniraj N and Peter KV. 2007. *Spices.* New India Publ. Agency.

Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic Spices.* New India Publ. Agency.

Peter KV. 2001. *Hand Book of Herbs and Spices.* Vols. I-III. Woodhead Publ. Co. UK and CRC USA.

Ponnuswami V *et al.* 2018. *Medicinal Herbs and Herbal Cure.* Narendra Publishing House, New Delhi.

Pruthi JS. Ed. 1998. *Spices and Condiments.* National Book Trust.

Pruthi JS. 2001. *Minor Spices and Condiments- Crop Management and Post HarvestTechnology.* ICAR.

Purseglove JW, Brown EG, Green CL and Robbins SRJ. Eds. 1981. *Spices.* Vols. I, II. Longman.

Ramachandra *et al.* 2018. *Breeding of Spices and Plantation crops.* Narendra Publishing House, New Delhi.

Ravindran PN. 2000. *Black pepper*, *Piper nigrum*. CRC press.

Ravindran PN. 2002. *Cardamom, the genusElettaria.* CRC press

Ravindran PN. 2003. *Cinnamon and cassia.* CRC press

Ravindran PN. 2004. *Ginger, the genus Zingiber.* CRC press

Ravindran PN. 2007. *Turmeric, the genus curcuma.* CRC press

Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices.* CABI

Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production Technology of Spices and Plantation Crops.* Agrobios.

Sharangi AB, Datta S and Deb P. 2018. Spices "*Agrotechniques for quality produce*". Apple Acadamic Press (Tylor and Francis Groups), New Jersey, USA.

Sharangi AB. 2018. Indian Spices "*The legacy, production and processing of India's treasured export.*" Springer International publishing AG, Part of Springer Nature 2018, Cham, Switzerland.

Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
Sharangi AB and Acharya SK. 2008. *Quality Management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.
Thamburaj S and Singh N. Eds. 2004. *Vegetables, Tuber Crops and Spices,* ICAR.
Tiwari RS and Agarwal A. 2004. *Production Technology of Spices*. International Book Distr. Co.

I. Course Title : Production of Medicinal and Aromatic Crops

II. Course Code : PSM 503

III. Credit Hours : (2+1)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. These crops also provide health security to all. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various medicinal and aromatic crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

To impart comprehensive knowledge on the production technology of important medicinal and aromatic crops

The course is organized as follows:

No	Blocks	Units
1	Importance of Medicinal and Aromatic Crops	I Classification of medicinal and aromatic crops
		II Medicinal plant based industry
		III Aromatic plant based industry
2	Production technology	I Varietal wealth
		II Propagation and nursery management
		III Agro techniques
3	Harvest and Post harvest management	I Maturity indices and harvest
		II Post harvest management

Theory

Block 1: Importance of Medicinal and Aromatic Crops

Unit 1: Classification of medicinal and aromatic crops: Importance of medicinal plants, Importance of aromatic plants, Role in national economy, utility sectors of medicinal and aromatic crops, classification of medicinal and aromatic crops, role of institutions, Medicinal Plant Board and NGO's in research and development of medicinal and aromatic crops.

Unit 2: Medicinal and plant based industry: Indian system of medicine, traditional systems of medicine, tribal medicine, medicinal industry, source of medicinal plants, area, production, export and import of major crops, problems, prospects and challenges, IPR issues.

Unit 3: Aromatic plant based industry: Essential oils, classification, physical and chemical properties and storage of essential oils. Indian perfumery industry,area, production, export and import status of major aromatic crops, history and advancements, problems, prospects and challenges, IPR issues.

Block 2: **Production technology of medicinal and aromatic crops**

Unit 1: Varietal wealth: Botany and taxonomy, species, cultivars, commercial varieties/ hybrids in medicinal and aromatic crops.

Unit 2: Propagation and nursery management: Seed, vegetative and micro-propagation methods, nursery techniques and nursery management practices.

Unit 3: Agro techniques: Climatic and soil requirements, site selection, layout, sowing/ planting times and methods, seed rate and seed treatment, nutritional and irrigation requirements, intercropping, mixed cropping, intercultural operations, weed control, mulching, plant protection.

Block 3: **Harvest and Post harvest management**

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons in medicinal and aromatic crops.

Unit 2: Post harvest management: Post harvest management including primary processing, extraction, grading, packaging and storage, GMP in medicinal and aromatic crops.

Crops

A. Medicinal crops: Senna, periwinkle, medicinal coleus, aswagandha, glory lily, sarpagandha, *Dioscorea* sp., *Aloe vera*, *Andrographis paniculata, Digitalis,* medicinal solanum, isabgol, opium poppy, safedmusli, *Stevia rebaudiana, Mucuna pruriens, Piper longum, Plumbago zeylanica*

B. Aromatic crops: Palmarosa, lemongrass, citronella, vetiver, mentha, patchouli, sweet flag, jasmine, geranium, artemisia, lavender, *Ocimum* sp., eucalyptus, sandal

VI. Practical

- Description of botanical and varietal features;
- Nursery techniques;
- Lay out and planting;
- Manuring practices;
- Maturity standards;
- Harvesting;
- Primary processing;
- Extraction of oils;
- Herbarium preparation;
- Project preparation for establishing herbal gardens;
- GAP in medicinal and aromatic crops;
- GMP in medicinal and aromatic crops;
- Exposure visits to institutes, herbal gardens and industries.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

VIII. Learning outcome

After successful completion of this course, the students are expected to:
- Develop the technical skill in commercial cultivation of medicinal and aromatic crops
- Be able to start medicinal and aromatic crop-based enterprises

IX. Suggested Reading

Atal CK and Kapur BM. 1982. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu.

Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.

Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi

Farooqi AA and Sriram AH. 2000. *Cultivation Practices for Medicinal and Aromatic Crops*. Orient Longman Publ.

Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.

Gupta RK. 2010. *Medicinal and Aromatic plants*. CBS publications.

Hota D. 2007. *Bio Active Medicinal Plants*. Gene Tech Books. Jain SK. 2000. *Medicinal Plants*. National Book Trust.

Khan IA and Khanum A. 2001. *Role of Biotechnology in Medicinal and Aromatic Plants*. Vol. IX. Vikaaz Publ.

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Panda H. 2002. *Medicinal Plants Cultivation and their Uses*. Asia Pacific Business Press.

Panda H. 2005. *Aromatic Plants Cultivation, Processing and Uses*. Asia Pacific Business Press.

Ponnuswami *et al*. 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi.

Prajapati SS, Paero H, Sharma AK and Kumar T. 2006. *A Hand book of Medicinal Plants*. Agro Bios.

Ramawat KG and Merillon JM. 2003. *BioTechnology – Secondary Metabolites*. Oxford and IBH.

Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.

Skaria PB, Samuel M, Gracy Mathew, Ancy Joseph, Ragina Joseph. 2007. *Aromatic Plants*. New India Publ. Agency.

I. Course Title : Breeding of Plantation and Spice Crops

II. Course Code : PSM 504

III. Credit Hours : (2+1)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. For maximizing the production, productivity and quality of plantation and spice crops, fundamental knowledge on breeding methods of the major crops is essential. This course will impart theoretical as well as hands-on experience to the learner on reproductive biology, breeding methods and breeding achievements in various plantation and spice crops

V. Aim of the course

To impart comprehensive knowledge on the principles and practices in the breeding of important plantation and spice crops

The course is organized as follows:

No	Blocks	Units
1	Genetic diversity	I Species and cultivar diversity II Germplasm evaluation
2	Crop improvement	I Breeding objectives II Breeding methods
3	Breeding achievements and future thrusts	I Breeding achievements II Future thrusts

VI. Theory

Block 1: Genetic diversity

Unit I: Species and cultivar diversity: Floral and reproductive biology, cytogenetics, male sterility, incompatibility, wild and cultivated species, popular cultivars.

Unit II: Germplasm evaluation: Survey, collection, conservation and evaluation of germplasm.

Block 2: Crop improvement

Unit I: Breeding objectives: Breeding objectives/ goals on the basis of yield, quality, stress tolerance, adaptation.

Unit II: Breeding methods: Approaches for crop improvement, introduction, selection, hybridization, mutation breeding, polyploidy breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses.

Block 3: Breeding achievements and future thrusts

Unit I: Breeding achievements: Breeding achievements in terms of released varieties, parentage, salient features.

Unit II: Future thrusts: Molecular breeding and biotechnological approaches, marker-assisted selection, bioinformatics, breeding for climate resilience

Crops

A. Plantation crops: Coconut, Arecanut, Cashew, Cocoa, Rubber, Oil palm, Coffee, Tea, Palmyrah, Betel vine

B. Spice crops: Black pepper, small and large cardamom, Ginger, Turmeric, Fenugreek, Coriander, Fennel, Cumin, Ajwain, Garlic, Nutmeg, Cinnamon, Clove, Allspice, Garcinia, Tamarind

VII. Practical

- Characterization and evaluation of germplasm;
- Floral biology, anthesis; pollen behaviour, fruit set;
- Practices in hybridization, selfing and crossing techniques;
- Polyploidy breeding;
- Mutation breeding;
- Induction of somaclonal variation and screening the variants;
- Evaluation of biometrical traits and quality traits;
- Salient features of improved varieties and cultivars;
- Screening for biotic and abiotic stresses;

- Bioinformatics;
- Exposure visits to research institutes for plantation and spice crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in breeding of plantation and spice crops
- Be able to start plantation and spice crop-based seed production/ nursery centres

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Anonymous. 1985. *Rubber and its Cultivation.* The Rubber Board of India.

Chadha KL, Ravindran PN and Sahijram L. 2000. *Biotechnology in Horticultural and Plantation Crops*. Malhotra Publ. House.

Chadha KL. 1998. *Advances in Horticulture*. Vol. IX,X. *Plantation and Spices Crops*. Malhotra Publishing House, New Delhi.

Chadha KL and Rethinam P. Eds. 1993. *Advances in Horticulture.* Vol. IX. *PlantationCrops and Spices.* Part-I. Malhotra Publ. House.

Chopra VL and Peter KV. 2002. *Handbook of Industrial Crops*. Haworth Press, USA and. Panama International Publ. (Indian Ed.).

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E-manual on Advances in Cashew Production Technology. ICAR –Directorate of Cashew Research, Puttur –574 202, DK, Karnataka

Harver AE. 1962. *Modern Coffee Production.* Leonard Hoff.

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Ponnuswami *et al*. 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi

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Ramachandra *et al*. 2018. *Breeding of Spices and Plantation Crops.* Narendra Publishing House,New Delhi

Ravindran PN. 2002. *Cardamom, the genus Elettaria*. CRC press

Ravindran PN. 2003. *Cinnamon and cassia.* CRC press

Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press

Ravindran PN. 2007. *Turmeric, the genus Curcuma*. CRC press

Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
Sera T, Soccol CR, Pandey A, Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
Sethuraj MR and Mathew NT. 1992.*Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.

I. Course Title : Breeding of Medicinal and Aromatic Crops
II. Course Code : PSM 505
III. Credit Hours : (1+1)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. For maximizing the production, productivity and quality of medicinal and aromatic crops, fundamental knowledge on breeding methods of the major crops is essential. This course will impart theoretical as well as hands-on experience to the learner on reproductive biology, breeding methods and breeding achievements in various medicinal and aromatic crops.

V. Aim of the course

To impart comprehensive knowledge on the principles and practices in the breeding of important medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Genetic diversity	1. Species and cultivar diversity 2. Germplasm evaluation
2	Crop improvement	1. Breeding objectives 2. Breeding methods
3	Breeding achievements and future thrusts	1. Breeding achievements 2. Future thrusts

VI. Theory

Block 1: Genetic diversity

Unit 1: Species and cultivar diversity: Floral and reproductive biology, cytogenetics, male sterility, incompatibility, wild and cultivated species, popular cultivars.

Unit 2: Germplasm evaluation: Survey, collection, conservation and evaluation of germplasm, IPR issues.

Block 2: Crop improvement

Unit 1: Breeding objectives: Breeding problems in medicinal and aromatic crops. Genetics of active principles, breeding objectives/ goals on the basis of yield, quality, stress tolerance, adaptation.

Unit 2: Breeding methods: Approaches for crop improvement, introduction, selection, hybridization, mutation breeding, polyploidy breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses.

Block 3: Breeding achievements and future thrusts

Unit 1: Breeding achievements: Breeding achievements in terms of released varieties, parentage, salient features.

Unit 2: Future thrusts: Molecular breeding and biotechnological approaches, marker-assisted selection, bioinformatics, breeding for climate resilience.

Crops

A. Medicinal crops: *Cassia angustifolia*, *Catharanthus roseus*, *Gloriosa superba, Coleus forskohlii*, *Stevia rebaudiana*, *Withania somnifera*, *Papaver somniferum*, *Plantago ovata*, *Chlorophytum* sp., *Rauvolfia serpentina*, *Aloe vera, Piper longum, Plumbago zeylanica*

B. Aromatic crops: Mint, geranium, patchouli, lemon grass, palmarosa, citronella, vetiver, Artemisia, ocimum, lavender, *Kaempferia galanga,* eucalyptus

VII. Practical

- Description of botanical features;
- Cataloguing of cultivars, varieties and species in medicinal and aromatic crops;
- Floral biology;
- Selfing and crossing;
- Evaluation of hybrid progenies;
- Induction of economic mutants;
- High alkaloid and high essential oil mutants;
- Evolution of mutants through physical and chemical mutagens;
- Introduction of polyploidy;
- Screening of plants for biotic and abiotic stress;
- *In-vitro* breeding in medicinal and aromatic crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in breeding of medicinal and aromatic crops
- Be able to start medicinal and aromatic crop-based seed production/ nursery centres

X. Suggested Reading

Chadha KL and Gupta, R. 1995. *Advances in Horticulture.* Vol. XI. Malhotra Publ. House.

Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops.* Natural Remedies Pvt. Ltd.

Gupta R.K. 2010. *Medicinal and Aromatic plants*. CBS publications

Jain SK. 2000. *Medicinal Plants*. National Book Trust.

Julia F and Charters MC. 1997. *Major Medicinal Plants – Botany, Cultures and Uses*. Thomas Publ.

Kurian A and Asha Sankar M. 2007. *Medicinal Plants.* Horticulture Science Series, New India Publ. Agency.

Ponnuswami *et al.* 2018. *Blossom biology of Horticultural crops.* Narendra Publishing House, New Delhi

Ponnuswami *et al.* 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi

Ponnuswami *et al*. 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi

Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals*. New India Publishing Agency, New Delhi

I. Course Title : Systematics of Plantation and Spice Crops

II. Course Code : PSM 506

III. Credit Hours : (1+1)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. For the crop improvement programme of these crops, fundamental knowledge on origin and development, evolutionary process, taxonomy and cytogenetics and is most essential. This course will impart theoretical knowledge to the learner on the origin and distribution, evolutionary process, taxonomy and cytogenetics of various plantation and spice crops.

V. Aim of the course

To impart basic knowledge on the origin and development, evolutionary process, taxonomy, chemotaxonomy, cytogenetics and genetic resources of plantation and spice crops.

The course is organized as follows:

No	Blocks	Units
1	Origin and evolution	1. Centre of origin 2. Systematics
2	Genetic diversity	1. Species and cultivar diversity 2. Germplasm
3	Cataloguing	1. Descriptors 2. DUS guidelines

VI. Theory

Block 1: Origin and evolution

Unit I: Centre of origin: Centre of origin, distribution, taxonomical status, phylogeny.

Unit II: Systematics: Botany, cytology, ploidy status, sex forms, flowering and pollination biology, cytogenetics.

Block 2: Diversity

Unit I: Species and cultivar diversity: Wild and related species, cultivars.

Unit II: Germplasm: Indigenous and exotic germplasm.

Block 3: Cataloguing

Unit I: Descriptors: Biovarsity/ NBPGR descriptors and their salient features.

Unit II: DUS guidelines: DUS guidelines, molecular aspects of systematics.

Crops

A. Plantation crops: Coconut, Arecanut, Oil Palm, Tea, Coffee, Cocoa, Cashew, Rubber, Betel Vine

B. Spice crops: Black Pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Vanilla, Coriander, Fennel, Cumin, Fenugreek, Garlic

VII. Practical

- Genus, species and cultivar features of various plantation and spice crops;
- Characterization based on descriptors;
- Characterization based on DUS guidelines;
- Study of sex forms and floral biology;
- Study of molecular markers;
- Exposure visits to national institutes including NBPGR.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- have thorough understanding on the systematics of plantation and spice crops

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Chadha KL and Gupta R. 1995. *Advances in Horticulture*. Vol. XI. Malhotra Publ. House.

Charles B. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications,

Diwan AP and Dhakad NK. 1996. *Genetics and Development*. Anmol Publications Private Limited, New Delhi.

E-manual on Advances in Cashew Production Technology. ICAR –Directorate of Cashew Research, Puttur –574 202, DK, Karnataka

Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

Pillay PNR. 1980. *Handbook of Natural Rubber Production in India.* Rubber Research Institute, Kottayam. pp.668

Ponnuswami *et al.* 2018. Blossom biology of Horticultural crops. Narendra Publishing House, New Delhi

Ponnuswami *et al.* 2018. Botany of Horticultural crops. Narendra Publishing House, New Delhi

Ravindran PN. 2000. *Black pepper*, *Piper nigrum*. CRC press

Ravindran PN. 2002. *Cardamom, the genusElettaria.* CRC press

Ravindran PN. 2003. *Cinnamon and cassia.* CRC press

Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press

Ravindran PN. 2007. *Turmeric, the genus curcuma.* CRC press

Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI

Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.

Sethuraj MR and Mathew NT. 1992.*Natural Rubber: Biology, Cultivation and Technology* (*Developments in Crop Science*). Elsevier Science.

Sharma G. 2009. *Systematics of fruit Crops*. New India Publishing House, India.

Strickberger MW. 2005. *Genetics* (III Ed). Prentice Hall, New Delhi, India

Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publishers

I. Course Title : Systematics of Medicinal and Aromatic Crops

II. Course Code : PSM 507

III. Credit Hours : (1+1)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. For the crop improvement programme of these crops, fundamental knowledge on origin and development, evolutionary process, taxonomy and cytogenetics is most essential. This course will impart theoretical knowledge to the learner on the origin and distribution, evolutionary process, taxonomy and cytogenetics of various medicinal and aromatic crops.

V. Aim of the course

To impart basic knowledge on the origin and development, evolutionary process, taxonomy, cytogenetics and genetic resources of medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Origin and evolution	I Centre of origin
		II Systematics
2	Genetic diversity	I Species and cultivar diversity
		II Germplasm
3	Cataloguing	I Descriptors
		II DUS guidelines

VI. Theory

Block 1: Origin and evolution

Unit I: Centre of origin: Centre of origin, distribution, taxonomical status, phylogeny, chemotaxonomy.

Unit II: Systematics: Botany, cytology, ploidy status, sex forms, flowering and pollination biology, cytogenetics.

Block 2: Diversity

Unit I: Species and cultivar diversity: Wild and related species, cultivars.

Unit II: Germplasm: Indigenous and exotic germplasm.

Block 3: Cataloguing

Unit I: Descriptors: Biovarsity/ NBPGR descriptors and their salient features.

Unit II: DUS guidelines: DUS guidelines, molecular aspects of systematics.

Crops

1. Medicinal crops: Opium poppy, Isabgol, Aswagandha, Senna, Medicinal coleus,Glory Lily, Periwinkle, Sarpagandha, Long Pepper, Stevia, Safed musli, *Plumbago zeylanica*

2. Aromatic crops: Lemongrass, Citronella, Palmarosa, Vetiver, Mint, Patcholi, Geranium, Ocimum, Rosemary, Lavender, *Kaempferia galanga*, Eucalyptus

VII. Practical

- Genus, species and cultivar features of various medicinal and aromatic crops;

- Characterization based on descriptors;
- Characterization based on DUS guidelines;
- Study of sex forms and floral biology;
- Study of molecular markers;
- Exposure visits to national institutes including NBPGR.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to have thorough understanding on the systematics of medicinal and aromatic crops

X. Suggested Reading

Birel Shah and Seth AK. 2005. *Text book of Pharmacognosy and Phytochemistry*. CBS Publishers and distributors, New Delhi.

Charles Burnham. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications

Diwan AP and Dhakad NK. 1996. *Genetics and Development*. Anmol Publications Private Limited, New Delhi.

Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.

Gupta RK. 2010. *Medicinal and Aromatic plants*. CBS publications

Prajapati ND, Purohit SS, Sharma AK, Kumar T. 2006. *A Hand book of Medicinal Plants*. Agro Bios (India).

Ponnuswami *et al*. 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi.

Ponnuswami *et al*. 2018 *Botany of Horticultural crops*. Narendra Publishing House, New Delhi

Raju R Wadekar. 2015. *Pharmacognosy and phytochemistry*, Event publishing house

Ranjal Kandall. *Bioactive compounds and genomic study of medicinal plants*. LAMBERT Academic Publishing

Sharma G. 2009. *Systematics of fruit Crops*. New India Publishing House, India.

Skaria P Baby *et al*. 2007. *Aromatic Plants*. New India Publ. Agency.

Strickberger MW. 2005. *Genetics* (III Ed). Prentice Hall, New Delhi, India

Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publishers.

Thakur RS, Pauri HS and Hussain A. 1989. *Major Medicinal Plants of India*. CSIR.

I. Course Title : Underexploited Plantation, Spice, Medicinal and Aromatic Plants

II. Course Code : PSM 508

III. Credit Hours : (2+0)

IV. Why this course ?

There are many number of underexploited plantation, spice, medicinal and aromatic crops which are becoming important in line with the major ones. They could very well be the major crops of tomorrow. This course will impart comprehensive knowledge to the learner on the importance and scientific production technology of various under utilised plantation, spice, medicinal and aromatic plants in India.

V. Aim of the course

To facilitate understanding on the importance and cultivation of underutilized and lesser known plantation, spice, medicinal and aromatic plants.

The course is organized as follows:

No	Blocks	Units
1	Importance and status	I Importance and uses II Status and future prospects
2	Production technology	I Propagation and varieties II Agro techniques
3	Harvest and post harvest management	I Harvest indices II Post harvest management

VI. Theory

Block 1: Importance and status

Unit I: Importance and Uses: Introduction, importance, economic parts used, traditional uses.

Unit II: Status and future prospects: Present status, origin, distribution and future prospects of under exploited PSMAs.

Block 2: Production technology

Unit I: Propagation and varieties: Propagation and nursery techniques, species varieties.

Unit II: Agro techniques: Climatic and soil requirements, planting and after care, weed and water management, manuring, plant protection.

Block 3: Harvest and post harvest management

Unit I: Harvest indices: Maturity indices, harvesting time, techniques, crop duration.

Unit II: Post harvest management: Primary processing, extraction and value addition, storage, active ingredients.

Crops

A. Plantation crops: Wattle, minor species of Areca, Coffea, Hevea

B. Spice crops: *Illicium verum*, *Myristica malabarica, M. beddomei, Cinnamomum tamala*, *C. malabatrum*, *Xanthoxylum* sp., *Curcuma caesia, C. aromatica, C. zedoaria, C. amada, Anethum graveolense, Hyssopus officinalis*, *Eringiumfoetidum, Pimpinella anisum, Artocarpus lacucha.*

C. Medicinal plants: *Flacourtia montana*, *Plectranthus aromaticus*, *Adhatoda* sp. *Hemidesmus indicus*, *Tinospora cordifolia*, *Gymnema sylvestre*, *Psoralea corylifolia*, *Eclipta alba*, *Aristalochia indica*, *Morinda citrifolia*, *Caesalpinia sappan*, *Terminalia chebula, T. bellerica, Phyllanthus amarus, Strychnos nuxvomica, S. indicum, S. xanthocarpum*, *Aegle marmelos*, *Alpinia* sp., *Hibiscus subdariffa, Anthocephalus kadamba, Costus* sp., *Kaempferia rotunda, K. parviflora, Picrorrhiza kurroa*, *Nardostachis jatamansi,Valeriana officinalis*, *Swertia chiraita, Aconitum* sp., *Salvia officinalis*, *Centella asiatica, Bixa orellana, Bacopa monnieri*

D. Aromatic plants: *Bursera* sp., *Commiphora wightii*, *Ocimum kilimandjaricum, Melaleuca, Michaelia champaka*, *Rosa damascena, Cananga odorata,* marjoram, chamomile

VII. Practical

- Botanical characteristics of species and varieties of various underexploited plantation, spice, medicinal and aromatic plants;
- Economic parts and their products;
- Propagation and nursery techniques;
- Harvesting and primary processing of under utilised PSMAs;
- Exposure visits to institutes, botanical gardens, herbal gardens and distillation units.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- be thorough with the importance and commercial production technology of underutilized and lesser known plantation, spice, medicinal and aromatic plants.
- be able to startunderutilized and lesser known plantation, spice, medicinal and aromatic plants-based enterprises

X. Suggested Reading

Atal CK and Kapur BM. *Cultivation and Utilization of Aromatic plants*. R.R.L. Jammu

Barche Swati. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi

Chadha KL and Gupta R. 1995. *Advance in Horticulture*. Vol. XI. *Medicinal and AromaticPlants*. Malhotra Publ. House.

CSIR, *The Wealth of India*. Volume A-Z CSIR

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Peter KV. *Under exploited and underutilized Horticulture crops*. Volume I-IV. New India Publication Agency.

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Ponnuswami *et al*. 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi

Ponnuswami *et al*. 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi

Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.

Sharangi AB, Bhutia PH, Chandani Raj A and Sreenivas M. 2018. *Underexploited spice crops: Present status, agrotechnology and future research directions*. Apple Academic Press (Taylor and Francis Group), Waretown, NJ, USA, p.326.

Sivarajan VV and Balachandran I. 1994. *Ayurvedic Drugs and their Plant Sources*. Oxford and IBH.

I. Course Title : Growth and Development of Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 509

III. Credit Hours : (2+1)

IV. Why this course ?

Understanding on growth and development of plantation, spice, medicinal and aromatic crops is vital towards quality production as well as yield. Fundamental knowledge on developmental physiology, biology and biochemistry and the associated changes is most essential. This course will impart theoretical as well as hands-on experience to the learner on these aspects of PSMA crops for improving their productivity.

V. Aim of the course

To impart comprehensive knowledge on the growth, developmental stages and crop regulation to increase the productivity in PSMAs

The course is organized as follows:

No	Blocks	Units
1	Growth and development	I Stages of growth II Growth pattern III Assimilate partitioning
2	Canopy management	I Canopy management II Plant bio regulators
3	Developmental physiology and biochemistry	I Vegetative phase II Flowering and fruit set III Growth and development during stress

VI. Theory

Block 1: Growth, development, assimilate partitioning and plant bio regulators

Unit I: Stages of growth: Growth and development, definitions, components, photosynthetic productivity, different stages of growth, growth curves, growth analysis, morphogenesis in PSMAs.

Unit II: Growth pattern: in annual, semi-perennial and perennial crops, growth dimorphism, environmental impact on growth and development: effect of light, temperature, photoperiod.

Unit III: Assimilate partitioning: Assimilate partitioning during growth and development, influence of water and mineral nutrition.

Block 2: Canopy management

Unit I: Canopy management: Canopy management for conventional and high density planting pruning, training, chemicals, crop regulation for year round and off season production in PSMAs.

Unit II: Plant bio regulators: plant bio regulators- auxins, gibberellins, cytokinins, ethylene, inhibitors and retardants, basic functions, biosynthesis and role in crop growth and development.

Block 3: Developmental physiology and biochemistry

Unit I: Vegetative phase: Developmental physiology and biochemistry during dormancy, bud break, juvenility.

Unit II: Flowering and fruit set

Physiology of flowering, photoperiodism, vernalisation, effect of temperature, heat units, thermoperiodism, pollination, fertilisation, fruit set, fruit drop, fruit growth, ripening, seed development in PSMAs.

Unit III: Growth and development process during stress: Growth and development process during stress, production of secondary metabolites, molecular and genetic approaches in growth and development.

VII. Practical

- Dormancy mechanisms in seeds, seed rhizomes;
- Techniques of growth analysis;
- Evaluation of photosynthetic efficiency under different environments;
- Technologies for crop regulation in cashew, coffee, cocoa, etc.;
- Root shoot studies, flower thinning, fruit thinning;
- Crop regulation for year round production;
- Use of growth regulators in PSMA crops.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Demonstrations
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to

- have thorough understanding on growth and development of PSMA crops
- will enable them to formulate crop regulation strategies for productivity enhancement.

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Buchanan BW. Gruiessam and Jones, R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley and Sons.

E- manual on Advances in Cashew Production Technology. ICAR -Directorate of Cashew Research, Puttur –574 202, DK, Karnataka

Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*.Wiley.

Fosket DE. 1994. *Plant Growth and Development: A Molecular approach*. Academic Press.

Leoplod AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rdEd.McGraw-Hill

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Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

Pillay PNR. 1980. *Handbook of Natural Rubber Production in India*. Rubber Research Institute, Kottayam. pp.668

Ravindran PN. 2000. *Black pepper*, *Piper nigrum*. CRC press

Ravindran PN. 2002. *Cardamom, the genus Elettaria*. CRC press

Ravindran PN. 2003. *Cinnamon and cassia*. CRC press

Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press

Ravindran PN. 2007. *Turmeric, the genus curcuma*. CRC press

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Roberts JS Downs and P Parker. 2002. *Plant Growth Development*. In: *Plants* (L. Ridge, Ed.), pp. 221-274, Oxford University Press
Salisbur FB and Ross CW. 1992. *Plant Physiology*. 4th Ed. Wadsworth Publ.
Sera T, Soccol CR, Pandey A. and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science).* Elsevier Science.

I. Course Title : Biochemistry of Plantation, Spices, Medicinal and Aromatic Crops

II. Course Code : PSM 510

III. Credit Hours : (2+1)

IV. Why this course ?

Postharvest physiology and biochemistry of plantation, spice, medicinal and aromatic crops contributes immensely towards quality improvement in crude as well as processed products. Fundamental knowledge on biochemistry of various crops is also essential for formulating their management practices in the field. This course will impart theoretical as well as hands-on experience to the learner on the biochemistry of PSMA crops.

V. Aim of the course

To impart comprehensive knowledge on the biochemistry, production of primary and secondary metabolites and the extraction of bioactive principles from PSMAs

The course is organized as follows:

No	Blocks	Units
1	Post harvest physiology	I Physiological and biochemical changes
		II Contaminants
2	Value addition	I Value added products
		II Quality standards
3	Extraction techniques	I Extraction techniques
		II Plant tissue culture

VI. Theory

Block 1: Post-harvest physiology

Unit I: Physiological and biochemical changes: Maturity indices, changes during ripening, processing, factors affecting quality. Secondary metabolites and their biosynthetic pathways, factors affecting production of secondary metabolites.

Unit II: Contaminants: Adulterants, and substitutes, sources of contamination-microbial, heavy metal, pesticide residues in PSMAs.

Block 2: Value addition

Unit I: Value added products: Fixed oils, essential oils, dyes, oleoresins, aroma chemicals and other value added products, their content, storage, medicinal and pharmacological properties, use in the food, flavour perfumery and pharmaceutical industries.

Unit II: Quality standards: Quality standards of raw materials and finished products.

Block 3: Extraction techniques

Unit I: Extraction methods: Basic and advanced extraction techniques in PSMAs-Soxhlet, SCFE, Membrane extraction. Chemical characterization-HPTLC, GCMS, LCMS, NMR.

Unit II: Plant tissue culture: Plant tissue cultures in the industrial production of bioactive plant metabolites. Cell suspension culture systems for large scale culturing of plant cells and production of secondary metabolites. Advantages of cell culture over conventional extraction techniques.

VII. Practical

- Biochemical characterisation;
- Detection of adulterants and substitutes;
- Extraction and quantification of secondary metabolites;
- Chromatographic separation of the products;
- Quality assurance;
- Testing the product;
- Exposure visit to leading industries;
- Assessment of antimicrobial properties;
- *In-vitro* production of secondary metabolites.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- develop the technical know- how on postharvest biochemistry of plantation, spice, medicinal and aromatic crops.

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Daniel M and Mammen D. 2016. *Analytical methods for medicinal plants and economic botany*. Scientific publishers.

Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi.

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Hammon JM and Yusibov V. 2000. *Plant Biotechnology*: New Products and application. Springer-Verlag.

Orhan I. 2012. *Biotechnological Production of Plant Secondary Metabolites*. Bentham Science Publishers.

Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

Panda H. 2016. The Complete Book on Cultivation and Manufacture of Tea (2nd Revised Edition). Asia Pacific Business Press Inc.

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Ponnuswami *et al*. 2018 Medicinal Herbs and herbal cure. Narendra Publishing House, New Delhi.

Raaman N. 2006. *Phytochemical techniques*. New India Publishing Agency, New Delhi.

Raju R Wadekar. 2015. *Pharmacognosy and phytochemistry*, Event publishing house.

Ramawat KG. 2007. *Biotechnology: secondary metabolites: plants and microbes*. Science Publishers.

Ranjal Kandall. *Bioactive compounds and genomic study of medicinal plants*. LAMBERT Academic Publishing.

Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.

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Shah B and Seth AK. 2005. *Text book of Pharmacognosy and Phytochemistry*. Cbs Publishers and distributors, New Delhi.

Shankar SJ. 2018. Comprehensive post harvest technology of flowers, medicinal and aromatic plants. Narendra Publishing House, New Delhi

Shukla YM. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi

Syed Aftab Iqbal and Noor Ahmed Khan. 1993.*Text book of Phytochemistry*. Discovery Publishing house Pvt. Ltd.

Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.

Trivedi C. 2004. *Herbal drugs and biotechnology*. Pointer Publishers.

Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals*. New India Publishing Agency, New Delhi.

I. Course Title : Biodiversity and Conservation of Plantation, Spices Medicinal and Aromatic Crops

II. Course Code : PSM 511

III. Credit Hours : (2+1)

IV. Why this course ?

India is the homeland of several plantation, spice, medicinal and aromatic crops. Biodiversity conservation is considered as the primary step in protecting the gene pool available in these crops. Fundamental knowledge on centres of diversity, germplasm evaluation, documentation, data base management and cataloguing is most essential. This course will impart theoretical as well as hands-on experience to the learner on these areas.

V. Aim of the course

To impart basic knowledge on natural as well as agro bio diversity, its value and conservation strategies with respect to PSMAs.

The course is organized as follows:

No	Blocks	Units
1	Plantation and spice crops	I Biodiversity II Germplasm collection and quarantine III Documentation and cataloguing IV National and international issues
2	Medicinal and aromatic crops	I Biodiversity II Germplasm collection and quarantine III Documentation and cataloguing IV National and international issues

VI. Learning outcome

After successful completion of this course, the students are expected to develop thorough understanding on biodiversity conservation of plantation, spice, medicinal and aromatic plants.

VII. Theory

Block 1: Plantation and Spice crops

Unit I: Biodiversity: Biodiversity, issues and goals, centres of origin of Plantation and spice crops, primary and secondary centres of genetic diversity.

Unit II: Germplasm collection and quarantine: Exploration and germplasm collection, planning and logistics, exchange of germplasm, plant quarantine principles, regulations plant quarantine systems in India. Components of germplasm evaluation, descriptor lists. Conservation of genetics resources, Concept of base and active collections, long and short term storage of Plantation and spice crops, gene bank management.

Unit III: Documentation and cataloguing: Recent approaches and role of biotechnology in PGR conservation documentation and data base management, cataloguing gene bank information. Molecular markers in characterisation of plant genetic resources. GIS in biodiversity mapping.

Unit IV: National and international issues: Genetic resources management of Plantation and Spice crops in India and in International perspective. Utilization and achievements in major crops. Concepts of rarity, threat, endangerment and extinction in major plantation and spice crops. Bio diversity concerns, national and international regulations, conservation networks. Good collection practices, domestication, PPV and FRA and DUS testing. Geographical indication, Biodiversity act and biodiversity legislations.

Block II: Medicinal and aromatic crops

Unit I: Biodiversity: Biodiversity, issues and goals, centres of origin of medicinal and aromatic crops, primary and secondary centres of genetic diversity.

Unit II: Germplasm collection and quarantine: Exploration and germplasm collection, planning and logistics, exchange of germplasm, plant quarantine principles, regulations plant quarantine systems in India. Components of germplasm evaluation, descriptor lists. Conservation of genetics resources, Concept of base and active collections, long and short term storage of Plantation and spice crops, gene bank management.

Unit III: Documentation and cataloguing: Recent approaches and role of biotechnology in PGR conservation documentation and data base management, cataloguing gene bank information. Molecular markers in characterisation of plant genetic resources. GIS in biodiversity mapping.

Unit IV: National and international issues: Genetic resources management of Plantation and Spice crops in India and in International perspective. Utilization and achievements in major crops. Concepts of rarity, threat, endangerment and extinction in major plantation and spice crops. Bio diversity concerns, national and international regulations, conservation networks. Good collection practices, domestication, PPV and FRA and DUS testing. Geographical indication, Biodiversity act and biodiversity legislations.

VIII. Practical

- Collection and identification of different plantation, spice, medicinal and aromatic plants from natural sources;
- Preparation of herbarium;
- Botanical and phyto-chemical grouping of PSMAs;
- Classification of PSMAs based on plant parts used;
- Documentation of germplasm;
- Maintenance of passport data and other records;
- Field explorations;
- Detection of adulterants and substitutes in PSMAs;
- Ethno botanical studies in tribal areas;
- Planning and layout of herbal gardens;
- Exposure visits to herbaria, herbal gardens and important organisations engaged in collection and utilization of PSMAs.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Demonstrations
- Exposure visits

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Choudhari AB. *Megadiversity Conservation: Flora, Fauna and Medicinal Plants of India's hot spots*.

Devi AR, Sharangi AB, Acharya SK and Mishra GC. 2017. *Coriander in Eastern India: The landraces and genetic diversity*. Krishi Sanskriti Publications. New Delhi. ISBN: 978-93-85822-48-3.

E- manual on Advances in Cashew Production Technology. ICAR -Directorate of Cashew Research, Puttur –574 202, DK, Karnataka

Kassahun Beemnet, Jemal Omar Sherif, TessemaTsion, Abate Solomon. 2009. *Production, Processing and utilization of Aromatic Plants*. EIAR.

Khan JB and Singh GP. 2012. *Biodiversity Management and Conservation* LAMBERT

Negi SS. *Biodiversity of India and its Conservation*.

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Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

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Ponnuswami *et al*. 2018. Spices. Narendra Publishing House, New Delhi

Pullaiah T. 2011. *Biodiversity in India* Vol.5.Daya Publishing house

Rajak RC and Rai MK. *Herbal Medicines, Biodiversity and Conservation strategies*. IBH.

Ramakrishnan N. 2018. *Biodiversity in Indian Scenario*. Daya publishing house.

Sera T, Soccol CR, Pandey A, Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.

Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.

Thirugnanakumar. 2018. *Genetic diversity and phenotypic stability in crop plants*. New India Publishing Agency, New Delhi

Trivedi PC. *Medicinal Plants: Utilization and Conservation*.

Course Title with Credit Load Ph.D. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
PSM 601*	Advances in Production of Plantation and Spice Crops	3+0
PSM 602*	Advances in Production of Medicinal and Aromatic Crops	3+0
PSM 603*	Recent Breeding Approaches in Plantation, Spice, Medicinal and Aromatic Crops	3+0
PSM 604	Advanced Methods in Laboratory Techniques	1+2
PSM 605	Biotechnological Approaches in PSMA Crops	3+0
PSM 606	Abiotic Stress Management in Plantation, Spice, Medicinal and Aromatic Crops	2+1
PSM 607	Organic Spice and Plantation Crops Production	2+1
PSM 608	Marketing and Export of Plantation, Spice, Medicinal and Aromatic Crops	2+1
	Minor courses	06
	Supporting courses	05
PSM 691	Seminar-I	0+1
PSM 692	Seminar-II	0+1
PSM 699	Research	0+75
	Total	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

I. Course Title : **Advances in Production of Plantation and Spice Crops**

II. Course Code : **PSM 601**

III. Credit Hours : **(3+0)**

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart knowledge to the learner on advanced scientific production technology of various plantation and spice crops in Indian perspectives. Hi-tech production technologies will be discussed in this course.

V. Aim of the course

The course is designed to provide advanced crop production techniques of various plantation and spice crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Plantation and spice Crops	I. Area, production, productivity: Indian and world scenario II. Export potential III. Promotional programmes
2	Advanced agro techniques	I. Varietal wealth and planting material production II. Mass multiplication techniques III. Hi-tech nursery techniques IV. Impact of climate change
3	Harvest and post harvest management	I. Maturity indices and harvest II. Post-harvest management III. Quality standards

VI. Theory

Block 1: Importance of Plantation and Spice Crops

Unit I: Area, production, productivity: Indian and world scenario: Role of plantation and spice crops in national economy, area-production statistics at national and international level, productivity challenges, industrial requirement of plantation and spice crops, demand-supply scenario of plantation and spice crop.

Unit II: Export potential: Export scenario, market opportunities and challenges in plantation and spice crops, global imports and exports, export of organic produce and products.

Unit III: Promotional programmes: Role of commodity boards and directorates in the development programmes of plantation and spice crops, contract farming, Farmer Producer Organizations (FPO) and Farmer Producer Companies (FPC).

Block 2: Advanced Agrotechniques

Unit I: Varietal wealth and planting material production: Cultivars and improved varieties in plantation and spice crops, mass multiplication techniques, hi-tech nursery techniques.

Unit II: Agrotechniques: Precision farming techniques, HDP systems, fertigation, chemical regulation of crop productivity, protected cultivation of high value crops, mechanization in plantation and spice crops, hydroponics, aeroponics, application of nanotechnology, robotics.

Unit III: Impact of climate change: Impact of biotic and abiotic factors on growth and productivity, climate resilient technologies in plantation and spice crops, soil health management, organic production systems.

Block 3: Harvest and postharvest management

Unit I: Maturity indices and harvest: Influence of pre and post harvest factors on quality of plantation and spice crops, pre and post harvest management techniques for improving quality, good manufacturing practices in plantation and spice sector.

Unit II: Quality standards: Domestic and international standards, HACCP, BIS standards, domestic and export grades, modern packaging techniques, export protocols.

Crops

Coconut, Arecanut, Oil palm, Cashew, Coffee, Tea, Cocoa, Rubber, Palmyrah, Black pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Vanilla, Garcinia, Coriander, Cumin, Fennel, Fenugreek, Ajwain, Dill, Safron

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, industries

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- be equipped with the latest research outcome in commercial cultivation of plantation and spice crops
- be able to start hi-tech plantation and spice crop based enterprises

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Agarwal S, Divkarasastry EV and Sharma RK. 2001. *Seed Spices, Production, Quality and Export*. Pointer Publ.

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Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

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Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops*. Parts I, II. New India Publ. Agency.

Purseglove JW, Brown EG, Green CL and Robbins SRJ. 1984. *Spices*. Vols. I, II. Longman.

Purseglove JW. 1968. *Tropical Crops–Dicotyledons*. Longman.

Ramachandra *et al*. 2018. *Breeding of Spices and Plantation crops*. Narendra Publishing House, New Delhi.

Ranganathan V. 1979. *Hand Book of Tea Cultivation*. UPASI, Tea Res. Stn. Cinchona.

Ravindran PN. 2003. *Cinnamon and cassia*. CRC press.

Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press

Ravindran PN. 2007. *Turmeric, the genus curcuma*. CRC press, Medicinal and Aromatic Plants – Industrial Profiles. Routledge, UK.

Ravindran PN. 2001. *Monograph on Black Pepper*. CRC Press.

Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI

Ravindran PN and Madhusoodanan KJ. 2002. *Cardamom, the Genus Elettaria*. CRC press.

Sera T, Soccol CR, Pandey A and Roussos S Coffee Biotechnology and Quality. Springer, Dordrecht.

Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology* (Developments in Crop Science). Elsevier Science.

Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production Technology of Spices and Plantation Crops*. Agrobios.

Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2

Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.

Sharangi AB, Datta S and Deb, P. 2018. *Spices: Agrotechniques for quality produce*, April, Academic Press (Tylor and Francis Groups), New Jersey, USA.

Sharangi AB. 2018. *Indian Spices: The legacy, production and processing of India's treasured export*. Springer International publishing. AG, Part of Springer Nature, 2018, Cham, Switzerland.

Srivastava HC, Vatsaya and Menon KKG. 1986. *Plantation Crops–Opportunities and Constraints*. Oxford and IBH.

Swain SC. 2018. *Precision Farming in Horticulture: Approaches and strategies*. Narendra Publishing House, New Delhi.
Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.
Varmudy V. 2001. *Marketing of Spices*. Daya Publ. House.
Winton AL and Winton KB. 1931. *The Structure and Composition of Food*. John Wiley and Sons.
Yagna Narayan Ayer AK. 1960. *Cultivation of Cloves in India*. ICAR.

I. Course Title : Advances in Production of Medicinal and Aromatic Crops

II. Course Code : PSM 602

III. Credit Hours : (3+0)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. They also cater to the primary health care needs of a large section of people. This course will impart knowledge to the learner on advanced scientific production technology of various medicinal and aromatic crops in Indian perspectives.

V. Aim of the course

The course is designed to provide latest developments and trends in the production technology of various medicinal and aromatic crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Medicinal and Aromatic Crops	1. Biodiversity of medicinal and aromatic crops 2. Area, production, productivity statistics 3. Export potential
2	Advanced Agro techniques	1. Domestication studies 2. Varietal wealth and planting material production 3. Agro techniques 4. Impact of climate change
3	Harvest and post Harvest Management	1. Maturity indices and harvest 2. Modern methods of extraction of MAPs 3. Quality standards

VI. Theory

Block 1: Importance of Medicinal and Aromatic Crops

Unit I: Biodiversity of medicinal and aromatic crops (MAPs): Biodiversity of MAPs, conservation networks, global initiatives on medicinal plants conservation and development, World history on usage of MAPs, preference to natural products. Indian traditional wisdom and heritage, Indian herbal wealth, documentations, databases, scientific validation.

Unit II: Area, production and productivity statistics: Role of medicinal and aromatic crops in national economy, area-production statistics at national and international level, productivity challenges, Trends in food, flavouring, perfumery and cosmetic industries, requirement in the ayurvedic, pharmaceutical, perfume and cosmetic industries, demand-supply scenario of MAPs.

Unit III: Export potential: Export and import of crude drugs, standardized extracts, aromatic plants, essential oils. Intellectual Property Rights, patents. Contract farming. Role of Medicinal Plant Board in promotional programmes of MAPs.

Block 2: Advanced agro-techniques

Unit I: Domestication of medicinal and aromatic crops: Need for domestication, changes on domestication, influence of environment on secondary metabolite production, developing cultivation packages for emerging crops.

Unit II: Varietal wealth and planting material production: Cultivars and improved varieties in medicinal and aromatic crops, mass multiplication techniques, micropropagation, hi-tech nursery techniques.

Unit III: Agro techniques: Advanced research in the field of growth and development, nutrition and irrigation requirements, inter culture, mulching, weed control.

Precision farming techniques, HDP systems, fertigation, chemical regulation of crop productivity, protected cultivation of high value crops, hydroponics, aeroponics, application of nanotechnology, nano-fertilizers, nano-pesticides, robotics.

Unit IV: Impact of climate change: Impact of biotic and abiotic factors on growth, productivity and quality, climate resilient technologies in medicinal and aromatic crops, soil health management, organic production systems.

Block 3: Harvest and post harvest management

Unit I: Maturity indices and harvest: Influence of pre and post harvest factors on quality of medicinal and aromatic crops, pre and post harvest management techniques for improving quality, good manufacturing practices in herbal sector.

Unit II: Modern methods of extraction of MAPs: Advanced essential oil extraction and value addition methods in aromatic plants, advances in phytochemical extraction technologies, separation of bio-molecules, phytochemicals and drug development. Pharmacology and pharmacognosy, *in vivo* and *in-vitro* extraction of secondary metabolites, bioreactors.

Unit III: Quality standards: Quality standards in medicinal and aromatic plants, quality standards in crude drugs and finished products, use of aroma chemicals, aroma therapy, advanced research in biomedicines, nutraceuticals and natural drugs, American, European and Asian legislations on plant drugs, domestic and international standards, modern packaging techniques.

Crops

A. Medicinal crops: Coleus, Glory lily, Senna, Periwinkle, Stevia, Aswagandha, Sarpagandha, Aloe, *Phyllanthus amarus*, *Andrographis paniculata*, Isabgol, Poppy, *Digitalis* sp., *Commiphora* sp., Ipecac, Henbane, *Ocimum* sp., Centella, Bacopa, Saraca, Valerian, Jatamansi, Aconits, Ephedra and Bael.

B. Aromatic crops: Palmarosa, Lemongrass, Citronella, Vetiver, Geranium, Artemisia, Mint, Eucalyptus, Rosemary, Thyme, Patchouli, Rose, Jasmine, Lavender.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, industries

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- be equipped with the latest research out come in commercial cultivation of medicinal and aromatic crops
- be able to start hi-tech medicinal and aromatic crop based enterprises

IX. Suggested Reading

Dharamvir H. 2007. *Bioactive Medicinal Plants*. Gene Tech Books.

Farooqi AA and Sriramu AH. 2000. *Cultivation Practices for Medicinal and Aromatic Crops*. Orient Longman Publ.

Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.

Jain SK. 2000. *Medicinal Plants*. National Book Trust.

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Panda H. 2002. *Medicinal Plants Cultivation and their Uses*. Asia Pacific Business Press.

Ponnuswami *et al*. 2018. *Medicinal Herbs and herbal cure*. Narendra Publishing House, New Delhi.

Prajapati ND, PaeroHit SS, Sharma AK and Kumar T. 2006. *A Hand Book of Medicinal Plants*. Agro Bios.

Ramawat KG and Merillon JM. 2003. *Biotechnology–Secondary Metabolites*. Oxford and IBH.

Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.

Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.

Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.

Swain SC. 2018. *Precision farming in Horticulture: Approaches and strategies*. Narendra Publishing House, New Delhi.

Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.

I. Course Title : Recent Breeding Approaches in Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 603

III. Credit Hours : 3+0

IV. Why this course ?

Plantation, spice medicinal and aromatic crops (PSMA) play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers and cater to the primary health care needs of a large section of people. This course will impart knowledge to the learner on the advanced breeding approaches followed in important PSMA crops in Indian perspectives.

V. Aim of the course

The course is designed to provide knowledge on modern approaches in the breeding of various PSMA crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Plantation crops	I Genetic resources II Breeding methods III Breeding achievements
2	Spice crops	I Genetic resources II Breeding methods III Breeding achievements
3	Medicinal and Aromatic crops	I Genetic resources II Breeding methods III Breeding achievements

VI. Theory

Block 1: Plantation Crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, types of pollination and fertilization mechanisms, sterility and incompatibility systems in Plantation crops.

Unit II: Breeding methods: Introduction and selection, chimeras, clonal selections, intergeneric, interspecific and inter-varietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Breeding objectives, ideotype breeding, breeding problems and achievements in Plantation crops.

Block 2: Spice crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, types of pollination and fertilization mechanisms, sterility and incompatibility systems in Spice crops.

Unit II: Breeding methods: Introduction and selection, chimeras, clonal selections, intergeneric, interspecific and intervarietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Breeding objectives, ideotype breeding, breeding problems and achievements in Spice crops.

Block 3: Medicinal and aromatic crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, chemotaxonomy, pollination and fertilization mechanisms, sterility and incompatibility systems in Medicinal and Aromatic crops.

Unit II: Breeding methods: Introduction and selection, clonal selections, intergeneric, interspecific and intervarietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, genetic mechanisms associated with secondary metabolites, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Specific breeding objectives in medicinal and aromatic crops, ideotype breeding, breeding problems and achievements in medicinal and aromatic crops.

Crops

A. Plantation crops: Coconut, Arecanut, Oil palm, Cashew, Coffee, Tea, Cocoa, Rubber

B. Spice crops: Black pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Garcinia, Coriander, Cumin, Fennel, Fenugreek, Ajwain, Dill.

C. Medicinal crops: Senna, Periwinkle, Aswagandha, Isabgol, Sarpagandha, Poppy, Glory lily, Medicinal coleus, *Mucuna pruriens*, Ocimum, *Centella asiatica*, *Bacopa monnieri*, *Andrographis paniculata*, *Aloe vera*, *Phyllanthus amarus*, Eucalyptus, Bael, Henbane.

D. Aromatic crops: Lemongrass, Palmarosa, Citronella, Vetiver, Mint, Sweet basil, Lavender, Geranium, Patchouli, Artemisia, Rosemary, Thyme, Sage, Marjoram, Fever few.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, PSMA crop based industries

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- be equipped with the latest research outcome in crop improvement of PSMA crops
- be able to start hi-tech PSMA crop based seed/ planting material production programmes

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Agarwal S, Divkarasastry EV and Sharma RK. 2001. *Seed Spices, Production, Quality and Export*. Pointer Publ.

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Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.
Chadha KL. 2001. *Hand Book of Horticulture*. ICAR.
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Srivastava HC, Vatsaya and Menon KKG. 1986. *Plantation Crops–Opportunities and Constraints*. Oxford and IBH.
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Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.
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Winton AL and Winton KB. 1931. *The Structure and Composition of Food*. John Wiley and Sons.
Yagna Narayan Ayer AK. 1960. *Cultivation of Cloves in India*. ICAR.

I. Course Title : Advances in Laboratory Techniques for Psma Crops
II. Course Code : PSM 604
III. Credit Hours : (1+2)

IV. Why this course ?

Plantation, spice, medicinal and aromatic crops demand specific post harvest management and value addition. At each step it has to undergo quality assessment using modern equipment and machinery. Export standards are also based on stringent quality parameters. This course is designed to make the learner well versed with modern analytical methods, instruments and machinery used in quality analyses.

V. Aim of the course

To equip the students with the latest laboratory techniques required for assessing the quality of PSMA crops.

The course is organised as follows

No	Blocks	Units
1	Plantation Crops	I Physiological and biochemical changes II Contaminants III Value addition
2	Spice Crops	I Physiological and biochemical changes II Contaminants III Value addition

No	Blocks	Units
3	Medicinal and Aromatic Crops	I Secondary metabolites and their biosynthetic pathways II Contaminants III Value addition

VI. Theory

Block 1: Plantation Crops

Unit I: Physiological and biochemical changes: Physiological and biochemical changes during maturity and ripening including post harvest changes. Factors influencing quality.

Unit II: Contaminants: Adulterants, substitutes, sources of contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, value added products, grading, storage, transportation.

Block 2: Spice Crops

Unit I: Physiological and biochemical changes: Physiological and biochemical changes during maturity and ripening including Post harvest changes. Factors influencing quality.

Unit II: Contaminants: Adulterants, substitutes, sources of contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, essential oils, value added products, grading, storage, transportation.

Block 3: Medicinal and aromatic crops

Unit I: Secondary metabolites and their biosynthetic pathways, factors affecting production of secondary metaboiltes, changes during maturity, harvesting and processing.

Unit II: Contaminants: Adulterants, substitutes, contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, essential oils, oleoresins, concretes, absolutes, dyes, natural colours, aroma chemicals, grading, storage, transportation. Quality standards of raw materials and finished products.

VII. Practical

- Sampling techniques in PSMA crops or their parts;
- Solvent extraction of spices and medicinal plants;
- Detection of adulterants and substitutes;
- Extraction of secondary metabolites from medicinal crops;
- Qualitative analyses of secondary metabolites;
- Quantitative estimation of secondary metabolites;
- Preparation of plant extracts;
- Chromatographic separation of extracts;
- Thin layer chromatography;
- Soxhlet extraction;

- Super critical fluid extraction;
- Determination of physical and chemical properties of essential oils;
- Flavor profile of essential oils by gas chromatography;
- Chemical characterization by HPTLC;
- Chemical characterization by GCMS;
- Chemical characterization by LCMS;
- Chemical characterization by NMR;
- Bioassay and High Throughput Screening;
- Techniques for assessment of antimicrobial property;
- Techniques for assessment of antioxidant property, pesticide residue analyses;
- Determination of heavy metals by flame photometry;
- Plant tissue cultures in the industrial production of bioactive plant metabolites;
- Exposure visit to leading medicinal and aromatic industries, accredited quality control labs.

VIII. Learning outcome

After completion of this course, the student will be equipped in

- the modern analytical methods of biochemistry
- handling of equipments and machinery used in biotechnology, processing and value addition

IX. Suggested Reading

Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.

Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi.

Hammon JM and Yusibov V. 2000. *Plant Biotechnology: New Products and application*. Springer-Verlag.

Orhan I. 2012. *Biotechnological Production of Plant Secondary Metabolites*. Bentham Science Publishers.

Raaman N. 2006. *Phytochemical techniques*. New India Publishing Agency, New Delhi.

Ramawat KG. 2007. *Biotechnology: secondary metabolites: plants and microbes*. Science Publishers.

Sadasivam S and Manickam A. 1991. *Biochemical methods*. New Age International Publishers.

Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.

Shukla Y.M. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi.

Parimelzhagan T. 2013. *Turning plants into medicines: Novel approaches*. New India Publishing Agency, New Delhi.

Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.

Trivedi C. 2004. *Herbal drugs and biotechnology*. Pointer Publishers.

Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals*. New India Publishing Agency, New Delhi.

I. Course Title : Biotechnological Approaches in Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 605

III. Credit Hours : (3 +0)

IV. Why this course ?

Tools of biotechnology are widely used in crop improvement, crop management, crop protection and post harvest management of PSMA crops. This course is designed to impart knowledge on advanced biotechnological tools used in various spheres of plantation, spices, medicinal and aromatic crops.

V. Aim of the course

The main objective of the course is to impart to the learner, knowledge on advanced biotechnological tools used in various spheres of plantation, spices, medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Plantation Crops	I *In-vitro* mass multiplication techniques
		II *In-vitro* breeding
		III Transgenic crops
2	Spice Crops	I *In-vitro* mass multiplication techniques
		II *In-vitro* breeding
		III Transgenic crops
3	Medicinal and Aromatic Crops	I *In-vitro* mass multiplication techniques
		II *In-vitro* breeding
		III Transgenic crops
		IV *In-vitro* production of secondary metabolites

VI. Theory

Block 1: Plantation Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of plantation crops, direct and indirect organogenesis, micro grafting, hardening techniques.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species. *In-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, fingerprinting of cultivars, etc., achievements, problems and future thrusts.

Block 2: Spice Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of spice crops. direct and indirect organogenesis, micro grafting, hardening techniques, production of microrhizomes.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, Protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species, *in-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, fingerprinting of cultivars, etc., achievements, problems and future thrusts.

Block 3: Medicinal and Aromatic Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of medicinal and aromatic crops, direct and indirect organogenesis, micro grafting, hardening techniques, production of microrhizomes.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, Protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species, *in-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, finger printing of cultivars, etc., achievements, problems and future thrusts.

Unit IV: *In-vitro* production of secondary metabolites: *In-vitro* production and characterization of secondary metabolites, bioreactors.

Crops

Coconut, Rubber, Oil palm, Coffee, Tea, Cocoa, Black pepper, Cardamom, Turmeric, Ginger, Vanilla, Periwinkle, Rauvolfia, Mint, Cymbopogon grasses, Medicinal coleus, *Ocimum* sp., Aswagandha, Aloe, Safed musli, Stevia

VII. Learning outcome

The learner is expected to be:

- acquainted with the applications of biotechnology in PSMA crops
- able to start modern labs based on biotechnology in PSMA crops

VIII. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Bajaj YPS. Ed. 1987. *Biotechnology in Agriculture and Forestry*. Springer.

Chadha KL, Ravindran PN and Sahijram L. Eds. 2000. Biotechnology of Horticulture and Plantation Crops. Malhotra Publ. House.

Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*. Daya Publishing House, New Delhi.

Choudappa P, Niral V, Jerard BA and Samsudeen K. 2017. *Coconut*. Daya Publishing House, New Delhi.

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Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
Panopoulas NJ. (Ed.). 1981. *Genetic Engineering in Plant Sciences*. Praeger Publ.
Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vols. I-III. Naya Prakash.
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Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
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Shukla YM. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi.
Singh BD. 2001. *Biotechnology*. Kalyani.
Skoog F and Miller CO. 1957. *Chemical Regulation of Growth and Formation in Plant Tissue Culture in-vitro*. Symp. Soc. Exp. Biol. 11, 118-131.
Williamson R. 1981-86. *Genetic Engineering*. Vols. I-V. Academic Press.

I. Course Title : Abiotic Stress Mangement in Plantation, Spices, Medicinal and Aromatic Crops

II. Course Code : PSM 606

III. Credit Hours : (2+1)

IV. Why this course ?

Global climate is undergoing drastic changes and crops find it difficult to adapt to the changed environments. Abiotic stress due to temperature, water, salts, radiations, nutrients, pollutants, etc. affects the growth, physiology, yield and quality attributes of PSMA crops. This course is designed for the learner to understand the influence of these abiotic stress factors on PSMA crops.

V. Aim of the course

The course aims to impart knowledge on the influence of abiotic stress factors on growth, physiology, yield and quality attributes of PSMA crops along with advanced approaches in the management of these stresses.

The course is organized as follows:

No	Blocks	Units
1	Abiotic Stress	I Temperature and water stress
		II Stress due to soil conditions and salt
		III Pollution stress
		IV Other stresses
2	Climate Change	I Contributing factors
		II Carbon trading
		III Impact of climate change on PSMA crops
3	Climate Resilient Technologies	I Varieties
		II Climate resilient technologies
		III Waste management

VI. Theory

Block 1: Abiotic Stress

Definition, soil conditions (salinity, alkalinity, ion toxicity, fertilizer toxicity, etc.), salt stress

Unit I: Temperature and water stress: Stresses due to water (high and low), temperature (high and low), symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit II: Stress due to soil conditions and salts: Alkainity, salinity, iron toxicity, fertilizer toxicity symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit III: Pollution stress: Gaseous pollutants and heavy metals, symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit IV: Other stresses: Stress due to radiation, wind, nutrients. symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Block 2: Climate change

Unit I: Contributing factors: Introduction to climate change, factors contributing to climate change, change in temperature, rainfall, humidity, rise in the atmospheric CO_2 levels, tropospheric ozone levels, extreme climatic events.

Unit II: Carbon trading: Global warming, carbon trading, role of green housegases, impact on productivity of PSMA crops. Clean development mechanism.

Unit III: Impact of climate change on PSMA crops: Plantation crops, Spice crops, Medicinal and aromatic crops.

Block 3: Climate resilient technologies

Unit I: Varieties: Plantation crops, Spice crops, Medicinal and aromatic crops.

Unit II: Climate resilient technologies: Plantation crops, Spice crops, Medicinal and aromatic crops.

Unit III: Waste management: Alternate farming systems, Zero waste management, Microbial waste management.

VII. Practical

- Analysis of plant stress factors;
- Relative water content;
- Chlorophyll stability index;
- Plant waxes;
- Stomatal diffusive resistance;
- Transpiration;

- Photosynthetic rates;
- Calculation of water use efficiency and growth rates;
- Identifying abiotic stress symptoms and injuries;
- Use of antitranspirants;
- Managing nutrient stress;
- Stress management by hormones;
- Screening for abiotic stress tolerance;
- Weather data analyses and quantification of climate change;
- Cropping pattern changes due to climate extremities;
- Phenological and quality changes in PSMAs;
- Pesticide residue analysis in PSMAs.

VIII. Learning outcome

The learner is expected to get empowered on

- the impact of abiotic stress on PSMA crop production
- the mitigation measures to be adopted for sustaining PSMA crop production

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Ahmad, Parvaiz, and Prasad MNV. 2012. *Abiotic Stress Responses in Plants Metabolism, Productivity and Sustainability*. Springer.

E- manual on *Advances in Cashew Production Technology*. ICAR- Directorate of Cashew Research, Puttur– 574 202, D.K., Karnataka.

Prasad HC, Rao, Sriniv NK, Shivashankar and Seetharamaiah K. 2013. *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*. Springer.

Hebbar KB, Kumar SN and Choudappa P. 2017. *Impact of climate change on Plantation Crops*. Daya Publishing House, New Delhi.

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Levitt J. 1972. *Response of Plants to Environmental Stresses*. Academic Press.

Manish B. 2018. *Climate resilient agriculture: Adaptation, mitigation strategies*. New India Publishing Agency, New Delhi.

Mussell H and Staples R. 1979. *Stress Physiology in Crop Plants*. Wiley Inter. Science.

Nickell LG. 1983. *Plant Growth Regulating Chemicals*. CRC Press.

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Rao Prasada GSHLV, Rao, GGSN and Rao, VUM. 2008. *Climate Change and Agriculture over India*. Kerala Agricultural University, Thrissur.

Roy B and AK Basu. 2009. *Abiotic stress tolerance in crop plants*. New India Publ. House.

Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.

Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science*). Elsevier Science.

Shanker AK and Venkateswarlu B. 2011. *Abiotic Stress in Plants– Mechanisms and Adaptations*. In tech, Croatia.

Turner NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley and Sons.

Venkateswarlu B, Shanker AK, Chitra M and Maheswari M. *Crop Stress and its Management: Perspectives and Strategies*. Springer.

www.plantphysiol.org, www.plantsress.com

I. Course Title : Organic Spice and Plantation Crops Production

II. Course Code : PSM 607

III. Credit Hours : (2+1)

IV. Why this course ?

A shift to organic agriculture is happening in different parts of the world. Demand for organic plantation and spice crops is also increasing globally. This course is designed to give comprehensive knowledge on scientific organic farming technology in plantation and spice crops.

V. Aim of the course

To impart knowledge on principles, concepts, techniques and certification procedures of organic farming in spice and plantation crops

The course is organized as follows

No	Blocks	Units
1	Concepts of Organic Farming	I. Importance II. Organic conversion plan III. Organic farming systems
2	Organic Production Technologies	I. Plantation crops II. Major spices III. Minor spices
3	Certification and Quality Control	I. Accreditation II. Organic standards III. Quality control

VI. Theory

Block 1: Concepts of Organic Farming

Unit I: Importance: Principles, perspectives, concepts and components of organic farming, present status of organic farming at national and global level, domestic and global demand for organic products with respect to spice and plantation crops, organic production and export–opportunities and challenges.

Unit II: Organic Conversion Plan: Advanced methods for enhancing soil fertility, soil amendments. Modern methods of composting, vermicomposting, coir pith composting, bio fertilizers, pest and disease management in organic farming; crop rotation in organic horticulture, weed management, botanicals and bio- control agents.

Unit III: Organic Farming Systems: Natural farming, permaculture, biodynamic farming, Zero budget farming, Homa farming, EM technology.

Block 2: Organic Production Technology

Unit I: Plantation crops: Coconut, Coffee, Cocoa, Tea.

Unit II: Major Spices: Black pepper, Cardamom, Ginger, Turmeric, Vanilla.

Unit III: Seed spices: Coriander, Cumin, Fennel, Fenugreek.

Block 3: Certification and Quality Control

Unit I: Accreditation: Accreditation agencies, certification agencies, procedure of certification, types of certification.

Unit II: Organic standards: Domestic and international standards, NPOP, IFOAM, CODEX, HACCP standards.

Unit III: Quality control: Participatory Guarantee System (PGS) in quality control, quality control for organic products.

VII. Practical

- Enrichment of composts;
- Biofertilizers;
- Bio control agents;
- Biodynamic preparations;
- Zero- budget preparations;
- Biopesticides;
- AMF in organic production;
- Waste management techniques;
- Exposure visits to organic fields, certification and marketing centers.

VIII. Learning outcome

The learner is expected to get empowered on

- the organic farming techniques in Spice and Plantation crops
- the organic certification procedures in Spice and Plantation crops

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Dahama AK. 2005. *Organic Farming for Sustainable Agriculture*. 2nd Ed. Agrobios.

E- manual on *Advances in Cashew Production Technology*. ICAR- Directorate of Cashew Research, Puttur –574 202, D.K., Karnataka.

Gehlot G. 2005. *Organic Farming: Standards, Accreditation, Certification and Inspection*. Agrobios.

Palaniappan SP and Annadarai K. 2003. *Organic Farming: Theory and Practice*. Scientific Publ.

Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic Spices. New India* Publ. Agency.

Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2008. *Management of Horticultural Crops*. New India Publ. Agency.

Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.

Shivashankar K. 1997. *Food Security in Harmony with Nature*. 3, IFOAM- RD, ASIA, Scientific Conference. 1-4 Dec., 1997, UAS, Bangalore.

I. Course Title : Marketing and Trade of Plantation, Spices, Medicinal and Aromatic Crops

II. Course Code : PSM 608

III. Credit Hours : (2+1)

IV. Why this course ?

Marketing and trade are two important aspects in the domestic as well as international movement of PSMA crops. Instability in the price structure as well as demand of various plantation and spice crops often puts the farmers and enterpruners at risk. This course is designed to impart in the learner a deeper understanding on marketing and trade in raw materials and value added products of PSMAs crops both at the domestic and international level.

V. Aim of the course

This course is designed to impart in the learner a deeper understanding on marketing and trade in raw materials and value added products of PSMAs crops both at the domestic and international level.

The course is organized as follows

No	Blocks	Units
1	Importance of Marketing and Trade	I. Market opportunities II. Marketing strategies
2	Marketing Channels	I. Market organisations II. Value chain management and total quality management
3	Entrepreneurship Development	I. Decision making II. Price structure

VI. Theory

Block 1: Importance of marketing and trade

Unit I: Market opportunities: Market opportunities and challenges in PSMA crops at the domestic and global level, consumption in India's plantation, herbal and spice and other industries, Demand-supply scenario of PSMAs at the national and international level, Marketing and trade in raw materials and value added products

Unit II: Marketing strategies: Direct and indirect marketing, niche marketing, specialty markets, market intermediaries and their role, market infrastructure needs, marketing efficiency. market organization, planning, promotion, cost control, contract farming

Block 2: Marketing Channels

Unit I: Market organizations: Marketing co-operatives including tribal co-operatives, public private partnerships (PPP), Farmer Producer Companies (FPC) and Farmer Producer Organisations (FPOs).

Unit II: Supply chain management and total quality management: Good transportation procedures, cold storage facilities, State trading, warehousing and other govt. agencies. Role of commodity boards and export promotion councils in marketing and export of PSMA crops

Block 3: Entrepreneurship development

Unit I: Decision making: Risk taking, motivation, importance of planning, monitoring, evaluation and follow up, SWOT analysis, generation, incubation and commercialisation of ideas and innovations. Communication skills, domestic and export market intelligence, export standards. Role of information technology and telecommunication in marketing of PSMAs

Unit II: Price structure: Price analysis and price forecasting in PSMA crops, policies on export, import and re-export of commodities and value added products, guidelines for marketing of organic produce and organic products

VI. Practical

- Study of requirement of various raw materials by the plantation, spice and ayurveda industries;
- Demand supply analysis of various PSMA crops;
- Exposure visit to trading centres, exporters, ware houses, value addition units, etc.;
- Study of FPOs and FPCs in various crops;
- Preparation and evaluation of projects;
- Documentation of case studies.

VII. Learning outcome

The learner is expected to get empowered on

- the marketing and trade oppurtunites and channeles in PSMA crops
- the enterprenureship development and value chain in PSMA crops
- decision support and pricing system in PSMA crops

VIII. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Chinnappa B. 2018. *Economics and marketing of Arecanut in India.* Narendra Publishing House, New Delhi.

CUTS. 2004. *Data base on Medicinal Plants*. CUTS Centre for International Trade, Economics and Environment, Calcutta.

E-manual on *Advances in Cashew Production Technology*. ICAR- Directorate of Cashew Research, Puttur-574 202, D.K., Karnataka.

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Tyagi SK. 2015. *Spices, Plantation Crops, Medicinal and Aromatic plants-a hand book*. New India Publishing Agency.

Varmudi. 2001. *Marketing of Spices*. Daya publishing house.

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e-Resource

www.nmpb.nic.in

Suggested Journals

Sr. No.	Name of the Journal	ISSN No.
1	*Annals of Horticulture*	0976-4623
2	*Biological Agriculture and Horticulture*	2165-0616
3	*Current Horticulture*	2455-7560
4	*European Journal of Medicinal Plants*	2231-0894
5	*Horticulture Enviornment and Biotechnology*	2211-3460
6	*Indian Coconut Journal*	0970-0579
7	*Indian Horticulture Journal*	2347-3029
8	*Indian Journal of Arecaunt Spices and Medicinal Plant*	0972-2483
9	*Indian Journal of Arid Horticulture*	2249-5258
10	*Indian Journal of Horticulture*	0974-0112
11	*International Journal of Horticulture*	1927-5803
12	*International Journal of Horticulture, Agriculture and Plant Sciences*	2572-3154
13	*International Journal of Innovative Horticulture*	2320-0286
14	*International Journal of Seed Spices*	
15	*International Journal of Tea Science*	0972-544X
16	*Journal of Applied Horticulture*	0972-1045
17	*Journal of Herbs, Spices, and Medicinal Plants*	1540-3580
18	*Journal of Medicinal and Aromatic Plant Sciences*	0253-7125
19	*Journal of Medicinal Food*	1557-7600
20	*Journal of Medicinal Plant Research*	1996-0875
21	*Journal of Medicinal Plant Studies*	2320-3862
22	*Journal of Plantation Crops*	2454-8480
23	*Journal of Spices and Aromatic Crops*	0971-3328
24	*Medicinal Plants: International Journal of Phytomedicines and Related*	0975-4261
25	*Polycyclic Aromatic Compounds*	1040-6638
26	*Progressive Horticulture*	2249-5258
27	*Rubber Science (Natural Rubber Research)*	2524-3993
28	*Spice India*	0970-5805
29	*The Asian Journal of Horticulture*	0973-4767

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Post-harvest Management

Preamble
(Post-harvest Managment)

Postharvest Management is an interdisciplinary science and technology applied to horticulture produce after its harvest for its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of people. India is the 2nd largest producer of fruits and vegetables in the world. Several studies suggest that around 30–40% of produced fruits and vegetables are lost before they reach final consumer. These losses occur during different stages of harvesting, handling, packaging, transportation, in wholesale and retail markets. Moreover, only 2.5% of the produce is processed, to minimize the losses of fruits, vegetables, flowers, plantation and spice crops and to increase the farmers income there by guaranteeing the national food and nutritional security. Postharvest losses vary greatly among commodities and production areas and seasons. There is a need for man power with specialization in postharvest management to meet and tackle the above demands and to develop an action plan for establishing an effective post harvest research and extension programme to strengthen the link between researchers and extensionists. Looking to the importance of this sector,the Post Harvest Technology (Horticultural Crops), was considered as an independent discipline till the recent past, but it was deleted as independent discipline horticulture since 2009. However, 22 universities have continued department of Post-Harvest Management/ Technology and in some universities the discipline combined with Fruit Science department. The post-harvest agri/ horticulture management of perishable commodities like horticultural crops, which are primarily physiological in nature, is distinctly different than the PHT of the food grains, fish, dairy and meat. It was therefore suggested that an independent discipline of Postharvest Management should be considered in horticulture discipline.

There is a need for post-graduate students to conduct in-depth research on several aspects of postharvest management in order to reduce the losses in quality and quantity and to maintain safety of the produce between harvest and consumption and also to support the farmers and encourage entrepreneurs thereby providing employment opportunities as well as conducting research programmes after obtaining their degrees. They would serve in different universities as teaching faculty and in research stations as scientists and also can serve the nation by creating employment as entrepreneurs. M.Sc. and Ph.D. syllabi in Postharvest Management were drafted through a series of meetings/ workshops conducted at VCSGUUHF, Uttarakhand, BCKV, Mohanpur and IARI, New Delhi.

Courses have been designed emphasising the following thrust areas: Storage methods to extend shelf life and to enhance the nutritional compounds in functional foods, Standardization of processing technologies (drying, canning, freezing, etc.) for extending shelf life, Preserve the phytochemical and nutritional content of fruits and vegetables at every step of the food distribution system, Waste processing and value addition in fruits, Integrating available technologies (bio-, info- and nanotechnology) through a system, Pre and Post-harvest treatments to enhance shelf life, Testing bioactive compounds from fruits and vegetables and their action against pathogens, Safe and minimal processing, Use of robotics for harvesting, packing and handling of individual through bulk items; managing logistics and supply chains effectively and efficiently, Physiological and biochemical systems regulating product deterioration and senescence, Innovations in packaging and storage technology of fresh produce, Active and smart packaging film for food and Postharvest treatment, Studies of reusable/ recyclable packages, Inexpensive and safer ripening systems, Low-cost cooling methods and Sanitation and food safety practices.Besides due importance has been given while designing the course contents towards the national priorities and policies, viz., skill developmet and employment generation, doubling farmers income, nutritional security and minimising food loss/ waste.

Course Title with Credit Load
M.Sc. (Hort.) in Post-Harvest Management

Course Code	Course Title	Credits Hours
PHM 501 *	Postharvest Management of Horticultural Produce	2+1
PHM 502*	Postharvest Physiology and Biochemistry of Perishables	2+1
PHM 503	Packaging and Storage of Fresh Horticultural Produce	1+1
PHM 504	Packaging and Storage of Processed Horticultural Produce	1+1
PHM 505*	Principles and Methods of Fruit And Vegetable Preservation	2+1
PHM 506	Laboratory Techniques in Postharvest Management	1+2
PHM 507*	Processing of Horticultural Produce	2+2
PHM 508	Quality Assurance, Safety and Sensory Evaluation of Fresh and Processed Horticultural Produce	2+1
PHM 509	Functional Foods from Horticultural Produce	2+0
PHM 510	Marketing and Entrepreneurship in Postharvest Horticulture	1+1
	Minor Courses (08 credits)	08
	Supporting Courses (06 credits)	06
	Common compulsory courses (05 credits)	05
PHM 591	Seminar	0+1
PHM 599	Research	0+30
	Total	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Post-harvest Management

I. Course Title : Postharvest Management of Horticultural Produce

II. Course Code : PHM 501

III. Credit Hours : (2+1)

IV. Why this course ?

Fruits and vegetables are perishable crops that suffer great losses both in quantity and quality after harvest. These produce require integrated approach to arrest their spoilage and overcome the present day challenges that assimilates millions of tons annually. Lack of postharvest awareness and absence of sufficient and functioning equipment in the postharvest chain result in serious postharvest losses in developing countries. Clear and comprehensive understanding of postharvest deteriorative factors is necessary to overcome these challenges. Pre and postharvest management such as good cultural practices, use of improved varieties, good handling practices pre and postharvest, temperature and relative humidity management, storage atmosphere management, use of permitted chemicals, design of appropriate packaging materials and storage structures are some of the control measures use in reducing postharvest losses. Hence this customized course

V. Aim of the course

To impart comprehensive knowledge on management of horticultural produce thus extending the post-harvest life of the produce by various treatments.

The course is organized as follows:

No	Blocks	Units
1	Postharvest management of horticultural produce	I Importance and scope II Regulation of ripening III Treatments for extending shelf life IV Handling system and marketing of horticultural crops

VI. Theory

Block 1: Postharvest Management of Horticultural Produce

Unit I: History, Importance and scope of Postharvest technology of horticultural produce. Nature and structure of horticultural produce. Pre and Postharvest losses and their causes.

Unit II: Climacteric and non-climacteric fruits. Regulation of ripening by use of chemicals and growth regulators. Control of sprouting, rooting and discoloration in vegetables.

Unit III: Maturity indices for harvest. Harvesting and harvesting tools. Curing in roots and tubers. Prepackage Operation: Preecooling, washing, sorting, grading of horticultural perishables for local markets and export. Postharvest handling of spices, plantation crops, medicinal and aromatic plants. Equipments for washing, sizing, grading.

Unit IV: Pre and Postharvest treatments for extending storage life/ vase life. VHT, irradiation treatment, skin coating, degreening, etc. Prepackaging, Packaging techniques for local market and export. Standardsand specifications for fresh produce.

Unit V: Postharvest handling system for horticulture crops of regional importance. Principles of transport, modes of transportation, types of vehicles and transit requirements for different horticultural produce. Marketing: Factors influencing marketing of perishable crops, marketing systems and organizations.

VII. Practical

- Study of maturity indices for harvest of fruits, vegetables, spices and plantation crops;
- Protective skin coating with wax emulsion and pre and Postharvest treatment with fungicides, chemicals and growth regulators to extend the shelf life of fruits and vegetables;
- Prepackaging of perishables;
- Extension of vaselife of cut flowers by use of chemicals and growth regulators;
- Control of sprouting of potato and onion by using growth regulators;
- Study of modern harvesting, sorting and grading equipments;
- Study of effect of pre-cooling on shelf-life and quality of fresh fruits, vegetables and flowers;
- Visit to packaging centers;
- Visit to local markets, cooperative organizations, super markets dealing with marketing of Perishables.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentation
- Group Work/ seminars

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Regulation of ripening by use of chemicals and growth regulators
- Pre and Postharvest treatments for extending storage life/ vase life
- Standards and specifications for fresh produce

X. Suggested Reading

Bhattacharjee SK and Dee LC. 2005. *Postharvest technology of flowers and ornamental plants*. Pointer publishers, Jaipur.

Chattopadhyay SK. 2007. *Handling, transportation and storage of fruit and vegetables*. Gene-Tech books, New Delhi.

FAO. 2007. *Handing and Preservation of Fruits and Vegetables by Combined methods for Rural Areas*-Technical Manual. FAO Agr.Ser.Bull., 149.

Kader AA. 1992. *Postharvest technology of horticultural crops*. 2nd ed university of California.
Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest Biology and Technology of Fruits, Vegetables and Flowers*, Wiley-Blackwell, ISBN: 9780813804088.
Pruthi JS. 2001 (Reprint). *Major spices of India crop management and Postharvest technology*. ICAR, NewDelhi
Stawley J Kays. 1998. *Postharvest physiology of perishable plant products*. CBS publishers.
Sudheer KP, Indira V. 2007. *Postharvest Technology of Horticultural Crops*, Peter K.V. (Ed.), New India Publishing Agency, ISBN 9788189422431.
Sunil Pareek (Ed.) 2016. *Postharvest Ripening Physiology of Crops*, CRC Press, ISBN 9781498703802.
Thompson AK. (Ed.) 2014. *Fruit and Vegetables: Harvesting, Handling and Storage* (Vol. 1 & 2) Blackwell Publishing Ltd, Oxford, UK. ISBN: 9781118654040.
Verma LR and Joshi VK. 2000. *Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.
Wills RBH and Golding J. 2017. *Advances in Postharvest Fruit and Vegetable Technology*, CRC Press, ISBN 9781138894051.

Websites:

Horticulture-Post harvest management CSIR-NISTADS http://www.nistads.res.in/indiasnt2008/t6rural/t6rur13.htm
Post harvest technology- MANAGE http://www.manage.gov.in/ftf-itt/prgReports/iihr.pdf
Role of post-harvest management http://www.fao.org/3/y5431e/y5431e02.htm

I. Course Title : Postharvest Physiology and Biochemistry of Perishables

II. Course Code : PHM502

III. Credit Hours : (2+1)

IV. Why this course ?

Immediately after harvesting, vegetables and fruits are subjected to the active processes of degradation. Numerous physiological and biochemical processes continuously change the original composition of the crop until which decrease the shelf life of the produce. Postharvest physiology is the scientific study of the physiology of living plant tissues after picking. It is very much necessary to learn about it as has direct applications to postharvest handling in establishing the storage and transport conditions that prolong shelf life. Hence this customized course.

V. Aim of the course

To impart comprehensive knowledge on physiology of horticultural produce after harvest and to understand different physiological processes like respiration ripening

The course is organized as follows:

No	Blocks	Units
1	Biochemistry of perishable	I. Structure and composition of horticultural produce II Biochemical Changes after harvest

No	Blocks	Units
2	Postharvest physiology of perishables	I Maturity, Ripening and respiration II Respiratory climacteric and transpiration III Factors affecting shelf-life

VI. Theory

Block 1: Biochemistry of perishables

Unit I: Introduction, biochemical structure and composition of fruits, vegetables and ornamentals.

Unit II: Biochemical changes during development and ripening. Structural Deterioration of the Produce-cell wall degradation, change in membrane lipid.: Biosynthesis of ethylene and its regulation. Ethylene action and ripening processes, its perception-action and regulation.

Block 2: Postharvest physiology of perishables

Unit I: Determining maturity and maturity indices. Ripening processes: events of ripening and factors affecting them.

Unit II: Physiology of preharvest and postharvest; factors affecting shelf-life and quality of fruits, vegetables and ornamentals.

Unit III: Respiration: respiratory climacteric, its significance. Transpiration and water stress during postharvest. Postharvest oxidative stress: active oxygen species, AOS generation, physiological effects on horticultural commodity, control of oxidative injury.

VII. Practical

- Determination of physical parameters like specific gravity, fruit firmness, etc.;
- Determination of physiological loss in weight;
- Determination of chemical constituents like sugar, starch, pigments, Vitamin C, acidity during maturation and ripening in fruits/ vegetables;
- Estimation of ethylene evolved from ripening fruits;
- Delay/ Hastening of ripening by ethylene treatments;
- Determination of firmness, TSS, moisture, Titratable acid, sugar, protein, starch, fats, chlorophyll, carotene, anthocyanin, phenols and tannins;
- Measurement of respiration and ethylene evaluation.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Work

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand about different factors affecting shelf life
- Processes of respiration and ripening
- Biosynthesis of ethylene and its action on ripening

X. Suggested Reading

Chadha KL and Pal RK. 2015. *Managing postharvest quality and losses in horticultural crops*. Vol-1: General Issues, 1-231p Astral International (P) Ltd., New Delhi

Chadha KL and Pal RK. 2015. *Managing postharvest quality and losses in horticultural crops*. Vol-2: Fruit Crops, 253-561p Astral International (P) Ltd., New Delhi

Chadha KL and Pal RK. (2015) *Managing postharvest quality and losses in horticultural crops*. Vol-3: Vegetables, Flowers and Plantation Crops, 581-727p Astral International (P) Ltd., New Delhi

Hodges DM. 2003. *Postharvest Oxidative Stress in Horticultural Crops*, 1st Edition, ISBN 9781560229636

Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest Biology and Technology of Fruits, Vegetables and Flowers*, Wiley-Blackwell, ISBN: 9780813804088.

Sunil Pareek (Ed.) 2016. *Postharvest Ripening Physiology of Crops*,CRC Press, ISBN 9781498703802.

Thompson AK. 1995. *Post harvest Technology of fruits and vegetables*. Blackwell Sciences

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Wills RBH and Golding J. 2017. *Advances in Postharvest Fruit and Vegetable Technology*, CRC Press, ISBN 9781138894051.

Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.

Websites

Food and Agriculture Organization http://www.fao.org/home/en/

Respiration in plants http://ncert.nic.in/ncerts/l/kebo114.pdf

Ethylene biosynthesis and its response http://www.biologydiscussion.com/plants/hormones-plants/ethylene-biosynthesis-and-its-responses-plant-hormones/25986

I. Course Title : Packaging and Storage Offresh Horticultural Produce

II. Course Code : PHM 503

III. Credit Hours : (1+1)

IV. Why this course ?

Being a potential source of minerals, vitamins and proteins and carbohydrates, horticultural commodities play an important role in the health and nutritional security of the people. Proper packaging and storage will utilize market surplus during glut season and thus give boost to the food industry. Horticultural produce is highly perishable particularly under tropical conditions of India. The spoilage of these commodities can be reduced to a large extent by this storage technology. Hence this customized course

V. Aim of the course

To acquaint with the different storage systems and packaging systems for perishable horticultural produce.

The course is organized as follows:

No	Blocks	Units
1	Storage systems	I. Importance of storage II. Different methods of storage III. Modified methods of storage

No.	Block	Unit
2	Packaging	I. Importance of packaging and packaging methods II. New technologies in packaging

VI. Theory

Block 1: Storage Systems

Unit I: Importance of storage of horticultural produce, present status and future scope. Principles and methods of storage – field storage structures and designs for bulk storage of horticultural produce- onion and potato, etc. Evaporative cool chambers. Physiological changes during storage.

Unit II: Refrigerated storage – principles of refrigeration, types of refrigerants, refrigeration equipments. Cold storage rooms – Calculation of refrigeration load. Storage requirements of different fruits, vegetables, flowers. Storage disorder symptoms and control.

Unit III: Controlled or modified atmosphere (CA/MA) storage – principles, uses, structures and equipments, methods and requirements. Effect of CA storage on the physiology of stored produce. Hypobaric storage-principle, uses, and requirements. Storage disorders.

Block 2: Packaging

Unit I: Importance of packaging of fresh and processed horticultural produce, present status and future scope. Gaps in packaging concepts. Packaging requirements of fresh horticultural produce. Packaging patterns and methods. Food packaging systems: Different forms of packaging such as rigid, semi-rigid, flexible forms. Traditional, improved and specialized packages. Paper based packages: corrugated fibre board boxes – raw material and types of boxes. Flexible packaging materials – types and their properties. Consumer and intermediate flexible bulk containers. Testing of flexible packaging material. Barrier properties of packaging materials.

Unit 2: New technology in packaging – stretch wrapping system, vacuum packaging, gas packaging, controlled atmosphere (active and intelligent) packaging, vibra packaging, skin packaging, shrink packaging, form-fill-seal packaging, Packaging machines.Quality control and safety aspects of packaging materials.

VII. Practical

- Study of special storage structures for bulk storage of onion/ potato, etc.;
- Study of storage behavior of different fruits and vegetables in zero energy cool chamber;
- Determination of refrigeration requirements (capacity) for given quantity of fruits and vegetables;
- Study of storage behaviour of different fruits and vegetables in cold room;
- Study of chilling injury and storage disorders;
- Study of shelf-life of fruits and vegetables in modified atmosphere packaging. Visit

to special storage structures, cold storage units. Study of types of packaging materials, types of plastic films and their properties;
- Determination of water vapour transmission rate (WVTR) and gas transmission rate (GTR) of packaging material;
- Applications of packaging material for fresh fruits and vegetables, beverages, spice products;
- Determination of shelf-life of fresh products in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrapping machine, double seamer, etc. Visit to packaging unit.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Work/ seminars

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Importance of storage of horticultural produce
- Different methods of storage
- Importance of packaging for fresh horticultural produce
- Different methods of packaging

X. Suggested Reading

Ahvenainen R. 2003. Novel Food Packaging Techniques, CRC Press, ISBN 0849317894.

Ahvenainen R. 2001. *Novel Food Packaging Techniques*. CRC.

Burg SP (Ed.). 2004. *Postharvest physiology and hypobaric storage of fresh produce*, CABI Publishing, ISBN 0851998011.

Chattopadhya SK. 2007. *Handling, transportation and storage of fruits and vegetables*. Gene-Tech books, New Delhi.

Chandra GopalaRao. 2015. *Engineering for Storage of Fruits and Vegetables*; Academic Press, 1st Edition.

Coles R, McDowell D and Kirwan MJ. (Eds.). 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.

Mahadevaiah M and Gowramma RV. 1996. *Food packaging materials*. Tata McGraw Hill.

Painy FA. 1992. *A handbook of food packaging*. Blackie Academic.

Pantastico B. 1975. Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables. AVI Publ.

Robertson GL. (Ed.). 2010. Food packaging and shelf life: a practical guide CRC Press, ISBN 9781420078442.

Thompson AK. 2010. *Controlled atmosphere storage of fruits and vegetables* (2nd Edition), CABI International, ISBN 9781845936464.

Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press, ISBN 9780849391668.

Websites

Storage practices and structures UCANR http://ucanr.edu/datastoreFiles/234-1303.pdf

Low cost storage technologies for preservation-IARI http://www.iari.res.in/download/pdf/story4_eng.pdf

https://energypedia.info/wiki/Cold_Storage_of_Agricultural_Products

I. Course Title : Packaging of Processed Horticultural Produce

II. Course Code : PHM 504

III. Credit Hours : (1+1)

IV. Why this course ?

Horticulture industry is dominated by market interaction in terms processing and their packaging. Much of the total cost of produce is determined by nature of packaging and packaging material used. Packaging cost sometimes exceed the raw material cost, depending on the nature of the produce, time and period. This course helps in understanding the packaging interaction with produce, environment and time. And it also helps to take informed decision on package requirement for horticulture produce.

V. Aim of the course

To acquaint with the different and packaging systems for processed horticultural produce.

The course is organized as follows:

No	Blocks	Units
1	Packaging principles and functions	Functions of packaging Basic principles of packaging materials Manufacture of packaging materials Types of packaging materials Testing of packaging

VI. Theory

Block 1: Packaging principles and functions

Unit I: Functions of packaging; Type of packaging materials; Selection of packaging material for different foods; Selective properties of packaging film; Methods of packaging and packaging equipment.

Unit II: Mechanical strength of different packaging materials; Printing of packages; Barcodes and other marking; Interactions between packaging material and foods; Environmental and cost consideration in selecting packaging materials.

Unit III: Manufacture of packaging materials; Potential of biocomposite materials for food packaging; Packaging regulations; Packaging and food preservation; Disposal of packaging materials.

Unit IV: Metal cans: types, fabrication, lacquering and tin quality. Double seaming technology – defects and causes. Glass containers – types; testing quality – thermal shock resistance, thermal shock breakage, impact breakage.

Unit V: Testing of packaging; Rigid and semi rigid containers; Flexible containers; Sealing

Equipment. Labeling; Aseptic and shrink packaging; Secondary and transport packaging. Different packaging systems for dehydrated foods, frozen foods, dairy foods, fresh fruits and vegetables.

VII. Practical

- Testing of packaging material: compression strength/drop test/thermal shock test/ seam evaluation/ seam defects;
- Determination of shelf-life of processed products in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrapping machine, double seamer, etc.;
- Visit to packaging units.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Discussions

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Importance of packaging for processed horticultural produce
- Different methods of packaging, methods and their applications in food industry.

X. Suggested Reading

Ahvenainen R. 2001. *Novel Food Packaging Techniques*.CRC

Ahvenainen R. 2003. *Novel Food Packaging Techniques*, CRC Press, ISBN 0849317894.

Coles R, McDowell D and Kirwan MJ. (Eds.) 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.

Joseph H Hotchkiss. 1987. *Food and Packaging Interactions*, (ACS symposium series -365, April 5-10, 1987. American Chemical Society, Washington DC. 1988)

Mahadevaiah M and Gowramma RV. 1996. *Food packaging materials*. Tata McGraw Hill.

Painy FA. 1992. A handbook of food packaging. Blackie Academic.

Robertson G. L. Ed. 2010. *Food packaging and shelf life: a practical guide CRC Press*, ISBN 9781420078442.

Thompson AK. 2010. *Controlled Atmosphere Storage of Fruits and Vegetables*, CABI Publishing; 2nd revised edition.

Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press, ISBN 9780849391668.

I. Course Title : Principles and Methods of Fruit and Vegetable Preservation

II. Course Code : PHM 505

III. Credit Hours : (2+1)

IV. Why this course ?

The fruits and vegetables are comparative higher value than cereals and more perishables. Losses in the fruits and vegetables are high and chances to reduce the waste and enhancing the employability through post-harvest processing are more. The processing includes pre-processing of fruits and vegetables before these are fit to final conversation into processed foods. The food preservation and processing industry has now become of a necessity than being a luxury. It has an important role in conservation and better utilization of fruits and vegetables. In order to avoid the glut and utilize the surplus during the season, it is necessary to employ modern methods to extend storage life for better distribution and also processing techniques to preserve them for utilization in the off season on both large scale and small scale. Hence this customized course.

V. Aim of the course

Understanding spoilage, underlying principles and methods of processing of fruits and vegetables.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand Principles and different methods of preservation
- Principal spoilage organisms, food poisoning and their control measures
- Canning of fruits and vegetables
- Processing equipments and layout of processing industry

VII. Theory

Block 1: Principles and Methods of Fruit and Vegetable Processing

Unit I: Introduction, Historical development in food processing, type of food and causes for food spoilage. Basic principles of fruits and vegetables processing;

Unit II: Thermal processing, pH classification of foods, heat resistance of microorganism; Heat resistance of enzymes in foods, Spoilage of thermal processed food; Containers – canning, rigid tin plates and cans, aluminium cans, glass containers – types; flexible packaging materials, Composite can, specification, corrosion of cans, heat penetration into containers and methods for determination of process time.

Unit III: Effects of low temperature on fresh commodities and prepared product. Freezing preservation, freezing points of foods, slow and quick freezing, Cryogenic freezing and frozen food storage. Drying and dehydration, sun drying solar dehydration, mechanical drying types of driers, osmotic dehydration.

Unit IV: Food fermentation – alcoholic, acetic and lactic fermentation. Pickling and curing; Effect of salt on food preservation, types of salt cured products. Traditional and new products; chemical preservation, SO2, benzoic acid, sorbic acid, antioxidants and antibiotics, newer preservatives. Preservation by controlling water activity – high sugar products, intermediate moisture food, food concentration.

Unit V: Food irradiation, principles, types and sources of radiation, mode of action of ionizing radiation; radiation effect on food constituents and regulation.

VII. Practical

- List and cost of equipment, utensils, and additives required for small scale processing industry;
- Chemical analysis for nutritive value of fresh and processed fruits and vegetables;

- Preparation and preservation of fruit based beverages and blended products from fruits and vegetables;
- Evaluation of pectin grade; preparation and quality evaluation of fruit jam;
- Preparation of papain;
- Blanching and its effects on enzyme;
- Preparation of dehydrated vegetables;
- Study of different types of spoilages in fresh as well as processed horticultural produce;
- Study of biochemical changes and enzymes associated with spoilage;
- Sensory evaluation of fresh and processed fruits and vegetables;
- Visit to processing units.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Exposure visits
- Student presentation
- Group Work

IX. Suggested Reading

Barret DM, Somogyi LP and Ramaswamy H. Eds. 2005. *Processing Fruits: Science and Technology* (2nd Edition), CRC Press, ISBN 9780849314780.

FAO. 2007. *Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas- Technical Manual*. FAO Agricultural Services Bulletin 149.

Fellows PJ. 2009. Food Processing Technology: Principles and Practice (3rd Edition), Woodhead Publishing, ISBN 9781845692162.

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Ramaswamy H and Marcotte M. 2006. *Food Processing: Principles andApplications*. Taylor & Francis.

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Srivastava RP and Kumar S. 2014. *Fruit and Vegetable Preservation: Principles and Practices* (3rd Edition), CBS Publishing, ISBN 9788123924373.

Verma LR and Joshi VK. 2000. *Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.

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http://agriinfo.in/default.aspx?page=topic&superid=2&topicid=2065
http://www.fao.org/docrep/x0209e/x0209e02.htm
http://www.cstaricalcutta.gov.in/images/CTS%20Fruits_and_Vegetables%20NSQF.pdf

I. Course Title : Laboratory Techniques in Postharvest Horticulture

II. Course Code : PHM 506

III. Credit Hours : (1+2)

IV. Why this course ?

To familiarize with the conventional analysis of raw and processed food products of all commodity technologies used for routine quality control in food industry, and their role on nutritional labeling. To develop an understanding and methodologies of instrumental techniques in food analysis used for objective methods of food quality parameters.

V. Aim of the course

To familiarise with advances in instrumentation and Postharvest management

VI. Theory

Block 1: Laboratory Techniques in Postharvest Management

Unit I: Rheological techniques and instrumentation used in food industry. Analysis of food additives like food colour, antioxidants, emulsifier, etc.

Unit II: Analysis of pesticide residues, metallic contaminants, aflatoxin. Analysis of food flavours.

Unit III: Quality analysis of processed fruits and vegetables, coffee, tea and spices. Identification and enumeration of microbial contaminants.

Unit IV: Principles of chromatography (GC, GCMS, HPLC, LCMS), spectrophotometry (Atomic absorption spectrophotometer, ICAP spectrophotometer), ICP-MS, ICPOES, NMR, ESR, amino acid analyser, flame photometry, electrophoresis.

Unit V: Colour measurement in foods, IRGA, Radio-isotopic techniques. Non destructive quality evaluation (NDQE)- E-nose, E-tongue, machine vision. electrophoresis.

VII. Practical

- Sample preparation for quality analysis. Energy calculation, sample calculations;
- Texture analysis, Rheology of different foods;
- Instrumental colour analysis;
- Sensory evaluation and microbiological examinations of fresh and processed products;
- Estimation of tannin/ phytic acid by spectrometric method;
- Moisture and fat analysis by NIR spectroscopy;
- Separation and identification of sugars in fruit juices;
- Separation and identification of carotenoids by column chromatography;
- Estimation of respiration in fruits and vegetables;
- Flavour profile in essential oils using GC;
- Identification and determination of organic acids by HPLC;
- Capsaicin content and Scoville Heat Units in chillies;
- Heavy metal analysis using atomic absorption spectrometry;
- Residue analysis.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Techniques and instrumentation used in food industry
- Analysis of pesticide residues
- Quality analysis of processed fruits and vegetables

- Principles of chromatography and Spectrophotometry
- Non-destructive quality evaluation

X. Suggested Reading

Lundanes E., Reubsaet L and Greibrokk T. 2013. *Chromatography: Basic Principles, Sample Preparations and Related Methods*, ISBN-13: 978-3527336203, Wiley VCH

Mark F Vitha. 2016. *Chromatography: Principles and Instrumentation*. John Wiley & Sons, ISBN 9781119270881

Suzanne NS. 2010. *Introduction to Food Analysis*, ISBN 978-1-4419-1478-1, Springer.

Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill ISBN 9780074518519.

Semih Otles (Ed). 2016. *Methods of Analysis of Food Components and Additives* (*Chemical and Functional Properties of Food Components*) CRC Press, ISBN-13: 978-1138199149,

I. Course Title : Processing of Horticultural Produce

II. Course Code : PHM 507

III. Credit Hours : (2+2)

IV. Why this course ?

Postharvest system deals with ensuring the delivery of a crop from the time and place of harvest to the time and place of consumption, with minimum loss, maximum efficiency and returns to all concerned including grower, processors and consumer. The term 'system' represents a dynamic, complex aggregate of locally interconnected functions or operations within a particular sphere of activity. While, the term pipeline of operations refers to the functional succession of various operations but tends to ignore their complex interactions. Primary processing processing operations include washing/ cleaning,sorting, grading, dehulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, whitening and milling and secondary operations include mixing, cooking, drying, frying, moulding, cutting, extrusion product preparation.

V. Aim of the course

This course gives an overview of status of fruit and vegetable processing in the country, objectives and importance of preservation, important constraints and different unit operations processing industry which helps in expansion of industry and scope for further growth in this sector.

This course is organized as follows:

No	Blocks	Units
1	Importance and Thermal processes	I Scope and Importance II Thermal processes III Evaporation
2.	Processing equipment and enzyme kinetics	I Processing equipment and facilities II Enzyme kinetics

VI. Theory

Block 1: Importance and Thermal processes

Unit I: Processing unit- layout and establishment, processing tools. Quality requirements of raw materials for processing, preparation of raw material, primary processing: grading, sorting, cleaning, washing, peeling, slicing and blanching; minimal processing.

Unit II: Preparation of various processed products from fruits and vegetables, flowers; role of sugar and pectin in processed products. Freezing of fruits and vegetables. Containers, equipment and technologies in canning.

Unit III: Juice extractions, clarification and preservation, recent advances in juice processing technology, application of membrane technology in processing of juices, preparation of fruit beverages and juice concentrate. Sensory evaluation.

Block 2: Processing equipment and enzyme kinetics

Unit I: Dehydration of fruits and vegetables using various drying technologies and equipment, solar drying and dehydration, packaging technique for processed products.

Unit II: Quality assurance and storage system for processed products. Nutritive value of raw and processed products, plant sanitation and waste disposal. Types of horticultural and vegetables wastes and their uses, utilization of by- products from fruits and vegetables processing industries.

VII. Practical

- Handling of harvesting equipments;
- Determination of physical and thermal properties of horticultural commodities;
- Thermal process calculations;
- Particle size analysis, Storage structure design;
- Numerical problems in freezing, drying, conveying and calculations pertaining to texture and Rheology;
- Handling of heating equipment, pulper, juice extractor, deaerator, juice filters;
- Processing industries waste treatment;
- Working of a canning unit;
- Visit to commercial processing units and storage units.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Unit operations of processing
- Planning for domestic as well as commercial storage and processing facilities
- Kinetics of growth and enzyme reaction

X. Suggested Reading

Karel M and Lund DB. 2003. *Physical Principles of Food Preservation* (2nd Edition), CRC Press, ISBN 9780824740634.

Paul Singh R and Heldman DR. 2009. *Introduction to Food Engineering* (4th Edition), Academic Press, ISBN 9780123709004.

Rao DG. 2010. *Fundamentals of Food Engineering*, PHI Learning Pvt. Ltd., ISBN 9788120338715.

Ratti C. 2008. *Advances in Food Dehydration*, CRC Press, ISBN 9781420052527.
Toledo RT. 2007. *Fundamentals of Food Process Engineering* (3rd Edition), Springer, ISBN 9780387290195.
Smith PG. 2011. *Introduction to Food Process Engineering*, Springer, ISBN 9781441976611.

I. Course Title : Quality Assurance, Safety and Sensory Evaluation of Fresh and Processed Horticultural Produce

II. Course Code : PHM 508

III. Credit Hours : (2+1)

IV. Why this course ?

The quality of fresh horticultural commodities is a combination of characteristics, attributes, and properties that give the commodity value for food (fruits and vegetables) and enjoyment (ornamentals). Producers are concerned that their commodities have good appearance and few visual defects, but for them a useful cultivar must score high on yield, disease resistance, ease of harvest, and shipping quality. To receivers and market distributors, appearance quality is most important; they are also keenly interested in firmness and long storage life. Although consumers buy on the basis of appearance and feel, their satisfaction and repeat purchases are dependent upon good edible quality. Assurance of safety of the products sold is extremely important to the consumers. Hence this customized course.

V. Aim of the course

To understand the quality and safety management system and the process of sensory analysis for horticultural products

This course is organized as follows:

No	Blocks	Units
1	Quality Assurance	I Concept of quality
		II Food laws and regulations
2	Safety	I Food safety
		II Quality management
3.	Sensory Evaluation	I Introduction to sensory evaluation
		II Methods of sensory evaluation

VI. Theory

Block 1: Quality Assurance

Unit I: Concept of quality: Quality attributes- physical, chemical, nutritional, microbial, and sensory; their measurement and evaluation. Concepts of quality management: Objectives, importance and functions of quality control; Quality management systems in India; Sampling procedures and plans.

Unit II: Food laws and regulations in India, Quality management standards, ISO,BIS, PFA, AGMARK and QMS standards, quality system components and their requirements.

Block 2: Safety

Unit I: Food safety and standards act (FSSA,2006); Strategies for compliance with international agri-food standards; Export specification and guidelines by APEDA. Hazard analysis and critical control points (HACCP), design and implementation of an HACCP system, steps in the risk management process. Traceability in food supply chains.

Unit II: Organic Certification, GAP, GMP, TQM. Indian and International quality systems and standard like, Codex Alimentarius, ISO, etc. Consumer perception of safety; Ethics in food safety.

Block 3: Sensory Evaluation

Unit I: Introduction to sensory analysis; general testing conditions, Requirements of sensory laboratory; organizing sensory evaluation programme. Selection of sensory panellists; Factors influencing sensory measurements; Sensory quality parameters -Size and shape, texture, aroma, taste, colour and gloss; Detection, threshold and dilution tests. Different tests for sensory evaluation– discrimination, descriptive, affective; Flavour profile and tests; Ranking tests.

Unit II: Methods of sensory evaluation of different food products. Designing of experiments. Handling and interpretation of Data. Role of sensory evaluation in product optimization. Relationship between objective and subjective methods.Sensory analysis for consumer evaluation. Computer-aided sensory evaluation of food and beverage.

VII. Practical

- Analysis for TSS, pH, acidity, sugars, pectic substances, minerals, vitamin C, carotene, alcohol, benzoic acid and SO_2 contents, yeast and microbial examination in processed products;
- Demonstration of measurement of vacuum/ pressure, head space, filled weight, drained weight, cut-out analysis and chemical additives;
- Moisture content, rehydration ratio and enzymatic/ non-enzymatic browning in dehydrated products;
- Analysis of spices for quality parameters. Evaluation of processed products according to FSSAI specification;
- Selection and training of sensory panel;
- Identification of basic taste, odour, texture and colour;
- Detection and threshold tests; Ranking tests for taste, aroma, colour and texture; Sensory evaluation of various horticultural processed products using different scales, score cards and tests, Hedonic testing;
- Estimation of color and texture; optimising a product by sensory analysis;
- Studying relationship between objective and subjective methods.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to Understand:

- Concepts of quality management
- Food laws and regulation in India

- Export specification and guidelines by APEDA
- Consumer perception of safety and Ethics in food safety

X. Suggested Reading

Amerine MA, Pangborn RM and Rosslos EB. 1965. Principles of Sensory Evaluation of Food. Academic Press.

Curtis PA. 2005. *Guide to Food Laws and Regulations*, Wiley-Blackwell, ISBN 9780813819464.DGHS *Manual 8: Manual of Methods of Analysis of Foods-Food Additives*.

Curtis PA. 2005. *Guide to Food Laws and Regulations*, Wiley-Blackwell, ISBN 9780813819464.

Early R. 1995. *Guide to Quality Management Systems for the Food Industry*, Springer, ISBN 9781461358879.

Kemp SE, Hollowood T and Hort J. 2009. *Sensory Evaluation: A Practical Handbook*, Wiley-Blackwell Publisher, ISBN 9781405162104.

Krammer A and Twigg BA. 1973. Quality Control in Food Industry.Vol.I, II.AVI Publ.

Lawless, Harry T, Heymann and Hildegarde. 2010. Sensory Evaluation of Food: Principles and Practices, Springer, ISBN 9781441964885.

Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill ISBN 9780074518519.

Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill, ISBN 9780074518519.

The Food Safety and Standards Act, 2006 along with Rules & Regulations 2011, Commercial Law Publishers (India) Pvt. Ltd.

Websites

https://en.wikipedia.org/wiki/Sensory_analysis
https://link.springer.com/chapter/10.1007/978-1-4757-5112-3_5
https://www.foodqualityandsafety.com/

I. Course Title : Functional Foods from Horticultural Produce

II. Course Code : PHM 509

III. Credit Hours : (2+0)

IV. Why this course ?

Functional foods are foods that have a potentially positive effect on health beyond basic nutrition. This course examines the rapidly growing field of functional foods in the prevention and management of chronic and infectious diseases. It attempts to provide a unified and systematic account of functional foods by illustrating the connections among the different disciplines needed to understand foods and nutrients, mainly: food science, nutrition, pharmacology, toxicology and manufacturing technology. Advances within and among all these fields are critical for the successful development and application of functional foods

V. Aim of the course

To familiarise with functional foods from horticultural produce

This course is organized as follows:

No	Blocks	Units
1	Functional food and importance	I Introduction, Sources and classification
		II Functional Ingredients
2.	Bioactive Compounds	I Introduction and classes of bioactive compounds
		II Mechanism of Neuroprotection

No	Blocks	Units
3.	Neutraceuticals	1 Introduction, classification, role and health benefits

VI. Theory

Block 1: Functional food and importance

Unit I: Functional foods- Introduction, definition, history; Importance, relevance and need of functional foods. Sources and classification of functional foods.Importance of horticultural produce as functional foods. Functional foods derived from fruits, vegetables, medicinal and aromatics.

Unit II: Functional ingredients and their properties. Therapeutic potential and effects of horticultural produce; Herbs, herbal teas, oils, etc. in the prevention and treatment of various diseases. Effect of preservation and processing on functional properties of horticulture produce.

Block 2: Bioactive Compounds

Unit I: Introduction, Classes of bioactive compounds present in fruits and vegetables. Polyphenols: Phenolic acid, Stilbenes, Flavonoids, Lignin, Coumarin, Tannin, etc. –their chemistry, source, bioavailability, interaction in food systems; changes during storage and processing. Alkaloids; Nitrogen Containing Compounds; Sulphur compounds; phytosterols; carotenoids; dietary fibres, etc.–their chemistry, source, bioavailability, interaction in food systems; changes during storage and processing.

Unit II: Mechanism of neuroprotection by bioactive compounds. Techniques of Extraction, purification and concentration of bioactive compounds from fruits and vegetables.Bioactive compound and health benefits Incorporation of bioactive compounds in foods.

Block 3: Neutraceuticals

Unit I: Nutraceuticals- Introduction, classification of nutraceuticals, dietary supplements, fortified foods, functional foods and phytonutraceuticals. Role of medicinal and aromatic plants in nutraceutical industry. Health benefits of phytoneutraceuticals.

VII. Teaching Methods/ Activities

1. Lectures
2. Assignment (Reading/ Writing)
3. Exposure visits
4. Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Importance of functional foods
- Functional ingredients and their properties
- Classes of bioactive compounds present in fruits and vegetables
- Mechanism of neuroprotection by bioactive compounds
- Importance of Nutraceuticals

IX. Suggested Reading

Rosa LA, Alvarez-Parrilla E and Gonzalez-Aguilar GA. 2009. *Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value and Stability*, Wiley-Blackwell, ISBN 9780813803203.

Senrawat R, Khan KA, Goyal MR and Paul PK. 2018. *Technological Interventions in the Processing of Fruits and Vegetables*, Apple Academic Press, ISBN 9781771885867.

Vattem DA. 2016. *Functional Foods, Nutraceuticals and Natural Products: Concepts and Applications*. DEStech Publications, Inc, ISBN 978 1 60595 101 0.

Watson RR and Preedy V. 2009. *Bioactive Foods in Promoting Health: Fruits and Vegetables* (1st Edition), Academic Press, ISBN 9780123746283

I. Course Title : Marketing and Entrepreneurship in Post Harvest Horticulture

II. Course Code : PHM 510

III. Credit Hours : (1+1)

IV. Why this course ?

To develop marketing strategies and equip individuals to start their own food service.To develop Techniques for the development of entrepreneurial skills, positive self image and locus of control.

V. Aim of the course

To understand the market channel and appraise entrepreneurship opportunity in postharvest operations.

This course is organized as follows:

No	Blocks	Units
1	Marketing and entrepreneurship in processing industry	I Entrepreneurship II Business Plan III MSME Enterprise IV Marketing V Institutional supports

VI. Theory

Unit I: Entrepreneurship – Concept, need for entrepreneurship – Types of entrepreneurs -entrepreneurial opportunities in horticultural processing sector-Government schemes and incentives for promotion of entrepreneurship in processing sector.

Unit II: Writing Business Plan- Business Plan Format for Small and micro Enterprises-Generation, incubation and commercialization of business ideas – Environment scanning and opportunity identification.

Unit III: Steps in establishment of MSME Enterprise – Planning of an enterprise – Formulation and project report-Meaning – Importance Components and preparation.-Government Formalities and Procedures.

Unit IV: Marketing potential of processed products at domestic and international level-Marketing management-Marketing functions, market information and market research-Problems in marketing of processed products-Demand and supply analysis of important processed products-

Marketing channels – Marketing strategy (product strategy and pricing strategy)- Supply chain management – Meaning, importance, advantages, supply chain management of important processed products.

Unit V: Institutional support to Entrepreneurship Role of Directorate of Industries, District Industries, Centres (DICs), Industrial Development Corporation (IDC), State Financial corporation (SFCs), Commercial banks Small Scale Industries Development Corporations (SSIDCs), Khadi and village Industries Commission (KVIC), National Small Industries Corporation (NSIC), Small Industries Development Bank of India (SIDBI).

VII. Practical

- Consumer Behaviour towards Processed Foods;
- An Empirical Test-Carrying out the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of successful Enterprises;
- Constraints in setting up of horti based industries;
- Field visits to study any one of the Local Financial Institutions to study the MSME Policies;
- Preparation of business plan and proposal writing-Project evaluation techniques;
- Discounted and undiscounted techniques;
- Case studies of successful entrepreneurs.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Exposure visits
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Concept of entrepreneurship
- Writing Business Plan
- Steps in establishment of MSME Enterprise
- Marketing management
- Institutional support to Entrepreneurship

X. Suggested Reading

Adhikary MM. 2014. *Enterprise and Entrepreneurship for Agri-Business Management and Planning*. Daya Publishing House. New Delhi

Bhaskaran S. 2014. *Entrepreneurship Development and Management*. Aman Publishing House, Meerut.

Choudhury M and Barua N. 2014. *Marketing of Processed Fruit and Vegetable*. Daya Publishing House. New Delhi.

Gaur SC. 2012. *Handbook of Agro Food Processing and Marketing*. Agrobios. Jodhpur

Kadam MM and Bishe RN. 2018. *Textbook on Agricultural Entrepreneurship*. Narendra publishing house. New Delhi.

Sudheer KP and Indira V. 2018. *Entrepreneurship and Skill Development in Horticultural Processing*. New India Publishing Agency. New Delhi.

Sudheer KP and Indira V. 2018. *Entrepreneurship Development in Food Processing*. New India Publishing Agency. New Delhi.

Course Title with Credit Load
Ph.D. (Hort.) in Post-harvest Management

Course Code	Course Title	Credit Hours
PHM 601**	Ripening and Senescence of Fruits and Vegetables	1+1
PHM 602**	Recent Trends in Food Preservation	1+1
PHM 603	Management and Utilization of Horticultural Processing Waste	3+0
PHM604**	Supply Chain Management of Perishables	2+0
PHM 605	Export Oriented Horticulture	1+0
PHM 606	Food Additives	1+1
PHM 607	Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants	3+0
PHM 608	Value Addition in Ornamental Crops	1+1
	Minor courses	06
	Supporting courses	05
PHM 691	Seminar I	0+1
PHM 692	Seminar II	0+1
PHM 699	Research	0+75
	Total	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Post-harvest Management

I. Course Title : Ripening and Senescence of Fruits and Vegetables

II. Course Code : PHM 601

III. Credit Hours : (1+1)

IV. Why this course ?

Fleshy fruit experiences profound physiological, biochemical, and structural modifications during ripening to facilitate seed dispersal and to become attractive and nutritious for human consumption. The metabolic networks regulating fruit ripening are very complex, and ethylene appears to be a key factor acting in concert with other environmental signals and endogenous factors. The classical distinction between climacteric and nonclimacteric ripening is now questionable, as different patterns of synthesis and sensitivity to ethylene may operate in the ripening of different fruits. In recent years, much progress has been done in the characterization of the main biochemical pathways implicated in the different ripening-associated processes and in the identification of key genes controlling these events. This course highlights current understanding and advances in the regulation of fruit ripening and key metabolic pathways associated with the different ripening-related processes, with emphasis on their impact on fruit quality.

V. Aim of the course

To impart knowledge about physiological and molecular changes during senescence and ripening.

VI. Theory

Unit I: Environmental factors influencing senescence, ripening and post harvest life of fruits, flowers and vegetables.

Unit II: Molecular mechanism of senescence and ageing.Physiological, biochemical and molecular aspects of senescence and fruit ripening. Senescence associated genes and gene products.

Unit III: Functional and ultra structural changes in chloroplast membranes, mitochondria and cell wall during senescence and ripening.

Unit IV: Ethylene biosynthesis, perception and molecular mechanism of action; regulatory role of ethylene in senescence and ripening, biotechnological approaches to manipulate ethylene biosynthesis and action.

Unit V: Alternate post harvest methodology and quality attributes. Scope for genetic modification of post harvest life on flowers and fruits.Uses of GM crops and ecological risk assessment.

VII. Practical

- Physiological and biochemical changes during senescence and ripening;
- Estimation of ethylene during senescence and ripening;

- Determination of Reactive Oxygen Species and scavenging enzymes;
- Measurement of dark and alternate respiration rates during senescence and ripening;
- Estimation of ripening related enzyme activity, cellulases, pectin methyl esterases, polygalacturonase, etc.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Readomg/ writing)
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Physiological, biochemical and structural changes during scenecesnce and ripening.

X. Suggested Reading

Bartz JA and Brecht JK. 2003. *Post harvest physiology and pathology of vegetables*. Marcel Dekker Inc.

Davis PJ. 2004. *Plant Hormone: Biosynthesis, Signal transduction and action*. Kluwer Academic Publishers.

Dris R and Jain SM. 2004. *Production practices and quality assessment of food crops*, Vol. 4: Post harvest treatment and Technology. Kluwer Academic Publisher.

Khan NA. 2006. *Ethylene action in plants*. Springer Verlag.

Knee M. 2002. *Fruit Quality and its Biological Basis*. Sheffield Academic Press, CRC Press.

Nooden LD. 2004. *Plant cell death processes*. Elsevier Science, USA.

Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Post harvest biology and technology of fruits, vegetables and flowers*. Blackwel Publishing, Iowa, USA.

Seymour G, Taylor J and Tucker G. 1993. *Biochemistry of fruit ripening*. Edited Chapman andHall, London.

Valpuesta V. 2002. *Fruit and vegetable biotechnology*.Woodhead Publishing Limited, Cambridge, England.

I. Course Title : Recent Trends in Food Preservation

II. Course Code : PHM-602

III. Credit Hours : (1+1)

IV. Why this course ?

Commendable production with short storage life and strategic selling limits the produce to huge loss after harvest. To prevent the postharvest loss preservation of produce with appropriate technique enhances the finished product shelf life nearly 10 to 30 times. Food processing combines raw food ingredients to produce marketable food products that can be easily prepared and served by the consumer. Emerging technologies which have already found in the food industry or related sector are High pressure processing, pulsed electric fields, ultrasound, and cold plasma. The basic principles of these technologies as well as the state of the art concerning their impact on biological cells, enzymes, and food constituents.

V. Aim of the course

The present subject imparts knowledge on recent advancement in food preservation technologies. The basic principles of preservation technologies as well as the state of the art concerning their impact on biological cells, enzymes and food constituents.

Current and potential applications will be discussed, focusing on process-structure-function relationships, as well as recent advances in the food process development that make foods.

The course is organized as follows:

No	Blocks	Units
1	Hurdle technology and recent advances	I Hurdle technology II Thermal and Non-thermal technology III Recent food preservation techniques
2	Enzyme applications and quality parameters	I Enzyme and their applications II Quality specifications and standards

VI. Theory

Block 1: Hurdle technology and recent advances

Unit I: Hurdle technology, Principles of Hurdle Technology, Minimally Processed foods, Intermediate moisture foods, role of water activity in food preservation, Chemicals and biochemicals used in Food Preservation- Natural food preservatives, bacteriocins.

Unit II: Thermal and Non-thermal technology, Advanced Thermal and Nonthermal Technology- Pulsed electric field, microbial inactivation, application, present status and future scope. Fundamentals and Applications of High Pressure Processing to Foods, Advances in Use of High Pressure to Processing and Preservation of Plant Foods, Commercial High-Pressure Equipment. Food Irradiation – an Emerging Technology.

Unit III: Recent food preservation techniques, Ultraviolet Light and Food Preservation; Microbial Inactivation by Ultrasound; Use of oscillating Magnetic Fields. Nonthermal Technologies in Combination with Other Preservation Factors. Preservation by ohmic heating-Advances in Ohmic Heating and Moderate Electric Field (MEF) Processing; Radio-Frequency Heating in Food Processing;Current State of Microwave Applications to Food Processing.Supercritical Fluid Extraction: An Alternative to Isolating bioactive compounds.

Block 2: Enzyme applications and quality parameters

Unit I: Enzyme and their applications. Enzyme and their application in food processing, Principles of food biotechnology, fermentation and enzyme mediated food processing, production of high value products such as Single Cell Protein, nutritional additives, pigments and flavours.

Unit II: Quality specifications and standards. Quality parameters and specifications, Food laws and standards, HACCP, FSSAI amendments, ISO, FDA.

VII. Practical

- Determination of thermal resistance of food spoilage microorganisms;
- Determination of thermal death curve;
- Thermal process calculations;
- Demonstration of hurdle approaches in fruits and vegetables preservation.

Enumerate the hurdle approaches in food processing;
- Detection of microbes in each hurdle. Study of shelf life of fresh cut produce in each hurdle;
- Study of fresh cut produce packing, storage temperature and microbial interaction;
- Study of thermal and non thermal application in food preservation;
- Study of moisture content in food their water activity;
- Demonstration of microwave technology in fresh produce preservation and drying;
- Determination of dry matter content in food using microwave technology;
- Study the use of enzymes in different fruit juice extraction, quantification, time – Pectinase/cellulose and others;
- Incubation techniques of enzymes using fermenter for juice extractions;
- Group discussions on current market potential of hurdle technology – Prose and cons;
- Visit to advanced food processing unit;
- Visit to SCFE unit.

VIII. Teaching Methods/ Activities
- Lectures
- Assignment (Reading/ Writing)
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the latest methods and techniques in preservation of food particularly of horticultural produce

X. Suggested Reading

Barbosa CGV, Pothakamury UR, Palou E and Swanson BG. 1998. *Nonthermal Preservation of Foods*, Marcel Dekker Inc., ISBN 9780824799793.

Karel M and Lund DB. 2003. *Physical Principles of Food Preservation* (2nd Edition), CRC Press, ISBN 9780824740634.

Sun Da-Wen (Ed.) 2014. *Emerging Technologies for Food Processing* (2nd Edition), Elsevier, ISBN 9780124114791.

Tewari G and Juneja V. 2007. *Advances in thermal and nonthermal food.* Blackwell Publishing, ISBN 9780813829685.

Websites

http://www.sciencepublishinggroup.com/specialissue/specialissueinfo?jo

http://www.ijpab.com/form/2017%20Volume%205,%20issue%206/IJPAB-2017-5-6-363-371.pdf

https://www.omicsonline.org/conferences-list/food-processing-technologies-and-advances-in-food-preservation

https://www.elsevier.com/books/advances-in-cold-plasma-applications-for-food-safety-and-preservation/bermudez-aguirre/978-0-12-814921-8

I. Course Title : Management and Utilization of Horticultural Processing Waste

II. Course Code : PHM-603

III. Credit Hours : (3+0)

IV. Why this course ?

Processing of fruit and vegetables generates varying level and kinds of wastage that can be managed differently. With the rapid progress in establishment of processing industries in our country on account of liberal government policies, the importance of waste management has become an essential and integral part of plant design as the inappropriate disposal of wastage has already caused great loss to environment and public health. Food processing is a capital intensive, high energy and water consuming, and moderate to highly polluting industry. However, one can minimize adverse effects on environment and public health and may also augment profit of processing unit by judicious disposal and utilization of waste materials. They can be used in composting, cattle feeding and biogas generation and certain types may also be utilized in production of value added products.

V. Aim of the course

Understanding the utilization and efficient management of waste from horticultural processing industry.

The course is organized as follows:

No	Blocks	Units
1	Waste treatment and disposal methods	I Introduction II Waste treatment processes III Waste disposal methods
2	Valorisation of wastes	I Recovery of useful products II Treatment of solid and liquid waste

VI. Theory

Block 1: Waste treatment and disposal methods

Unit I: Introduction: Waste and its consequences in pollution and global warming. Need for waste management. Waste and its classifications and characterization-sampling methods, analysis and standards for waste discharge. Importance of point and nonpoint sources of wastes, Solid and liquid wastes.

Unit II: Waste treatment processes: BOD, COD, DO, TS VS, ash, and different unit operations in waste treatment processes.

Unit III: Waste disposal methods: Nature of waste from processing industry and their present disposal methods. Waste segregation, Primary secondary and tertiary waste treatment processes, Conventional and non-conventional waste treatment processes, aerobic and anaerobic waste treatment processes.

Block 2: Valorisation of wastes

Unit I: Recovery of useful products: Valorization of wastes: Recovery of useful products and by-products from waste, viz., organic acids, bioethanol, biobutanol, colour, essence, pectin, oils, etc. animal feed and single cell protein.

Unit II: Treatment of solid and liquid waste: Technology of treatment of solid and liquid wastes from fruit and vegetable industries. Immobilized bioreactor in waste treatment.Anaerobic bioreactor and energy production.Circular economics and waste management.

VII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Student presentations

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Can identify the problems related waste treatments and disposal methods
- Problem related valuation of waste and recycling of waste

IX. Suggested Reading

Arvanitoyannis IS. 2008. *Waste Management for the Food Industries*, Academic Press, ISBN 9780123736543.

Joshi VK and Sharma SK. 2011. *Food Processing Waste Management: Treatment and Utilization Technology*, New India Publishing Agency, ISBN 9789380235592.

Waldron K. Ed. 2007. *Handbook of waste management and co-product recovery in food processing*, CRC Press, ISBN 9780849391323.

Websites

https://www.cabdirect.org/cabdirect/abstract/20153005486
http://www.3rmanagement.in/service/horticulture-waste-management/

I. Course Title : Supply Chain Management of Perishables

II. Course Code : PHM 604

III. Credit Hours : (2+0)

IV. Why this course ?

Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products. It involves the active streamlining of a business's supply-side activities to maximize customer value and gain a competitive advantage in the marketplace. SCM represents an effort by suppliers to develop and implement supply chains that are as efficient and economical as possible. Supply chains cover everything from production to product development to the information systems needed to direct these undertakings. Because of this, effective supply chain management also requires change management, collaboration and risk management to create alignment and communication between all the entities.

V. Aim of the course

To understand the intricacies of perishable supply chain and its management.

The course is organized as follows:

No	Blocks	Units
1	Supply chain management of perishables	I Introduction II Intrinsic Issues III Support system in supply chain- – Infrastructure IV. Support system in supply chain- Finance V. Support system in supply chain- Government

VI. Theory

Block 1: Supply chain management of perishables

Unit I: Introduction. Role of supply chain and logistics, Challenges faced in supply chain, Input suppliers, Farm output: Market intermediaries, Processors, Retailers.

Unit II: Intrinsic Issues: Perishability, Quality, Grading, Risk: Sources of risk, Classification of Agricultural risk- Production risk, Market and Price risk. Mnagement of risk.

Unit III: Support system in supply chain- Infrastructure: definition, role. Transport network, Cold storage, organised market, etc. Information technology-Enterprise resource planning, E-Choupal, Mobile Technology, web portal on agri-market information.

Unit IV: Support system in supply chain- Financial Systems: Introduction, Role and Relevance, Problems in Synchronization, Role of Technology; Credit Structure in India -Reserve Bank of India (RBI), NABARD; Commodity Markets, Corporates in Agribusiness.

Unit V: Support system in supply chain- Role of Government: Introduction; Agencies- As a Direct Player. Measures for improving supply chain and its effectiveness, involvement of organized retailers.

VII. Practical

- Present scenario of supply chain management;
- Case Study: Supply chain management of fruits and vegetables in Safal daily fresh/ APMC/ Reliance Fresh/ Amul/ D-Mart/ Spencer Retail/ Vipani/ Farmers Bazars/ Farm Fresh/ Apni Mandi, etc. based on regional importance.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/ Writing)
- Student presentationz

IX Learning outcome

After successful completion of this course, the students are expected to be able to:
- Can identify the problems related waste treatments and disposal methods

X. Suggested Reading

Chandrasekaran N and Raghuram G. 2014. *Agribusiness Supply Chain Management,* CRC Press, ISBN 9781466516755.

Chopra S and Meindl P. 2007. *Supply chain management: strategy, planning, and operation* (3rd Edition), Pearson Education, Inc.,ISBN 0132086085.

Websites

http://www.scmr.com/
https://blog.kinaxis.com/
http://www.supplychainnetwork.com/
http://supplychaininsights.com/
http://www.supplychain247.com/

I. Course Title : Export Oriented Horticulture

II. Course Code : PHM-605

III. Credit Hours : (1+0)

IV. Why this course ?

This course relates the national economy which is dependent on the contribution of the export-oriented income. Export oriented policies and laws must be followed by the growers to meet the requirement of the importing countries.

V. Aim of the course

To acquaint the students with the export oriented requirements of horticultural crops.

The course is organized as follows:

No	Blocks	Units
1	Product specifications and sanitary measures	I Introduction II Produce specifications and standards III Export oriented sanitary measures
2	Export related policies	I Export implications II Treatment of solid and liquid waste

VI. Theory

Block 1: Product specifications and sanitary measures

Unit I: Introduction: India's position and potentiality in world trade; export promotion zones in India. Export and import policy, problem in export of fresh horticultural produce, export infrastructure (sea port, airport, bulk storage facilities, irradiation, Vapour Heat Treatment, quarantine, transportation, etc.,).quarantine need, major export destination and competing nations for selected crops.

Unit II: Produce specifications and standards: Scope, produce specifications, quality and safety standards for export of fruits, viz., mango, grape, litchi, pomegranate, walnut, cashewnut, etc., vegetables, viz., onion, chilli, okra, bitter gourd, gherkin, etc., flowers, viz., rose, carnation, chrysanthemum, gerbera, specialty flowers, etc., cut green and foliage plants.

Unit III: Export oriented sanitary measures: Processed and value-added products, Postharvest management for export including packaging and cool chain; HACCP, Codex alimentarius, ISO certification; APEDA and its role in export, WTO and its implications, sanitary and phyto-sanitary measures. Codex norms and GAP and SOP for export of smajor horticultural crops from India.

Block 2: Export related policies

Unit I: Export implications: Export of seed and planting material; implications of PBR, treatments of horticultural produce, MRL for export of horticultural produce.

Unit II: Export oriented regulatory issues: Agriculture Export Policy, Export procedure; EXIM Policy, APMC act, Auction Centres, Regulatory issues of Ministry of Commerce, GoI.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- entry barriers, covering issues such as economies of scale, high capital investments, difficult access to distribution channels and markets, etc.
- bargaining power of buyers, which relates to issues such as the level of concentration of buying power, buyers' access to information, switching opportunities and costs, etc.

IX. Suggested Reading

Bartz JA. and Brecht JK. 2002. *Postharvest Physiology and Pathology of Vegetables* (IInd Edition) Marcel Dekkar, Inc, New York.

Bhattacharjee, SK. 2006. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ.

Bose TK and Yadav LP. 1989. *Commercial Flowers*. NayaProkash, Kolkata. Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. NayaProkash.

Chadha KL. 1995. *Advances in Horticulture*. Vol. XII. Malhotra Publ. House.

Islam CN. 1990. *Horticultural Export of Developing Countries: Past preferences, future prospects and policies*. International Institute of Food Policy Research, USA.

Reddy S, Janakiram T. Balaji T, Kulkarni S and Misra RL. 2007. *Hightech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi.

Sheela VL. 2007. *Flowers in Trade*. New India Publ. Agency.

I. Course Title : Food Additives

II. Course Code : PHM 606

III. Credit Hours : (1+1)

IV. Why this course ?

Food additives have been used for centuries to improve and preserve the taste, texture, nutrition and appearance of food. Food additives and preservatives are used in today's food supply to prevent foodborne illness, enable the transportation of food to areas that otherwise wouldn't be possible, and for the efficient manufacture of products to consistently meet the established quality standards. Although there may be certain ill effects of additives and preservatives in food, they increase its shelf life and help retain the flavour, color, and texture. They also help maintain or increase the nutritive value of food. Hence this customized course.

V. Aim of the course

To understand the chemistry of food additives and their functions in food processing This course is organized as follows:

No	Blocks	Units
1	Quality control of horticultural products	I Importance of food additives II Methods of preservation III Different additives types IV Flavour technology V Use of functional ingredients and safety and toxicological evaluation

VI. Theory

Block 1: Food Additives

Unit I: Importance of food additives in processing and preservation of horticultural produce by food additives. Food additives-definitions, classification, international numbering systems and functions.

Unit II: Principles and methods of preservation by use of sugar, salt, spices, essential oils, vinegar, mode of action of chemical preservatives.

Unit III: Antioxidants, colours and flavours (synthetic and natural), emulsifiers, sequester ants, humectants, hydrocolloids, sweeteners, acidulants, buffering salts, anticaking agents, clarifying agents, etc. – uses in horticulture foods and functions in formulations.

Unit IV: Flavour technology: types of flavours, flavour generated during processing – reaction flavours, flavour composites, stability of flavours during food processing, flavour emulsion, essential oils and oleoresins, etc.

Unit V: Uses of enzymes in extraction of juices. Pectic substances and their role as jellifying agents.Protein, starches and lipids as functional ingredients, functional properties and applications in horticultural food. Safety and toxicological evaluation of food additives: GRAS-tolerance levels and toxic levels in foods, LD_{50} value.

VII. Practical

- Extraction of fruit and vegetable juices using enzymes clarification;
- Role of additives and preservatives in RTS, cordial, squash, concentrate, syrup, jam, jelly, marmalade, ketchup, sauce, preserves, chutneys, pickles, candies, crystallized products;
- Estimation of benzoic acid, sulphur-di-oxide;
- Estimation of pectins.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Exposure visits
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Importance of food additives in processing and preservation of horticultural produce
- About Flavour technology
- Safety and toxicological evaluation of food additives

X. Suggested Reading

Branen AL, Davidson PM, Salminen S and Thorngate III JH. 2001. *Food Additives* (2nd Edition), Marcel Dekker Inc., ISBN 0824793439.

DGHS Manual 8: *Manual of Methods of Analysis of Foods-Food Additives*.

Gerorge AB. 1996. *Encyclopedia of Food and Color Additives*. Vol. III. CRCPress.

Madhavi DL, Deshpande SS and Salunkhe DK. 1996. *Food Antioxidants: Technological, Toxicological and Health Perspective*. Marcel Dekker.

Michael and Ash I. 2008. *Handbook of Food Additives* (3rd Edition), Synapse Information Resources, Inc., ISBN 9781934764008.
Nagodawithana T and Reed G. 1993. *Enzymes in food processing*. Academic Press.
Ötleº S. Ed. 2005. *Methods of Analysis of Food Components and Additives*, CRC Press, ISBN 9780849316470.
Taylor AJ. and Linforth RST. 2010. *Food Flavour Technology* (2nd Edition), Wiley- Blackwell, ISBN 9781405185431.
Wood R, Foster L, Damant A and Key P. 2004. *Analytical Methods for Good Sdditives*, CRC Press, ISBN 084932534X.

Websites

Additives and colors FDA-https://www.fda.gov/food/ingredientspackaginglabeling/foodadditivesingredients/ucm094211.htm
https://www.faia.org.uk/
https://www.eufic.org/en/whats-in-food/category/additives

I. Course Title : Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants

II. Course Code : PHM-607

III. Credit Hours : (3+0)

IV. Why this course ?

This course deals with post-harvest operations, processing and value addition details of plantation, spices, medicinal and aromatic plants. This course would be very useful for everyone who so ever is interested to know about harvesting and handling of spices, plantation, medicinal and aromatic plants.

V. Aim of the course

To familiarize with advances in processing of plantation, spices, medicinal and aromatic plants

The course is organized as follows:

No	Blocks	Units
1	Handling and utilization of plantation, spice, medicinal and aromatic plants	I Introduction II By product utilization III Value addition of medicinal and aromatic plants
2	Essential oil utilization and their storage	4.Recovery of useful products 5.Treatment of solid and liquid waste

VI. Theory

Block 1: Handling and utilization of plantation, spice, medicinal and aromatic plants

Unit I: Introduction: Commercial uses of spices and plantation crops. Introduction to processing and products in plantation and spice crops. Significance of on farm processing and quality of finished products. Processing of major spices, extraction of oleoresin and essential oils. Processing of produce from plantation and spice crops.

Unit II: By product utilization:By product utilization in plantation crops for coir production, mushroom culture, cocopeat, bee keeping, toddy tapping, Oil cake production and utilization, vermi-composting, Fuel wood and timber wood from perennial spices and plantation crops (crops, viz., coconut, areca nut, cashew nut, oil palm, palmyrah, date palm, cocoa, tea, coffee, rubber, etc. cardamom, black pepper, ginger, turmeric, chilli and paprika, vanilla, cinnamon, clove, nutmeg, allspice, coriander, fenugreek, curry leaf, etc.).

Unit III: Value addition of medicinal and aromatic plants: Value addition on aromatic oils and medicinal herbs. Principles and practices of different types of extraction – distillation, solvent extraction, enfleurage, soxhlet, supercritical fluid extraction, phytonics, counter current extraction. Commercial uses of essential oils, aroma therapy.Commercial utilization of spent material.

Block 2: Essential oil utilization and their storage

Unit I: Quality determination of essential oils: Qualitative determination of essential oils. Quality analysis and characterization through chromatographs.

Unit V: Storage of essential oils: Storage of essential oils. Utilization of spent material of medicinal and aromatic crops in manufacture of agarabatti, organic manures and other useful products. Detoxification of waste materials. Role of spent material in bio-control of diseases and pest in organic farming. Role of micro-organisms in conversion of waste in to useful products.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Learn utilization and processing of spice, plantation, medicinal and aromatic plants
- Apply appropriate processing technique to the crop related processing technique

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*, CRC Press, ISBN 9781138033825.

Chakraverty A, Majumdar AS, Raghavan GSV and Ramaswamy HS. 2003. *Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices*, CRC Press, ISBN 9780824705145.

Chi-Tang Ho, Jen-Kun Lin and Fereidoon Shahidi. 2008. *Tea and Tea Products: Chemistry and Health-Promoting Properties*, CRC Press, ISBN 9780849380822.

Kumar N, Khader JBMM, Rangaswami P., and Irulappan I. 2017. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants* (2nd Edition), Oxford & IBH Publishers, ISBN 9788120417762.

Pruthi JS. 1993. *Major Spices of India Crop Management Postharvest Technology*, ICAR Publication, ISBN 1234567147556.

Siddiqui MW. 2015. *Postharvest Biology and Technology of Horticultural Crops: Principles and Practices for Quality Maintenance*, CRC Press, ISBN 9781771880862.

Websites

https://www.cabdirect.org/cabdirect/abstract/20006781145:
https://www.springerprofessional.de/en/value-addition-in-flowers/4657550

I. Course Title : Value Addition in Ornamental Crops

II. Course Code : PHM 608

III. Credit Hours : (1+1)

IV. Why this course ?

Ornamental crops provide better income from a unit area with higher profitability. The production of flower crops has increased significantly and there is huge demand for floricultural products in the world resulting in growing international flower trade. Value addition in floriculture increases the economic value and consumer appeal of any floral commodity. This course will be useful as a source of income generation.

V. Aim of the course

To acquaint the students about the scope and ways of value addition in ornamental crops.

The course is organized as follows:

No	Blocks	Units
1	Value addition of flowers	I Introduction II Value addition of flower crops III Neutraceuticals from petals
2	Floral arrangements and women empowerment	I Floral arrangements II Women empowerment

VI. Theory

Block 1: Value addition of flowers

Unit I: Introduction: Importance, opportunities and prospects of value addition in floriculture; national and global scenario; production and exports, supply chain management.

Unit II: Value addition of flower crops: Dry flower making including pot pourries, their uses and trade; extraction technology, uses, sources and trade in essential oils; aroma therapy; pigment and natural dyes extraction technology, sources, uses and trade.

Unit III: Neutraceuticals from petals: Pharmaceutical and neutraceutical compounds from flower crops; petal embedded hand made paper making and uses, preparation of products like gulkand, rose water, gulroghan, attar, pankhuri.

Block 2: Floral arrangements and women empowerment

Unit I: Floral arrangements: Floral craft including bouquets, garlands, flower arrangements, etc. tinting (artificial colouring) of flower crops;

Unit II: Women empowerment: Women empowerment through value added products making.

VII. Practical

- Dry flower making including pot pourries; extraction technology, uses, sources and trade in essential oils;
- Pigment and natural dyes extraction technology;
- Pharmaceutical and neutraceutical compounds from flower crops;
- Preparation of products like *gulkand*, rose water*gulroghanattar, pankhuri*;
- Petal embedded handmade paper making;
- Floral craft including bouquets, garlands, flower arrangements, etc.;
- Tinting (artificial colouring) of flower crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Student presentation
- Group Work/ Seminars
- Product preparation and income generation assessment

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Will be helpful in converting waste into wonder by making potpourris, greeting cards, etc.
- Students can give training to women and create a source of employment to rural women

X. Suggested Reading

Bhattacharjee SK and De LC. 2004. *Advances in Ornamental Horticulture* Vol. V, Pointer publishers, Jaipur.

Gary L. McDaniel. 1989. *Floral design and arrangement*. A Reston Book. Prentice hall. New Jersey.

Lauria A and Victor HR. 2001. *Floriculture – Fundamentals and Practices*. Agrobios. Lesniewicz Paul. 1994. *Bonsai in your home*. Sterling publishing Co, New York.

Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios.

Randhawa GS and Mukhopadhyay A. 2000. *Floriculture in India*, Allied publishers, India.

Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hightech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi.

Salunkhe K, Bhatt NR and Desai BB. 2004. *Postharvest biotechnology of flowers and ornamental plants*. NayaProkash, Kolkata.

Websites

http://www.vedamsbooks.com/no103218/user_forgot_pass.php

https://www.springerprofessional.de/en/value-addition-in-flowers/4657550

www.ihc2018.org/en/S29.html

Journals on Postharvest Management of Horticultural Crops

Sr. No.	Name of the Journal	ISSN No.
1.	*Annual Review of Food Science and Technology*	ISSN 19411421, 19411413
2.	*Comprehensive Reviews in Food Science and Food Safety*	ISSN 15414337
3.	*Trends in Food Science and Technology*	ISSN 09242244
4.	*Food Chemistry*	ISSN 03088146
5.	*Food Microbiology*	ISSN 10959998, 07400020

Sr. No.	Name of the Journal	ISSN No.
6.	*Postharvest Biology and Technology*	ISSN 09255214
7.	*Food Research International*	ISSN 09639969
8.	*Critical Reviews in Food Science and Nutrition*	ISSN 15497852, 10408398
9.	*Journal of Food Engineering*	ISSN 02608774
10.	*International Journal of Food Microbiology*	ISSN 01681605
11.	*Food Control*	ISSN 09567135
12.	*Innovative Food Science and Emerging Technologies*	ISSN 14668564
13.	*Food and Bioprocess Technology*	ISSN 19355130, 19355149
14.	*LWT-Food Science and Technology*	ISSN 10961127, 00236438
15.	*Journal of Functional Foods*	ISSN 17564646
16.	*Food Quality and Preference*	ISSN 09503293
17.	*Journal of Food Composition and Analysis*	ISSN 08891575, 10960481
18.	*Plant Foods for Human Nutrition*	ISSN 09219668, 15739104
19.	*Current Opinion in Food Science*	ISSN 22147993
20.	*Food Packaging and Shelf Life*	ISSN 22142894
21.	*Journal of the Science of Food and Agriculture*	ISSN 10970010, 00225142
22.	*International Journal of Food Science and Technology*	ISSN 13652621, 09505423
23.	*Journal of Food Science*	ISSN 00221147
24.	*Journal of Food Protection*	ISSN 0362028X
25.	*Phytochemical Analysis*	ISSN 09580344, 10991565
26.	*Food Reviews International*	ISSN 15256103, 87559129
27.	*European Food Research and Technology*	ISSN 14382377, 14382385
28.	*Biosystems Engineering*	ISSN 15375110, 15375129
29.	*Agribusiness*	ISSN 15206297, 07424477
30.	*Journal of Sensory Studies*	ISSN 08878250
31.	*Journal of Texture Studies*	ISSN 00224901
32.	*International Journal of Food Properties*	ISSN 10942912, 15322386
33.	*International Journal of Food Sciences and Nutrition*	ISSN 09637486, 14653478
34.	*Journal of Food Science and Technology*	ISSN 00221155
35.	*Advances in Food and Nutrition Research*	ISSN 10434526
36.	*Journal of Food Process Engineering*	ISSN 17454530, 01458876
37.	*British Food Journal*	ISSN 0007070X
38.	*Journal of Food Quality*	ISSN 01469428, 17454557
39.	*Food Science and Technology International*	ISSN 10820132
40.	*Irish Journal of Agricultural and Food Research*	ISSN 07916833, 20099029
41.	*Journal of Food Processing and Preservation*	ISSN 01458892
42.	*Stewart Postharvest Review*	ISSN 17459656
43.	*International Journal of Food Science*	ISSN 23145765, 23567015
44.	*Food Science and Technology*	ISSN 01012061, 1678457X
45.	*International Food Research Journal*	ISSN 19854668
46.	*International Food and Agribusiness Management Review*	ISSN 15592448, 10967508
47.	*Food Science and Technology Research*	ISSN 13446606
48.	*International Journal of Food Engineering*	ISSN 15563758, 21945764
49.	*Journal of Horticultural Research*	ISSN 23005009, 23533978
50.	*International Journal of Postharvest Technology and Innovation*	ISSN 17447550, 17447569
51.	*Food Technology*	ISSN 00156639
52.	*Open Nutraceuticals Journal*	ISSN 18763960
53.	*Advance Journal of Food Science and Technology*	ISSN 20424868, 20424876

ANNEXURE I

List of BSMA Committee Members for Horticultural Sciences

(Fruit Sciences/ Vegetable Sciences/ Floriculture and Landscape Architecture/ Plantation, Spices, Medicinal & Aromatic Plants/ Post-harvest Technology)

S.No.	Name and Address	Specialization
1.	**Dr RK Pathak** **Former Director** Central Institute for Subtropical Horticulture, Lucknow C-906, Oberoi Excutive, Goregaon, East Mumbai-400 063 Email: pathakramkripal@gmail.com Mob.: 09454974422/ 08828486737	**Chairman**
2.	**Dr K M Indiresh** **Registrar** University of Horticultural Sciences, Bagalkot, Karnataka Email; registrar@unsbagakot.edu.in; indiresh.kabbali@gmail.com Mob.: 09480696389	**Convener**
3.	**Dr Krishnan Kumar** **Professor & Head** Department of Fruit Science, College of Horticulture Dr YS Parmar University of Horticulture and Forestry Nauni, Solan-173 230 Email: drkrishankumar@gmail.com Mob.: 09418020518	**Fruit Science**
4.	**Dr M K Rana** **Professor** Department of Vegetable Science Chaudhary Charan Singh Haryana Agricultural University Hisar, Haryana-125 004 Email: maheshk2@hau.ernet.in Mob.: 0941634573	**Vegetable Science**
5.	**Dr K V Prasad** **Director** ICAR-Directorate of Floricultural Research College of Agriculture, Shivajinagar, Pune-411 005 Email: directordfr@gmail.com Mob.: 09868149259	**Floriculture**

S.No.	Name and Address	Specialization
6.	**Dr Amit Baran Sharangi** **Professor & Head** Department of Spices & Plantation Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur Email: drabsharangi@yahoo.co.in Mob.: 09433313117	**Spices & Plantation crops**
7.	**Dr Miniraj** **Professor** Department of Plantation Crop and Sciences, Kerala Agricultural University, Thrissur-680 656 Email: n.miniraj@kau.in Mob.: 09388673785	**Spices & Medicinal**
8.	**Dr Laxminarayan Hegde** **Department of Medical Crops, Arabhavi,** University of Horticultural Sciences, Bagalkot Email: hegdelax@gmail.com hrspepper@gmail.com Mob.: 08762189133	**Horticulture**
9.	**Dr M. Lakshminarayana Reddy** **Dean (Hort.)** Dr YSR Horticulture University, Venkatarmanagudem West Godavari Dist, Andhra Pradesh-534 101 Email: dh@drysrhu.edu.in Mob.: 09490402052	**Horticulture**

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 1

Forestry

- Silviculture and Agroforestry
- Forest Biology and Tree Improvement
- Forest Products and Utilization
- Forest Resource Management

Contents

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Dr H C Sharma, Hon'ble Vice Chancellor, YSP UHF, Nauni, Solan and Dr P K Mahajan, Dean, College of Forestry and Convener, BSMA took special interest in this committee and holding 1st meeting in their esteemed institute and providing administrative support during the said meeting. The BSMA committee is thankful to Hon'ble Vice Chancellor, CCS HAU, Hissar and Dr R.S. Dhillon, Head, Department of Forestry, College of Agriculture, Hissar and Coordinator for providing support for holding 2nd meeting at their institute. Our sincere gratitude to Hon'ble Vice Chancellor, Dr Bala Shabeb Sanwant Konkan Krishi Vidyapeeth, Dapoli (Maharashtra) and Dr S.S. Narkhede, Dean, College of Forestry for organizing two days workshop by him at Dapoli, where more than 36 Forestry scientists deliberated on the syllabi.

Our thanks are also due to different leading institutes of the country in Forestry education such as FRI, Dehradun, BAU, Ranchi, KAU, Thrissur, UAS, Dharwad, NAU, Navsari, SKUAST, Jammu and Kashmir for allowing their scientists to participate in the workshop and meetings and the valuable suggestions for the formulation of this syllabi.

Pawan Kumar Mahajan
Convener, BSMA (Forestry)
L K Dashora
Chairman, BSMA (Forestry)

Preamble

The world of Forestry is changing rapidly. The multi-valuable nature of forests is gaining wider recognition, thus, leading to increased understanding of the linkage between forests and society. Forests are significant to the well being of society providing multiple services and products *i.e.* tangible and intangible. Moreover, in the present era of climate change, our forests are crucial not only for supplying various products and services but also for ensuring a healthy environment. From providing livelihood security to generating business ventures; from being sources of rich biodiversity to carbon resources, the usefulness of forests to humankind indeed is wide-ranging. Forest as a commodity is to be managed scientifically to enhance its production and productivity and protection of environment as well as sustenance of our agriculture. Higher Forestry education has an important role to play in the future of the world's forests. The future decision makers; the students of today; will need to possess adequate skills to be able to meet the future challenges.

To produce high degree competence and skill oriented world class forestry professionals, Forestry education needs to be reoriented so as to meet the challenges of high forest productivity and global market along with eco-friendly environment.

The State Agricultural Universities undertake Forestry education with unique facilities and linkage between agriculture, horticulture, animal husbandry and forestry. To make the undergraduate degree programme more relevant and skill oriented quality education, the 5th Deans Committee of ICAR, New Delhi revised the B.Sc. Forestry programme with introduction of students' READY programme to develop entrepreneur skills among the Forestry students.

In India, Forestry education was introduced at the University level by starting M.Sc. Forestry in 1976 at Dr YS Parmar University of Horticulture and Forestry, Nauni (HP). Thereafter, many Agriculture Universities started UG, PG and Ph.D. programme in Forestry with the directive of MoEF and ICAR. Today, about 50 institutes of State/ Central/ Private University in 21 states of the country are offering different degree programmes in Forestry. The existing single M.Sc. Forestry programme is quite inadequate to meet the present and envisaged human resource requirement. Further, at present, PG degree in Forestry is being awarded under different nomenclatures by various Universities as per their own convenience, and no common courses are given to students for the same degree at M.Sc. or Ph.D level. In order to bring uniformity in the system of imparting Forestry education at University level, ICAR, New Delhi (5th Dean's Committee) recommended that each University which offers B.Sc programme in Forestry should have four departments namely: Silviculture and Agroforestry, Forest Biology and Tree Improvement, Forest Products and Utilization and Forest Resource Management.

The BSMA Committee on Forestry has been constituted by National Core Group (ICAR) to re-structure the M.Sc. and Ph.D programme in Forestry in accordance to the changes made in B.Sc. Forestry curriculum by 5th Dean's Committee, ICAR, New Delhi. In order to bring excellence in teaching and research at Master's and Ph.D. levels and making the degrees more professional and saleable, the core courses have been offered in those fields where opportunities are very high for employability and for development of entrepreneurship.

The BSMA Committee for Forestry organized two meetings at College of Forestry, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan and College of Agriculture, CCS Haryana Agricultural University, Hissar (Haryana), respectively, and a two-day workshop at College of Forestry, Dr Balasahib Swant Konkan Krishi Vidyaapeeth, Dapoli, Maharastra with participation from Agricultural Universities and other stakeholders from industries, State Forest Departments to develop the curricula. The envisaged M.Sc. and Ph.D. programmes have been restructured along with inclusion of new courses on important global issues like climate change, Biodiversity conservation, information technology, GIS, etc. in the syllabi. These M.Sc. and Ph.D. programmes are as follows:

1. Silviculture and Agroforestry (SAF)
2. Forest Biology and Tree Improvement (FBTI)
3. Forest Products and Utilization (FPU)
4. Forest Resource Management (FRM)

It is a belief of BSMA Committee on Forestry that the restructured PG academic programme including uniform degree nomenclature, course curricula and syllabi would prove ideal for generating world class professionals, human resource competent enough to meet the global challenges and competitiveness in Forestry and enhance their employability both in public and private sectors.

Career Opportunities

The new course programmes are more inclined to forestry and industry and have been deisgned in accordance to recent developments in the subject concerned hence will be helpful to fetch teaching, research and R&D jobs in colleges/ universities, research institutions and industries.

Pawan Kumar Mahajan
Convener, BSMA (Forestry)
L K Dashora
Chairman, BSMA (Forestry)

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry
– Silviculture and Agroforestry

Course Title with Credit Load
M.Sc. (Forestry) in Silviculture and Agroforestry

Course Code	Course Title	Credit Hours
	Major Courses	
SAF 501*	I Silviculture	2 + 1
SAF 502*	II Forest Biometry	1 + 1
SAF 503*	I Silvicultural Practices	1 + 1
SAF 504*	II Agroforestry Systems	2 + 1
SAF 505*	I Interactions in Agroforestry Systems	1 + 1
SAF 506	II Modern Nursery Technologies	1 + 1
SAF 507	I Plantation Forestry	2 + 1
SAF 508	II Industrial Agroforestry	1 + 1
SAF 509	I Climate Change and Conservation Silviculture	2 + 0
SAF 510	II Trees and Shrubs for Agroforestry	1 + 1
SAF 511	I Economics of Agroforestry Systems	2 + 1
SAF 512	II Tree Seed Technology	2 + 1
SAF 513	I Nutrient and Weed Management in Production Forestry	1 + 1
SAF 514	II Crops and Live Stock Management in Agroforestry	2+0
	Minor Courses	
	Courses from Forest Biology and Tree Improveemnt or Forest Products and Utilization	08
	Supporting Courses	
FOR 511*	I General Statistical Methods and Computer Applications	2+1
	Any other course relavent to MSc research problem	03
	Common Courses	
	Library and Information Services	1+0
	Technical Writing and Communications Skills	1+0
	Intellectual Property and its management in Agriculture	1+0
	Basic Concepts in Laboratory Techniques	1+0
	Agricultural Research, Research Ethics and Rural Development Programmes	1+0
SAF 591*	I/ II Master's Seminar	1+0
	ii) Thesis Research	
SAF 599	Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Silviculture and Agroforestry

I. Course Title : Silviculture

II. Course Code : SAF 501

III. Credit Hours : 2 + 1

IV. Aim of the course

To understand stand growth, development and provide knowledge regarding the application of silvicultural principles for the production and protection benefits from the forests.

V. Theory

Unit I

Forest ecosystems- Introduction to tropical/ temperate silviculture. Role of silviculture in forest and wild land management, major forest formations- classification, distribution, composition and structure. Vegetation dynamics- species richness-diversity indices. Vegetation forms of India and their productivity.

Forest ecosystem- structure and functioning, community development, competitive interactions in forest communities, forest succession, concepts and models of succession-Connell-Slatyer models, climax theories, tolerance.

Unit II

Ecophysiology of tree growth- effect of radiation and water relationship, mineral nutrients and temperature. Forest stand development – stand development, even-aged and uneven-aged stands, age and site quality. Tree architecture and its role in stand management.

Unit III

Stand density determination-stand density indices-stand density management- density management diagram, silvicultural treatments involved- thinning as a stand management tool, objectives of thinning, effects on growth and yield, thinning effect on economic yield of stands.

Forest site quality evaluation-direct and indirect methods.

Unit IV

Treatment analysis-silvicultural regimes- factors influencing choice of regimes, use of system analysis to determine regimes, models for evaluating silvicultural alternatives, development of silvicultural regimes to suit management objectives, optimum management strategies, silvicultural prescriptions for maximum production regime.

VI. Practical

- Visit to forest areas to study forest composition, classification, factors of locality, site quality, form and growth of forest trees- study plant succession- study stand density, changes on productivity- thinning effects;

VII. Suggested Reading

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture*. McGraw-Hill Book Company.

Julius E. 1992. *Plantation Forestry in the Tropics*. Oxford University Press.

Khanna LS. 1996. *Principle and Practice of Silviculture*. International Book Distributors.

Khanna LS. 2015. *Theory and Practice of Indian Silviculture Systems*. Bio-Green Publisher.

Lamprecht. 1986. *Silviculture in the Tropics*.Verlag Paul Parey, Hamburg und Berlin.

Nyland RD, Laura S, Kenefic, Kimberly K, Bohn and Susan LS.2016 *Silviculture: Concepts and Applications* (III edition), Kindle Edition, USA.

Pascal. 1988. *Wet Evergreen Forests of the Western Ghats.*

Shepherd KR. 1986. *Plantation Silviculture.* Springer.

Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture- Applied Forest Ecology*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest ecosystems- Introduction to tropical/ temperate silviculture	01
2.	Role of silviculture in forest and wild land management, major forest formations-classification, distribution, composition and structure	02
3.	Vegetation dynamics- species richness-diversity indices, various concepts	02
4.	Vegetation forms of India and their productivity	01
5.	Forest ecosystem- structure and functioning, community development, competitive interactions in forest communities	03
6.	Forest succession, concepts and models of succession-Connell-Slatyer models, climax theories, tolerance	03
7.	Ecophysiology of tree growth- effect of radiation and water relationship, mineral nutrients and temperature	02
8.	Forest stand development – stand development, even-aged and uneven-aged stands, age and site quality	02
9.	Tree architecture and its role in stand management	02
10.	Silvicultural treatments involved- thinning as a stand management tool, objectives of thinning, effects on growth and yield, thinning effect on economic yield of stands	03
11.	Forest site quality evaluation-direct and indirect methods	02
12.	Treatment analysis-silvicultural regimes- factors influencing choice of regimes, use of system analysis to determine regimes	03
13.	Models for evaluating silvicultural alternatives	02
14.	Development of silvicultural regimes to suit management objectives	02
15.	Optimum management strategies: silvicultural prescriptions for maximum production regime	02
	Total	32

Practical

1.	Visit to different forests to study forest composition and classification	4
2.	To study the effect of locality factor and determination of site quality in the different forests	4
3.	To study the plant sucession in different types of forests	2

Sr. No.	Topic	No. of Practical(s)
4.	To study the stand form, growth and stand density in major forest of the locality	2
5.	To carry out the productivity studies in different forests	2
6.	To study the impact of thinning in different periodic blocks/ selection forest	2
	Total	16

I. Course Title : Forest Biometry

II. Course Code : SAF 502

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about tree and stand measurements, forest inventory and yield concepts.

V. Theory

Unit I

Measurement of tree parameters. Determination of tree age and dendrochronology for growth history and climate change studies.

Unit II

Estimation of volume, growth and yield of individual tree and forest stands. Preparation of volume tables. Application of yield and stand tables.

Unit III

Forest inventory, sampling methods adopted in forestry, Use of GIS in forest inventory. Quantification of regeneration and stand establishment. Measurement of crown density and crown ratios. Simulation techniques. Growth and yield prediction models – their preparation and applications.

VI. Practical

- Calculations of volume of felled as well as standing trees;
- Volume table preparation;
- Application of different sampling methods;
- Preparation of yield and stand table;
- Quantification of regeneration and stand establishment;
- Measurement of crown density and crown ratios;
- Crown profiling of trees and stand;
- Dendrochronological studies.

VII. Suggested Reading

Chaturvedi AN and Khanna LS. 1994. *Forest Mensuration*. International Book Distributor.

Ram Parkash 1983. *Forest Surveying*. International Book Distributor.

Sharpe GW, Hendee CW and Sharpe WE. 1986. *Introduction to Forestry*. McGraw-Hill.

Simmons CE. 1980. *A Manual of Forest Mensuration*. Bishen Singh Mahender Pal Singh, Dehradun.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Measurement of tree parameters	01
2.	Determination of tree age and dendrochronology for growth history and climate change studies	01
3.	Estimation of volume, growth and yield of individual tree and forest stands	02
4.	Preparation of volume tables	02
5.	Application of yield and stand tables	02
6.	Forest inventory, sampling methods adopted in forestry	02
7.	Use of GIS in forest inventory	01
8.	Quantification of regeneration and stand establishment	02
9.	Measurement of crown density and crown ratios	01
10.	Simulation techniques	01
11.	Growth and yield prediction models – their preparation and applications	01
	Total	16
	Practical	
1.	Calculations of volume of felled as well as standing trees. Preparation of yield and stand table. Crown profiling of trees and stand Dendrochronological studies	5
2.	Volume table preparation. Application of different sampling methods	3
3.	Quantification of regeneration and stand establishment	2
4.	Measurement of crown density and crown ratios	2
5.	Crown profiling of trees and stand	2
6.	Dendrochronological studies	2
	Total	16

I. Course Title : Silvicultural Practices

II. Course Code : SAF 503

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with the advanced silvicultural practices in forestry with particular reference to commercial and short rotation forestry.

V. Theory

Unit I

Sivilculture under changing context of forestry- sivilculture and ecosystem management, stand dynamics, silvicultural practices for pure and mixed stand, even aged and uneven aged stand – silvicultural practices for changing climatic conditions.

Unit II

Silvicultural practices for natural and artificial regeneration – Ecology of regeneration, forest site management- enrichment of site – quality classes and site index models – stand density – spacing and tree growth – forest vegetation management – techniques for early stand growth- tending operations. Biomass allocation: belowground and aboveground. Changing trends in adoption of silvicultural systems.

Unit III

Stand development – stages- crown dynamics, Crown Competition factor, Maximum crown area, thinning – pruning – response of trees and impact on wood quality, salvage cutting – improvement felling and enrichment planting – management of weeds, Invasive weeds in forests, Silvicultural practices for short rotation forestry-coppice forestry, Continuous cover forestry.

Unit IV

Site specific selection of tree species. Precision silviculture –silvicultural practices for important fast growing trees and bamboos of India- *Populus species*, *Neolamarkia cadamba*, *Eucalyptus* sp., *Casuarina* sp.,*Tectona grandis*, *Melia dubia*, *Dalbergia sissoo, Gmelina arborea, Leucaena leucocephala, Ailanthus excelsa, Azadirachta indica, Swietenia macrophylla, Dendrocalamus* sp., *Bambusa* sp., – Mechanization of silvicultural practices.

VI. Practical

- Visit to different forest sites to study the influence of site factors on composition;
- Determination of site quality;
- Studies on stand structure and composition of different forest types;
- Practicing pruning and its impact on wood quality;
- Characterizing methods of thinning;
- Working out intensity of thinning;
- Study of stand densities in natural forest stand and plantation stand;
- Afforestation techniques, Wood management techniques for forest tree crops;
- Planning and designing a tree planting programme;
- Exercise on precision silviculture practices;
- Exercise on mechanized silvicultural practices.

VII. Suggested Reading

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture*. McGraw-Hill Book Company.

Julius E. 1992. *Plantation Forestry in the Tropics*. Oxford University Press.

Khanna LS. 1996. *Principle and Practice of Silviculture*. International Book Distributors.

Khanna LS. 2015. *Theory and Practice of Indian Silviculture Systems*. Bio-Green Publisher.

Lamprecht. 1986. *Silviculture in the Tropics*-Verlag Paul Parey, Hamburg und Berlin.

Nyland RD, Laura S, Kenefic, Kimberly K, Bohn and Susan LS.2016 *Silviculture: Concepts and Applications* (III edition), Kindle Edition, USA.

Shepherd KR. 1986. *Plantation Silviculture*. Springer.

Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture- Applied Forest Ecology*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Sivilculture under changing context of forestry- sivilculture and ecosystem management stand dynamics	01
2.	Silvicultural practices for pure and mixed stand, even aged and uneven aged stand	01
3.	Silvicultural practices for changing climatic conditions	01
4.	Silvicultural practices for natural and artificial regeneration	01
5.	Ecology of regeneration Forest site management- enrichment of site – quality classes	01
6.	Site index models – stand density – spacing and tree growth – forest vegetation management – techniques for early stand growth-tending operations	02
7.	Biomass allocation: belowground and aboveground	01
8.	Changing trends in adoption of silvicultural systems	01
9.	Stand development – stages- crown dynamics,site specific selection of tree species. Precision silviculture	01
10.	Crown Competition factor, Maximum crown area	01
11.	Thinning-pruning – response of trees and impact on wood quality, salvage cutting – improvement felling and enrichment planting	01
12.	Management of weeds, Invasive weeds in forest. Mechanization of silvicultural practices.	01
13.	Silvicultural practices for short rotation forestry- coppice forestry, Continuous cover forestry	01
14.	Precision silvicultural practices for important fast growing trees and bamboos of India- *Populus species*, *Neolamarkia cadamba*, *Eucalyptus* sp., *Casuarina* sp., *Tectona grandis*, *Melia dubia*, *Dalbergia sissoo*, *Gmelina arborea*, *Leucaena leucocephala*, *Ailanthus excelsa*, *Azadirachta indica*, *Swetenia macrophylla*, *Dendrocalamus* sp. and *Bambusa* sp.	03
	Total	17
	Practical	
1.	Visit to different forest sites to study the influence of site factors on composition, Determination of site quality; Studies on stand structure and composition of different forest types	3
2.	Practicing pruning and its impact on wood quality; Characterizing methods of thinning; Working out intensity of thinning	3
3.	Study of stand densities in natural forest stand and plantation stand, Afforestation techniques	3
4.	Wood management techniques for forest tree crops	2
5.	Planning and designing a tree planting programme	2
6.	Exercise on precision silviculture practices. Exercise on mechanized silvicultural practices	3
	Total	16

I. Course Title : Agroforestry Systems

II. Course Code : SAF 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the concept of agroforestry as a sustainable land use including diagnosis and design methodologies; overview of agroforestry and case studies.

V. Theory

Unit I

Agroforestry: objectives, importance, potentials and limitations for implementations. Land capability classification and land evaluation. Basis of classification of agroforestry systems and principles, indigenous *vs.* exotic, intraspecific variations, crown architecture of tropical/ temperate trees. Ideotype concept for selection of multipurpose trees. Nitrogen fixing trees. Overview and case studies of different agroforestry systems.

Unit II

Structural and functional attributes of agroforestry systems, shifting cultivation, taungya system, multiple and mixed cropping, alley cropping, silvopastoral systems, shelter-belts and windbreaks, energy plantations and home gardens.

Unit III

Role of trees in soil productivity and conservation– micro-site enrichment- litter and fine root dynamics, Nitrogen fixation and nutrient pumping. Soil productivity and management in agroforestry.

Unit IV

Community forestry and social forestry, linear strip plantations.

Unit V

Trends in agroforestry systems research and development, Diagnosis and Design –PRA-RRA tools in agroforestry problem diagnosis.

Unit VI

Climate Change mitigation and adaptation through agroforestry- climate negotiations- LULUCF- agroforestry options.

VI. Practical

- Survey and analysis of land use systems in the adjoining areas;
- Study of tree crown architecture;
- Design and plan of suitable models for improvement;
- PRA-RRA tools in agroforestry problem diagnosis.

VII. Suggested Reading

Buck LE, Lassoie, Fernandes ECM 1999. *Agroforestry in Sustainable Agri. Systems*. CRC Press.

Kumar BM and Nair PKR. 2006. *Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry*. Springer publication.

Kumar BM and Nair PKR. 2013. *Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges (Advances in Agroforestry)*. Springer publication.

Nair PKR and Latt 1998. *Directions in Tropical Agroforestry Research*. Kluwer.

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic Pub.
Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.
Peter Huxley. 1999. *Multiple Cropping with Woody and Non-Woody Plants*. John Wiley and Sons Ltd, Oxford, United Kingdom.
Tejwani KG. 1994. *Agroforestry in India*. Oxford & IBH Publishing Co. Pvt Ltd.
Thampan PK. 1993. *Trees and Tree Farming*. Peekay Tree Crops Development Foundation.
Young A. 1997. *Agroforestry for Soil Management*. CABI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Agroforestry: objectives, importance, potentials and limitations for implementations	02
2.	Land capability classification and land evaluation	02
3.	Basis of classification of agroforestry systems and principles	01
4.	Indigenous vs. exotic, intraspecific variations, crown architecture of tropical/ temperate trees	02
5.	Ideotype concept for selection of multipurpose trees, N fixing trees	01
6.	Overview and case studies of different agroforestry systems	04
7.	Structural and functional attributes of agroforestry systems, shifting cultivation, taungya system, multiple and mixed cropping, alley cropping, silvopastoral systems, shelter-belts and windbreaks, energy plantations and homegardens	06
8.	Role of trees in soil productivity and conservation-micro-site enrichment- litter and fine root dynamics, N fixation and nutrient pumping	04
9.	Soil productivity and management in agroforestry	02
10.	Community forestry and social forestry, linear strip plantations	02
11.	Trends in agroforestry systems research and development	01
12.	Diagnosis and Design –PRA-RRA tools in agroforestry problem diagnosis	02
13.	Climate Change mitigation and Adaptation through agroforestry- climate negotiations- LULUCF- agroforestry options	03
	Total	32
	Practical	
1.	Survey and analysis of land use systems in the adjoining areas.	5
2.	Study of tree crown architecture.	3
3.	Design and plan of suitable models for improvement.	4
4.	PRA-RRA tools in agroforestry problem diagnosis.	4
	Total	16

I. Course Title : Interactions In Agroforestry Systems

II. Course Code : SAF 505

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge to the students regarding tree-crop interaction,their quantification and techniques to neutralize the negative tree- crop interactions.

V. Theory

Unit I

Tree-crop interphase- biological factors affecting form and function in woody and non-woody plant mixtures. Nature and types of interactions- positive and negative, aboveground and belowground interactions- competition, complementarity in resource sharing.

Unit II

Method for quantifying interactions, principles of resource capture and utilization of light and water, nutrition and space. Tree-soil-crop interactions- nitrogen fixing trees interactions in agroforestry. Allelopathy. Use of radioisotopes in tree-crop interaction studies. Root distribution of trees and crops-competition and/ orcomplementarity. Animal-tree-crop interaction.

Unit III

Management options to neutralize negative (competitive) interactions, tree husbandry practices for alleviating competition- tree density manipulation, pruning, mixture of trees and herbaceous crops.

VI. Practical

- Different methods for quantifying interactions;
- Studies on allelopathy;
- Effect, microclimate modifications, different plant mixtures, tree-soil-crop interactions;
- Estimation of Land Equivalent Ratio, Estimation of competition indices;
- Measurement and interpretation of light interception in agroforestry systems;
- Interpretation of yield responses to shelter, soil water and drainage measurement, transpiration measurement, quantifying root distribution.

VII. Suggested Reading

Avery MA, Cannel MGR and Ong CK. 2005. *Biophysical Research for Asian Agroforestry*. Oxford and IBH Publishing Co. Pvt. Ltd.

Mac Dicken, KG and Vergara NT. 1989. *Agroforestry-classification and Management*.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic Pub.

Ong CK and P Huxley. 2002. *Tree-Crop Interactions- A Physiological approach*, CAB International.

Patra AK. 2013. *Agroforestry-Principles and Practices*. New India Publishing AGENCY, New Delhi (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Tree-crop interphase- biological factors affecting form and function in woody and non-woody plant mixtures	02
2.	Nature and types of interactions- positive and negative, aboveground and belowground interactions- competition, complementarity in resource sharing	02
3.	Methodforquantifyinginteractions	01
4.	Principlesof resource capture and utilization of light and water, nutrition and space	02

Sr. No	Topic	No. of Lecture(s)
5.	Tree-soil-crop interactions- nitrogen fixing trees interactions in agroforestry systems	02
6.	Allelopathy. Use of radioisotopes in tree-crop interaction studies	02
7.	Root distribution of trees and crops-competition and/ or complementarity	02
8.	Animal-tree-crop interaction	01
9.	Management options to neutralize negative interactions – management of competitive interactions in agroforestry, tree husbandry	01
10.	Practices for alleviating competition- tree density manipulation, pruning, mixture of trees and herbaceous crops	02
	Total	17

Practical

1.	Different methods for quantifying interactions	2
2.	Studies on allelopathy	2
3.	Effect, microclimate modifications, different plant mixtures, tree-soil-crop interactions	4
4.	Estimation of Land EquivalentRatio, Estimation of competition indices, Measurement and interpretation of light interception in agroforestry systems	4
5.	Interpretation of yield responses to shelter, soil water and drainage emeasurement, transpiration measurement, quantifying root distribution	4
	Total	16

I. Course Title : Modern Nursery Technologies

II. Course Code : SAF 506

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge and develop understanding about modern nursery techniques for mass production of quality planting stock using sexual and asexual propagation techniques.

V. Theory

Unit I

Introduction and importance of nursery. Types of nurseries-temporary and permanent, bare root, containerized and clonal nursery. Bare root nursery- nursery soil and water management, bed preparation, pre-sowing seed treatments, seed sowing and intermediate operations, viz., pricking, watering, fertilization, weeding and hoeing.

Unit II

Physiology and nursery environment interaction affecting seedling growth. Root culturing techniques. Containerized nursery—type and size of containers including root trainers, selection of growing medium. Types of green house and mist chamber for propagation.

Unit III

Vegetative propagation – importance, selection of superior genotypes, Advanced methods of propagation, containers, growing media, fertilizers, sanitation and management in vegetative propagation. Special requirement for clonal propagation. Propagation Structures and Management.

Unit IV

Clonal propagation: miniclonal and micro cuttings technology. Vegetative propagation of bamboos and canes. Factors affecting rooting of cuttings. Lifting windows. Important forest nursery pests and diseases and their management. Seedling quality assessment, grading, packaging, storing and transportation.

VI. Practical

- Introduction and identification of modern equipments and tools used in nursery;
- Pre-sowing seed treatments;
- Preparation of nursery beds and growing media for containerized nursery;
- Sowing of seed and other intermediate operations;
- Preparation and planting of cuttings;
- Use of vegetative propagation methods such as budding, grafting and layering;
- Miniclonal and microcutting technology;
- Use of plant bio-regulators for rooting;
- Assessment of seedling quality;
- Maintenance of nursery records. Identification of nursery insects and diseases and their control measures;
- Visit to forest nurseries;
- Nursery practices of commercially important tree species.

VII. Suggested Reading

Bhardwaj RL and Sarolia DK. 2011. *Modern Nursery Management.* Published by Agrobios Publishing. New Delhi (India).

Kumar GA and Gopikumar. 2003. *Forest Nursery and Tree Husbandry*.

Kumar V. 2012. *Nursery and Plantation Practices in Forestry*. Scientific Publishers (India).

Saini RS, Kaushik N, Kaushik RA and Godara NR. 2012. *Practical Nursery Production*. Agrobios, New Delhi (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction and importance of nursery,types of nurseries-temporary and permanent, bare root, containerized and clonal nursery	01
2.	Nursery soil and water management, bed preparation, pre- sowing seed treatments, seed sowing and intermediate operations, viz., pricking, watering, fertilization, weeding and hoeing	02
3.	Physiology and nursery environment interaction affecting seedling growth	01
4.	Root culturing techniques	01
5.	Containerized nursery – type and size of containers including root trainers, selection of growing medium	01
6.	Vegetative propagation – importance, selection of superior genotypes	01
7.	Advanced methods of propagation, containers, growing media, fertilizers, sanitation and management in vegetative propagation, types of green house and mist chamber for propagation.	03

Sr. No	Topic	No. of Lecture(s)
8.	Propagation structures and management	01
9.	Clonal propagation: miniclonal and micro cuttings technology, special requirement for clonal propagation	01
10.	Vegetative propagation of bamboos and canes. Factors affecting rooting of cuttings	02
11.	Lifting windows	01
12.	Important forest nursery pests and diseases and their management	01
13.	Seedling quality assessment, grading, packaging, storing and transportation	01
	Total	17

Practical

1.	Introduction and identification of modern equipments and tools used in nursery	1
2.	Pre-sowing seed treatments	1
3.	Preparation of nursery beds and growing media for containerized nursery	2
4.	Sowing of seed and other intermediate operations. Preparation and planting of cuttings	2
5.	Use of vegetative propagation methods such as budding, grafting and layering	2
6.	Miniclonal and microcutting technology	2
7.	Use of plant bio-regulators for rooting. Assessment of seedling quality	2
8.	Maintenance of nursery records. Identification of nursery insects and diseases and their control measures	2
9.	Visit to forest nurseries. Nursery practices of commercially important tree species	2
	Total	16

I. Course Title : Plantation Forestry

II. Course Code : SAF 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with various aspects of production, integrated nutrient and irrigation management and ecological factors in raising forest plantations.

V. Theory

Unit I

Role of plantation forestry in meeting the wood demand – status of plantation forestry in India and world. Purpose of plantation, factors determining scale and rate of plantation. Land suitability and choice of species. Preliminary site preparation for establishing plantation. Plantation planning, project formulation and appraisal. Planting programme, time of planting, spacing, pattern and planting methods.

Unit II

Nutritional dynamics and irrigation of plantation. Mechanization in plantation.

Protection and after care of plantation. Pruning and thinning in plantations for quality wood production. Rotation in plantation. Failures of plantations. Impact of interaction and integration of plantation forestry.

Unit III

Protective afforestation, afforestation of inhospitable sites. Plantation forestry for climate change mitigation- carbon forestry. Ecological factors and long term productivity. Sustainable yield from plantations. Case studies in plantations of Eucalyptus, Casuarina, Poplars, Acacias, Pine, Silver Oak, Gmelina, Teak, Sandal, Bamboo, etc. Production technology of energy plantations, industrial plantations. Emerging concepts in plantation forestry: mixed plantation, continuous cover forests.

VI. Practical

- Analysis of plantation problems in Asia and India;
- Preparation of plantation calendar –Preliminary arrangement for a plantation programme;
- Planting geometry and calculation of planting stock;
- Study of different cultural operations and site preparation for plantation;
- Studies on wood based industries – problems and prospects;
- Management of Eucalyptus, Casuarina, Teak, Sal, Poplar, Acacias and Bamboo plantations;
- Production technology for energy plantations. INM in plantations;
- Irrigation and plantations;
- Economics of pulpwood, timber and energy plantations. Study of mixed plantation model.

VII. Suggested Reading

Dwivedi AP. 1993. *Forestry in India*. Surya Publ.
Julius E. 1982. *Plantation Forestry in the Tropics*. Clarendon Press, Oxford.
Kumar V. 1999. *Nursery and Plantation Practices in Forestry*. Scientific Publ.
Luna RK. 1989. *Plantation Forestry in India*. International Book Distributors.
Prakash R, Chaudhari DC and Negi SS. 1998. *Plantation and Nursery Techniques of Forest Trees*. International Book Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Role of plantation forestry in meeting the wood demand – status of plantation forestry in India and world	02
2.	Purpose of plantation, factors determining scale and rate of plantation	01
3.	Land suitability and choice of species	02
4.	Preliminary site preparation for establishing plantation	02
5.	Plantation planning, project formulation and appraisal. Planting programme, time of planting, spacing, pattern and planting methods	03
6.	Nutritional dynamics and irrigation of plantation	02
7.	Mechanization in plantation	01
8.	Protection and after care of plantation	01
9.	Pruning and thinning in plantations for quality wood production. Rotation in plantation	01
10.	Failures of plantations. Impact of interaction and integration of plantation forestry	02

Sr. No	Topic	No. of Lecture(s)
11.	Protective afforestation, afforestation of inhospitable sites	03
12.	Plantation forestry for climate change mitigation- carbon forestry	02
13.	Ecological factors and long term productivity. Sustainable yield from plantations	02
14.	Case studies in plantations of Eucalypts, Casuarina, Poplars, Acacias, Pine, Silver Oak, Gmelina, Teak, Sandal, Bamboo, etc. Wasteland plantations	04
15.	Production technology of energy plantations, Industrial plantations	02
16.	Emerging concepts in plantation forestry: mixed plantation, continuous cover forests	02
	Total	32

Practical

1.	Analysis of plantation problems in Asia and India	1
2.	Preparation of plantation calendar –Preliminary arrangement for a plantation programme	2
3.	Planting geometry and calculation of planting stock	2
4.	Study of different cultural operations and site preparation for plantation	2
5.	Studies on wood based industries – problems and prospects	2
6.	Management of *Eucalyptus, Casuarina,* Teak, Sal, Poplar, *Acacias* and Bamboo plantations	2
7.	Production technology for energy plantations	1
8.	INM in plantations. Irrigation and plantations	2
9.	Economics of pulpwood, timber and energy plantations. Study of mixed plantation model	2
	Total	16

I. Course Title : Industrial Agroforestry

II. Course Code : SAF 508

III. Credit Hours : 1+1

IV. Aim of the course

To develop skill and expertise on industrial wood production and processing technology.

V. Theory

Unit I

Role of forests in industrial sector, industrial raw material, demand and supply, indigenous and exotic industrial resources, extent of area, policy and legal issues towards industrial wood plantation. Major wood based industries in India; timber, pulp wood, plywood, matches, etc. Raw material requirements and their procurements.

Unit II

Industrial wood plantations – status in India and different states, preferred species – current plantation management and establishment, propagation and plantation technique, economics of industrial agroforestry, pest and disease management for major industrial wood species, harvesting, reduced impact logging, mechanization.

Unit III

Supply chain; definition, concept, supply chain network, logistic activities, Marketing system; marketing type and channel, price patterns of various industrial wood agroforestry plantations. Contract farming: concept and methods, contract tree farming system in India. Industrial experiences– price support system – constraints. Corporates in industrial agroforestry: International and National corporate, success stories. Corporate social responsibilities. Tree insurance.

Unit IV

Impacts of industrial agroforestry – ecological impacts; climatic, edaphic and biotic– carbon sequestration. Carbon storage potential of industrial agroforestry and carbon trading mechanism of industrial agroforestry, socio-economic impacts–clean development mechanism. Certification of industrial plantations.

VI. Practical

- Study of various wood based industries;
- Study on raw material requirement and sourcing of plywood, pulp and paper, matchwood, timber processing;
- Biomass power generation industries;
- Value addition technology of various wood products;
- Industrial wood plantations – economics and impact assessment.

VII. Suggested Reading

Cosasalter C and C Pye-Smith. 2003. *Fast Wood Forestry – Myths and Realities*. CIFOR. Bogor, Indonesia. 50p.

Mehta T. 1981. *A Hand Book of Forest Utilization*. International Book Distributors, Dehradun.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic publishers.

Parthiban KT, Umarani R, Umesh Kanna S, Sekar I, Rajendran P and Durairasu P. 2014. *Industrial Agroforestry: Perspectives and Prospectives*. Scientific Publishers.

Tejwani KG. 1994. *Agroforestry in India*. Oxford and IBH publishing Co., New Delhi.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Role of forests in industrial sector, industrial raw material, demand and supply, indigenous and exotic industrial resources, extent of area, policy and legal issues towards industrial wood plantation	03
2.	Major wood based industries in India; timber, pulp wood, plywood, matches, etc. raw material requirements and their procurements	01
3.	Industrial wood plantations – status in India and different states, preferred species – current plantation management and establishment, propagation and plantation technique, economics of industrial agroforestry	02
4.	Pest and disease management for major industrial wood species, harvesting, reduced impact logging, mechanization	01
5.	Supply chain; definition, concept, supply chain network, logistic activities	01

Sr. No	Topic	No. of Lecture(s)
6.	Marketing system; marketing type and channel, price patterns of various industrial wood agroforestry plantations	02
7.	Contract farming; concept and methods, contract tree farming system in India	01
8.	Industrial experiences– price support system – constraints. Corporates in industrial agroforestry; International and National corporate, success stories. Corporate social responsibilities. Tree insurance	01
9.	Impacts of industrial agroforestry – ecological impacts; climatic, edaphic and biotic– carbon sequestration	01
10.	Carbon storage potential of industrial agroforestry and carbon trading mechanism of Industrial agroforestry, socio-economic impacts–clean development mechanism	02
11.	Certification of industrial plantations	01
	Total	16

Practical

1.	Industrial wood plantations – economics and impact assessment	3
2.	Study on raw material requirement and sourcing of plywood, pulp and paper, matchwood, timber processing	4
3.	Biomass power generation industries	3
4.	Value addition technology of various wood products	3
5.	Study of various wood based industries	3
	Total	16

I. Course Title : Climate Change and Conservation Silviculture

II. Course Code : SAF 509

III. Credit Hours : 2+0

IV. Aim of the course

To understand the scenario of climate change and international treaties on climate change, adaptive silviculture for climate change mitigation, silviculture for conservation of ecosystems.

V. Theory

Unit I

Global climate change-factors involved, green house gases, potential threats, global carbon cycle and C-budget, carbon sequestration. Forests and climate change: Forest responses and vulnerabilities to climate change mitigation.Status of forests in global climate change. Harnessing Forests for Climate Change Mitigation, International climate negotiation, UNFCCC, IPCC, CoP:LULUCF, REDD++ and CDM.

Unit II

Silviculture and sustainability-criteria and indicators for sustainable plantation forestry in India-CIFOR guidelines. Silvicultural and stand management strategies for carbon sink maximization and source minimization. Adaptive silviculture for climate change.

Unit III

Disturbance- natural and anthropogenic, short and long term impacts and their implications. Fire loss estimation in forests. Deforestation and degradation trends at global, national and regional levels. Mega development projects, Road widening projects and conservation of native and threatened species, management and rehabilitation plans.

Unit IV

Impacts of 'No Green Felling' on stand productivity and health. Restoration forestry-silvicultural treatments for habitat restoration, catchment area treatments, enrichment planting, Analog forestry for site productivity and carbon value. Expanding forest and tree cover area- TOF sector in India.

Unit V

Role of canopy in regulating functional inputs to stand: canopy and forest continuum, Continuous Cover Forestry. Silviculture of old growth stands and sacred grooves- their ecological significance and biodiversity values. Carbon sequestration potential of Trees Outside forests (TOFs), homegardens and urban forests.

VI. Suggested Reading

Anderson P and Palik B. 2011. *Silviculture for Climate Change.* U.S. Department of Agriculture, Forest Service, Climate Change Resource Center.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Global climate change-factors involved, green house gases, potential threats, global carbon cycle and C-budget, carbon sequestration	02
2.	Forests and climate change: Forest responses and vulnerabilities to climate change mitigation	02
3.	Status of forests in global climate change.Harnessing Forests for Climate Change Mitigation International climate negotiation, UNFCCC, IPCC, CoP:LULUCF, REDD++ and CDM	03
4.	Silviculture and sustainability-criteria and indicators for sustainable plantation forestry in India-CIFOR guidelines	03
5.	Silvicultural and stand management strategies for carbon sink maximization and source minimization	03
6.	Adaptive silviculture for climate change	01
7.	Disturbance- natural and anthropogenic, short and long term impacts and their implications. Fire loss estimation in forests	02
8.	Deforestation and degradation trends at global, national and regional levels	02
9.	Mega development projects, Road widening projects and conservation of native and threatened species, management and rehabilitation plans	02
10.	Impacts of 'No Green Felling' on stand productivity and health	01
11.	Restoration forestry-silvicultural treatments for habitat restoration, catchment area treatments, enrichment planting	02

Sr. No	Topic	No. of Lecture(s)
12.	Analog forestry for site productivity and carbon value	01
13.	Expanding forest and tree cover area- TOF sector in India	02
14.	Role of canopy in regulating functional inputs to stand,: canopy and forest continuum, Continuous Cover Forestry	02
15.	Silviculture of old growth stands and sacred grooves- their ecological significance and biodiversity values	02
16.	Carbon sequestration potential of Trees Outside forests (TOFs), homegardens and urban forests	02
	Total	32

I. Course Title : Trees and Shrubs for Agroforestry

II. Course Code : SAF 510

III. Credit Hours : 1+1

IV. Aim of the course

To make students familiar with trees and shrubs (fruit, fodder and small timber) suitable for agroforestry.

V. Theory

Unit I

Introduction, importance of woody elements in agroforestry systems, their role in biomass production. Suitability of species for different purposes. Multipurpose trees in agroforestry systems. Fodder from trees/ shrubs and their nutritive value, propagation techniques.

Unit II

Role of nitrogen fixing trees/ shrubs. Choice of species for various agro-climatic zones for the production of timber, fodder, fuel wood, fibre, fruits, medicinal and aromatic plants. Generic and specific characters of trees and shrubs for agroforestry.

Unit III

Fruit crop and small timber trees and their need and relevance in agroforestry, trees suitable for various assemblage and their planting plan in different agroclimatic zones and agroforestry system. Intercropping in fruit orchards like Apple, Walnut, Jack fruit, Mango, Sapota, Pomegranate, Orange, Citrus, Guava, etc. Modification in tending and pruning operations and canopy management. Fertility management, yield and quality improvement.

VI. Practical

- Field survey and acquaintance with specialized features of trees, shrubs and fruit species and varieties for Agroforestry;
- Planting plans including wind breaks;
- Training and pruning of forest trees, shrubs and fruit trees for enhancing production in agroforestry system.

VII. Suggested Reading

Dwivedi AP. 1992. *Agroforestry: Principles and Practices*. Oxford & IBH.
Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.
Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.
Srivastava KK. 2007. *Canopy Management of Fruit Crops*, IBD.
Thampan PK. 1993. *Trees and Tree Farming*. Peekay Tree Crops Development Foundation.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction, importance of woody elements in agroforestry systems, their role in biomass production	02
2.	Suitability of species for different purposes. Multipurpose trees in agroforestry systems	02
3.	Fodder from trees/ shrubs and their nutritive value, propagation techniques	02
4.	Role of nitrogen fixing trees/ shrubs	01
5.	Choice of species for various agroclimatic zones for the production of timber, fodder, fuel wood, fibre, fruits, medicinal and aromatic plants	02
6.	Generic and specific characters of trees and shrubs for agroforestry	01
7.	Fruit crop and small timber trees and their need and relevance in Agroforestry	01
8.	Trees suitable for various assemblage and their planting plan in different agroclimatic zones and agroforestry system	02
9.	Intercropping in fruit orchards like Apple, Walnut, Jack fruit, Mango, Sapota, Pomegranate, Orange, Citrus, Guava, etc.	02
10.	Modification in tending and, pruning operations and canopy management, fertility management, yield and quality improvement	02
	Total	17
	Practical	
1.	Field survey and acquaintance with specialized features of trees, shrubs and fruit species and varieties for Agroforestry	6
2.	Planting plans including wind breaks	4
3.	Training and pruning of tree, shrubs and fruit trees for enhancing production in agroforestry system	6
	Total	16

I. Course Title : Economics of Agroforestry Systems

II. Course Code : SAF 511

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with principles of economics and use of economic tools in appraisal of the agroforestry systems. Evaluation of ecosystem services from agroforestry- economic and ecological aspects of agroforestry.

V. Theory

Unit I

Basic principles of economics applied to agroforestry. Financial measures.

Quantification and valuation of inputs and outputs- direct and indirect methods.

Unit II

Optimization techniques-Planning, budgeting and functional analysis. Role of time, risk and uncertainty in decision making. Agroforestry budgeting. Risk analysis, re-assessment.

Unit III

Financial and socio-economic analysis of agroforestry projects. Principles of financial management and harvesting, post harvest handling, value addition, marketing of agroforestry products including benefit sharing.

Unit IV

Valuation of ecosystem services in agroforestry and payment for ecosystem systems. Bankable agroforestry projects, incentives, tree insurance, etc. Certification process in agroforestry based carbon projects, carbon finance, etc.

VI. Practical

- Exercises on agroforestry production relationships;
- Preparation of agroforestry based enterprise, partial and complete budgets;
- Application of various methods in formulation and appraisal of agro-forestry projects;
- Case studies on harvesting, post harvest management and marketing of agro-forestry products;
- Valuation of ecosystem services in agroforestry and payment for ecosystem services.

VII. Suggested Reading

Alavalapati JRR and Mercer D Evan. 2004 *Valuing Agroforestry Systems: Methods and Applications*. Kluwer Academic Publishers.

Kant S and Janaki A. 2014. *Handbook of Forest Resource Economics*. Publisher: Routledge

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer Academic Publishers.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic Publishers.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.

Sullivan Gregory M, Susan Hoke M and Jefferson M. Fox (editors). 1992. *Financial and Economic Analyses of Agroforestry Systems. Proceedings of a workshop held in Honolulu. Hawaii. USA. July* 1991. Paia, Ill: Nitrogen Fixing Tree Association.

Thampan PK. 1993. *Trees and Tree Farming*. Peekay Tree Crops Development Foundation.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Basic principles of economics applied to agroforestry	03
2.	Financial measures	02
3.	Quantification and valuation of inputs and outputs- direct and indirect methods	03
4.	Optimization techniques-Planning, budgeting and functional analysis	03
5.	Role of time, risk and uncertainty in decision making	02
6.	Agroforestry budgeting, risk analysis, re-assessment	03
7.	Financial and socio-economic analysis of agroforestry projects	03
8.	Principles of financial management and harvesting, post-harvest handling, value addition, marketing of agroforestry products including benefit sharing	04

Sr. No	Topic	No. of Lecture(s)
9.	Valuation of ecosystem services in agroforestry and payment for ecosystem systems	03
10.	Bankable agroforestry projects, incentives, tree insurance, etc.	03
11.	Certification process in agroforestry based carbon projects, carbon finance, etc.	03
	Total	32

Practical

1.	Exercises on agroforestry production relationships	3
2.	Preparation of agroforestry based enterprise, partial and complete budgets	4
3.	Application of various methods in formulation and appraisal of agro-forestry projects	3
4.	Case studies on harvesting, post harvest management and marketing of agro-forestry products	3
5.	Valuation of ecosystem services in agroforestry and payment for ecosystem services	3
	Total	16

I. Course Title : Tree Seed Technology

II. Course Code : SAF 512

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and to develop understanding about tree seed development, harvesting, processing, storage, dormancy, germination of tropical, sub-tropical and temperate species, their testing and certification.

V. Theory

Unit I

Introduction, trends and development in tropical, sub-tropical and temperate forestry and their influence on seed demand. Seed problems, limiting factors in tree propagation and afforestation.

Unit II

Reproductive biologyof seed plants – development and maturation of seed bearing organs and seeds – morphology of fruit and seed – seed dispersal – ecological fruit and seed types- seasonality and periodicity of flowering and fruiting – reproductive age – influence of external factors on seed production. Seed structure and chemical composition – development and maturation – germination – breakdown of storage products – endogenous hormonal regulation – effect of stimulators and inhibitors– dormancy – its causes and breakage specific problems of seeds of woody plants.

Unit III

Determining maturity indices. Factors influencing choice of collection methods.

Methods of seed collection and processing. Storage methods – loss of viability during storage. Dormancy and pre-treatment. Germination and seedling establishment and seed testing techniques.

Unit IV

Quality seed production technologies – seed certification.

Unit V

Eco-physiological role of seed storage. Classification of seed storage potential. Factors affecting seed longevity. Pre-storage treatment. Physiological change during ageing. Storage of orthodox, recalcitrant and intermediate seeds, Fumigation and seed treatment.

VI. Practical

- Identification of forest seeds;
- Seed sampling, different storage methods, Seed quality testing-purity, viability and germination, collection and processing of seeds/ fruit;
- Tests of viability, viz., cutting, hydrogen peroxide, excised embryo, tetrazolium, seed health testing primarily to the presence or absence of disease-causing organisms such as fungi, bacteria, virus and animal pests, recording, calculation and use of results of seed treatment.

VII. Suggested Reading

Baldwin HI. 1942. *Forest Tree Seed of the North Temperate Regions*. Periodical Experts Book Agency, Delhi.

Bedell PE. 1998. *Seed Science and Technology: Indian Forestry Species*. Allied Publisher Limited.

Chin HF and Roberts EH. 1980. *Recalcitrant crop seeds*. Tropical Press Sdn. Bhd. Malaysia.

Dutta M and Saini GC. 2010. *Forest Tree Improvement and Seed Technology*.

Hong TD and Ellis RH. 1996. *A protocol to determine seed storage behaviour*. IPGRI Technical Bulletin No. 1. (J. M. M. Engels and J. Toll, vol. Eds.) International Plant Genetic Resources Institute, Rome, Italy.

ISTA. 1993. *International Rules for Seed Testing*. International Seed Testing Association, Zurich, Switzerland.

Khullar P. *et al*. 1992. *Forest Seed*. ICFRE, New Forest, Dehra Dun.

Leadem CL. 1984. *Quick Tests for Tree Seed Viability*. B.C. Ministry of Forests and Lands, Canada.

Schmidt L. 2000. *Guide to handling of tropical and subtropical forest seed*. DANIDA Forest Seed Centre, Denmark.

Umarani R and Vanangamudi K. 2004. *An Introduction to Tree Seed Technology*. IBD, Dehradun.

Vanangamudi K. 2007. *Advances in Seed Science and Technology*: (Vol. 1. to 5).

Willan RL. 1985. *A guide to forest seed handling*. FAO Forestry Paper 20/2, DANIDA Forest Seed Centre, Denmark and FAO, Rome.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction, trends and development in tropical, sub-tropical and temperate forestry and their influence on seed demand	03
2.	Seed problems, limiting factors in tree propagation and afforestation	01
3.	Reproductive biology of seed plants – development and maturation of seed bearing organs and seeds	03
4.	Morphology of fruit and seed – seed dispersal – ecological fruit and seed types	02

Sr. No	Topic	No. of Lecture(s)
5.	Seasonality and periodicity of flowering and fruiting – reproductive age – influence of external factors on seed production	02
6.	Seed structure and chemical composition – development and maturation – germination – breakdown of storage products – endogenous hormonal regulation – effect of stimulators and inhibitors	03
7.	Dormancy – its causes and breakage, specific problems of seeds of woody plants	02
8.	Determining maturity indices	01
9.	Factors influencing choice of collection methods. Methods of seed collection and processing, storage methods – loss of viability during storage	02
10.	Dormancy and pre-treatment. Germination and seedling establishment and seed testing techniques	02
11.	Quality seed production technologies – seed certification	03
12.	Eco-physiological role of seed storage. Classification of seed storage potential. Factors affecting seed longevity	03
13.	Pre-storage treatment. Physiological change during ageing	02
14.	Storage of orthodox, recalcitrant and intermediate seeds. Fumigation and seed treatment	03
	Total	32

Practical

1.	Identification of forest seeds.	3
2.	Seed sampling, different storage methods, Seed quality testing-purity, viability and germination, collection and processing of seeds/ fruit	6
3.	Tests of viability, viz., cutting, hydrogen peroxide, excised embryo, tetrazolium, seed health testing primarily to the presence or absence of disease-causing organisms such as fungi, bacteria, virus and animal pests, recording, calculation and use of results of seed treatment.	7
	Total	16

I. Course Title : Nutrient and Weed Management in Oduction Forestry

II. Course Code : SAF 513

III. Credit Hours : 1+1

IV. Aim of the course

To make students to understand the concepts of nutrients and their management, weeds and their management in nurseries and plantations.

V. Theory

Unit I

History of nutrient management in forest nurseries and plantations. Essential nutrient elements and their deficiency. Mechanism of nutrient uptake by plants, functions and translocation/ interactions. Concept of nutrient availability.

Unit II

Climatic and soil conditions causing micronutrient deficiencies in plants. Occurrence and treatment of micronutrient disorders. Evaluation of soil for the supply of micronutrient. Rare and non-essential elements.

Unit III

Technology and use of complex liquid and suspension fertilizers. Fertilizer use efficiency. Biological nitrogen fixation and bio-fertilizers. Farm yard manure and other organic fertilizers. Mycorrhizal associations and their significance. Economic implications of nutrient management. Importance of renewable wastes and their recycling.

Unit IV

Principles of weed control. Methods of weed control-cultural, biological, mechanical and chemical. Herbicide/ weedicide classification, properties and their application.

VI. Practical

- Methods of soil and plantanalysis.
- Preparation of nutrient solutions.
- Practical application of fertilizers;
- Study of fertilizer response and diagnosis of deficiency symptoms.
- Fertilizer testing and pot experiments;
- Nursery inoculation techniques of bio-fertilizers;
- Methods of application of formulated products-seed treatment, root dip, suckers treatment, soil application, foliar application and combination of different methods;
- Important weeds in forest nurseries and plantations. Control of weeds.

VII. Suggested Reading

Allen V and Barker. 2007. *Handbook of Plant Nutrition*. Pilbeam London.
Gupta OP. 2011. *Modern Weed Management*. Agrobios, New Delhi (India).
Kumar D, Chowdhary S and Sharma R. 2011. *Weed Management: Principles and Practices*. Narendra Publishing House.
Rajaram C. 2012. *Hand book of Plant Nutrition*. Neha Publishers and Distributors.
Rammoorthy and Subbian P. 2012. *Weed Management*. Agrotech Publishing Academy, Udaipur (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	History of nutrient management in forest nurseries and plantations	01
2.	Essential nutrient elements and their deficiency	01
3.	Mechanism of nutrient uptake by plants, functions and translocation/ interactions	01
4.	Concept of nutrient availability	01
5.	Climatic and soil conditions causing micronutrient deficiencies in plants	01
6.	Occurrence and treatment of micronutrient disorders	01
7.	Evaluation of soil for the supply of micronutrient. Rare and non-essential elements	01
8.	Technology and use of complex liquid and suspension fertilizers	01
9.	Fertilizer use efficiency	01
10.	Biological nitrogen fixation and bio-fertilizers	01
11.	Farm yard manure and other organic fertilizers	01
12.	Mycorrhizal associations and their significance	01
13.	Economic implications of nutrient management	01

Sr. No	Topic	No. of Lecture(s)
14.	Importance of renewable wastes and their recycling	01
15.	Principles of weed control	01
16.	Methods of weedc ontrol-cultural, biological, mechanical and chemical	01
17.	Herbicide/ weedicide classification, properties and their application	01
	Total	17

Practical

1.	Methods of soil and plant analysis	2
2.	Preparation of nutrient solutions	2
3.	Practical application of fertilizers	1
4.	Study of fertilizer response and diagnosis of deficiencysymptoms	2
5.	Fertilizer testing and pot experiments	2
6.	Nursery inoculation techniques of bio-fertilizers.	2
7.	Methods of application of formulated products-seed treatment, root dip, suckers treatment, soil application, foliar application and combination of different methods.	3
8.	Important weeds in forest nurseries and plantations. Control of weeds	2
	Total	16

I. Course Title : Crops and Live Stock Management in Agroforestry

II. Course Code : SAF 514

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge on interactions between tree and live stock including their management, principles of crops and fodder production in agroforestry.

V. Theory

Unit I

Choice of inter-crops for different tree species, sowing and planting techniques. Planting patterns, crop geometry, nutrient requirements, and weed management. Management of fodder tree species, thinning, lopping, pruning. Ecological and socio-economic interactions.

Unit II

Role of tree architecture and its management on system's productivity. Production potentials of fodder based agroforestry systems in different agro-climatic conditions and crop combinations. Importance of cattle, sheep and goat vis-à-vis agro-forestry systems. Feed and fodder resources in agro-forestry systems and live stock management.

Unit III

Nutrient analysis of forages derived from fodder trees/ shrubs. Nutrient requirement for various livestock and their ration computation with agroforestry forages and tree leaves. Forage and tree leaves preservation.

Unit IV

Calendars for forage crop production in agro-forestry systems including lopping schedules. Optimization of animal production. Animal products technology and marketing.

Unit V

Integrated Agroforestry Farming System.

VI. Suggested Reading

Bran Powell. 2017. *Livestock Production and Management.* L & K Education.

Kundu SS, Dagar JC, Prakash O, Chaturvedi and Sirohi SK. 2008. *Environment, Agroforestry and Livestock Management.*

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Choice of inter-crops for different tree species, sowing and planting techniques	03
2.	Planting patterns, crop geometry, nutrient requirements, and weed management	03
3.	Management of fodder tree species, thinning, lopping, pruning	02
4.	Ecological and socio-economic interactions	02
5.	Role of tree architecture and its management on system's productivity	02
6.	Production potentials of fodder based agroforestry systems in different agro climatic conditions and crop combinations	02
7.	Importance of cattle, sheep and goat vis-à-vis agro-forestry systems	02
8.	Feed and fodder resources in agro-forestry systems and live stock management	02
9.	Nutrient analysis of forages derived from fodder trees/ shrubs	02
10.	Nutrient requirement for various livestock and their ration computation with agroforestry forages and tree leaves	02
11.	Forage and tree leaves preservation	02
12.	Calendars for forage crop production in agro-forestry systems including lopping schedules	02
13.	Optimization of animal production. Animal products technology and marketing	03
14.	Integrated Agroforestry Farming System	03
	Total	32

Course Title with Credit Load
Ph.D. (Forestry) in Silviculture and Agroforestry

Course Code	Course Title		Credit Hours
	Major Courses		
SAF 601*	I	Quantitative Silviculture	2+1
SAF 602*	II	Agroforestry Research and Management	2+1
SAF 603	I	Forest Stand Dynamics	1+0
SAF 604	II	Productivity and Evaluation of Agroforestry Systems	2+1
SAF 605	I	Forest Stand Management Techniques	1+1
SAF 606	II	Agroforestry for Ecosystem Services and Environmental Benefits	2+0
SAF 607	I	Plantation Forest Productivity	1+1
SAF 608	II	Restoration Forestry	1+0
SAF 609	I	Regeneration Silviculture	2+1
SAF 610	II	Forest Soil Management	1+1
SAF 611	I	Agroforestry for Sustainable Agriculture	1+0
	Minor Courses		
	Courses from Forest Biology and Tree Improvement or Forest Products and Utilization		06
	Supporting Courses		
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
SAF 691*	I/ II	Doctoral Seminar	1+0
SAF 692*	I/ II	Doctoral Seminar	1+0
	ii)	Thesis Research	
SAF 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Silviculture and Agroforestry

I. Course Title : Quantitative Silviculture

II. Course Code : SAF 601

III. Credit Hours : 2+1

IV. Aim of the course

To educate students with regard to forest stand growth and yield, quantitative techniques used for evaluating site quality, measuring stand density, predicting forest growth and yield.

V. Theory

Unit I

Principles of tree and stand growth and yield. Habitat types; site quality; site index.

Growth functions – empirical, exponential, allometry and Backman's growth functions. Growth pattern and growth increment curve. Growth cycle and phases. Quantifying site quality: Methods – tree and stand height data, periodic height growth. Techniques – guide curves, difference equations, parameter prediction.

Unit II

Stand density and stocking, measures of density: –3/2 power rule of self-thinning, point density, competition indices. Control of growing stock to achieve specific management objectives – growth-growing stock relations, Full site occupancy, Onset of competitive interactions. Langsaeter's hypothesis, stand density index and techniques for translating this understanding into rational density management regimes.

Unit III

Techniques: stand density management diagrams and stocking charts. Construction and use of stand density management diagrams. Designing density management regimes to suit specific management objectives.

Unit IV

Predicting growth and yield: normal and empirical yield tables, stand growth and yield equations, stand table projections. Simulation models: whole-stand models, size-class distribution models, single tree/ distance independent and distance-dependent models, process models, linkage of models at different levels. Evaluation, calibration, verification, and validation of forest growth and yield prediction systems. Introduction to existing forest growth and yield simulators.

VI. Practical

- Assessment of growth characteristics;
- Preparation of growth and increment curves;
- Site quality assessment, Stand density diagrams;
- Growth prediction models;
- Yield simulation techniques.

VII. Suggested Reading

Clutter JL, Fortson JC, Pienaar LV, Brister GH and Bailey RL. 1992. *Timber Management: A Quantitative Approach*. Krieger Publishing Company.

Davis LS and Johnson KN. 1987. *Forest Management*. 3rd Ed. McGraw-Hill.

Evans J. 1982. *Plantation Forestry in the Tropics*. Clarendon Press.

Johnson PS, Shifley SR and R. Rogers. 2009. *Self-thinning and Stand Density*. *The Ecology and Silviculture of Oaks*. CABI, Cambridge, MA.

Luna RK. 1989. *Plantation Forestry in India*. International Book distributors.

Vanclay JK. 1994. *Modeling Forest Growth and Yield: Application to Mixed Tropical Forests*. CAB International.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Principles of tree and stand growth and yield	02
2.	Habitat types; site quality; site index	02
3.	Growth functions – empirical, exponential, allometry and Backman's growth functions	03
4.	Growth pattern and growth increment curve. Growth cycle and phases	02
5.	Quantifying site quality: Methods – tree and stand height data, periodic height growth	02
6.	Techniques – guide curves, difference equations, parameter prediction	02
7.	Stand density and stocking, measures of density: –3/2 power law of self-thinning, point density, competition indices	03
8.	Control of growing stock to achieve specific management objectives – Growth-growing stock relations, Full site occupancy, Onset of competitive interactions. Langsaeter's hypothesis, stand density index and techniques for translating this understanding into rational density management regimes	03
9.	Techniques: stand density management diagrams and stocking charts. Construction and use of stand density management diagrams. Designing density management regimes to suit specific management objectives	03
10.	Predicting growth and yield: normal and empirical yield tables, stand growth and yield equations, stand table projections	03
11.	Simulation models: whole-stand models, size-class distribution models, single tree/ distance independent and distance-dependent models, process models, linkage of models at different levels	04
12.	Evaluation, calibration, verification, and validation of forest growth and yield prediction systems. Introduction to existing forest growth and yield simulators	03
	Total	32
	Practical	
1.	Assessment of growth characteristics	2
2.	Preparation of growth and increment curves	3
3.	Site quality assessment, Stand density diagrams	4
4.	Growth prediction models	3
5.	Yield simulation techniques	4
	Total	16

I. Course Title : Agroforestry Research and Management

II. Course Code : SAF 602

III. Credit Hours : 2+0

IV. Aim of the course

To teach how to refine the agroforestry systems, management practices and their integration for developing suitable agroforestry systems.

V. Theory

Unit I

Recent trends in agroforestry research and development. Agroforestry land use systems and their salient features. Research designs and analysis in agroforestry. Multi-functionality of agroforestry systems-multiplicity of products and services, food and nutritional security, livelihood security, gender related aspects. Constraints in agroforestry research – research prioritization.

Unit II

Study of systems specification, prioritizing potential interventions and technology specifications; space and time related considerations.

Unit III

Introduction to on-farm and on-station research experiments. Biomass production and allocation patterns- changes thorough agroforestry interventions.

Unit IV

Belowground dynamics- role of fine roots in agroforestry productivity. Tree husbandry practices in agroforestry for productivity optimization. Soil-site sustainability and environmental resource sharing. Site-species compatibility. Competition, predation, mutualism, commensalisms. Simulation modeling of agroforestry systems.

Unit V

Carbon and nutrient dynamics in agroforestry- carbon sequestration- carbon credits-mitigatory and adaptive roles of agroforestry in the context of climate change-climate negotiations and agroforestry.

Unit VI

Management of multifunctional agroforestry – sustainability, links with UNFCCC, UNCCD and UNCBD. Carbon conservation, sequestration, and substitution functions of agroforestry trees. Domestication of useful species and crafting market regimes for the products derived from agroforestry and ethno-forestry systems. Contract fuel wood schemes, small-scale nursery enterprises, charcoal policy reform, novel market information systems, facilitating and capacity building of farmer and farm forest associations. Climate change and reforestation incentive policies.

Unit VII

Market intelligence for agroforestry products. Agroforestry value chain models: consortia concepts. Successful case studies.

VI. Suggested Reading

Chin K Ong, Colin Black and Julia Wilson. 2015. *Tree-Crop Interactions*, 2nd Edition: Agroforestry in a Changing Climate. CAB International.

Kumar BM and Nair PKR. 2011. *Carbon Sequestration Potential of Agroforestry Systems: Oportunities and Challenges*. Springer.
Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.
Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.
Snelder DJ and Lasco RD. 2008. *Smallholder Tree Growing for Rural Development and Environmental Services*. Springer Science, Amsterdam.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Recent trends in Agroforestry research and development	02
2.	Agroforestry land use systems and their salient features. Research designs and analysis in agroforestry	02
3.	Multifunctionality of agroforestry systems – multiplicity of products and services, food and nutritional security, livelihood security, gender related aspects	02
4.	Constraints in agroforestry research – research prioritization	02
5.	Study of systems specification, prioritizing potential interventions and technology specifications; space and time related considerations	02
6.	Introduction to on farm and on station research experiments	01
7.	Biomass production and allocation patterns- changes thorough agroforestry interventions	01
8.	Belowground dynamics- role of fine roots in agroforestry productivity	02
9.	Tree husbandry practices in agroforestry for productivity optimization. Soil-site sustainability and environmental resource sharing. Site-Species compatibility	02
10.	Competition, predation, mutualism, commensalisms. Simulation modeling of agroforestry systems	02
11.	Carbon and nutrient dynamics in agroforestry- carbon sequestration - carbon credits- mitigatory and adaptive roles of agroforestry in the context of climate change- climate negotiations and agroforestry	02
12.	Management of multifunctional agroforestry – sustainability, links with UNFCCC, UNCCD and UNCBD	02
13.	Carbon conservation, sequestration, and substitution functions of agroforestry trees	02
14.	Domestication of useful species and crafting market regimes for the products derived from agroforestry and ethnoforestry systems	02
15.	Contract fuel wood schemes, small-scale nursery enterprises, charcoal policy reform, novel market information systems, facilitating and capacity building of farmer and farm forest associations	02
16.	Climate change and reforestation incentive policies	02
17.	Market intelligence for agroforestry products. Agroforestry value chain models: consortia concepts. Successful case studies	02
	Total	32

I. Course Title : Forest Stand Dynamics

II. Course Code : SAF 603

III. Credit Hours : 1+0

IV. Aim of the course

The purpose is to help silviculturists and forest managers to understand and anticipate how forests grow and respond to intentional manipulations and natural disturbances.

V. Theory

Unit I

Introduction-plant interactions and limitations of growth – mutualism and competition – the niche – limitations of growth – concept of growing space.

Unit II

Tree architecture and growth- general growth patterns – shoot development patterns, crown shapes, height growth, root growth, and tree development.

Unit III

Disturbances and stand development – impact of disturbances – major and minor-classification of disturbances – characteristics of disturbance agents. Stand structure and fire behaviour. Building resilience to disturbances.

Unit IV

Overview of stand development patterns – temporal and spatial patterns of tree invasion – stand initiation stage – stem exclusion stage – understorey reinitiation stage – old growth stage – multicohort stands – behaviour of component cohorts-development of multicohort stands – quantification of stand development – forest patterns over long times and large areas. Gap dynamics.

VI. Suggested Reading

Dagar JC, Tewari JC and Prasad V. 2018. *Agroforestry Anecdotal to Modern Science*. Springer.

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture*, 2nd edition, McGraw-Hill, 2nd ed.

Kimmins JP. 1997. *Forest Ecology*, Macmillan Publishing Company, New York Upper Saddle River, Prentice Hall.

Koop H. 1989. *Forest Dynamics Silvi-star: A Comprehensive Monitoring System*. Springer-verlag. New York.

Oliver CD and Larson BC. 1996. *Forest Stand Dynamics*. John Wiley & Sons, Inc. New York New York: John Wiley & Sons, Inc.

Smith DM. 1986. *The Practice of Silviculture*, 8th ed, Wiley, New York.

Waring RH and Schlesinger WH. 1985. *Forest ecosystems: Concepts and management*, Academic. Press, San Diego.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction – plant interactions and limitations of growth – mutualism and competition- the niche – limitations of growth – concept of growing space	03

Sr. No	Topic	No. of Lecture(s)
2.	Tree architecture and growth- general growth patterns – shoot development patterns, crown shapes, height growth, root growth, and tree development	03
3.	Disturbances and stand development – impact of disturbances – major and minor- classification of disturbances – characteristics of disturbance agents	03
4.	Stand structure and fire behaviour. Building resilience to disturbances	03
5.	Overview of stand development patterns – temporal and spatial patterns of tree invasion – stand initiation stage – stem exclusion stage – understorey reinitiation stage – old growth stage	02
6.	Multicohort stands – behaviour of component cohorts- development of multicohort stands – quantification of stand development – forest patterns over long times and large areas. Gap dynamics	03
	Total	17

I. Course Title : Productivity and Evaluation of Agroforestry Systems

II. Course Code : SAF 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with concepts in agroforestry systems productivity, managing the factors of production and sustained yield levels.

V. Theory

Unit I

Concept of crop productivity. Productivity potential in relation to light, water and nutrients.

Unit II

System complementarity, supplementarity, competitiveness, sustainability and management techniques. Tree root architecture, re-allocation of resources within the plant system.

Unit III

Biological yield and harvest index. Growth and yield functions. Land equivalent ratio. Water use efficiency, photosynthetic efficiency, radiation balance, canopy transmissivity, canopy management, plant geometry and crop yield.

Unit IV

Allelopathic effects. Strategies to improve the efficiency and productivity of different land use systems.

Unit V

Role of various financing agencies in agroforestry and critical evaluation of different credit systems with emphasis on agroforestry. Methodologies for evaluating agroforestry hedonic pricing, PES, LER and LEV.

Unit VI

Financial, economic and social accounting of agroforestry projects. Advances in marketing management of agroforestry products. Evaluating combined productivity and profitability of different agroforestry systems *vis-a-vis* other competitive agro-based systems. Tree insurance schemes.

VI. Practical

- Techniques for leaf area index;
- Photosynthetically active radiation ;
- Soil moisture and leaf water potential;
- Canopy density measurements;
- Exercises on developing alternative optimal agroforestry plans under perfect and imperfect knowledge situations;
- Socio-economic and financial evaluation of agroforestry projects.

VII. Suggested Reading

Alavalapati JRR and D Evan Mercer. 2004. *Valuing Agroforestry Systems: Methods and applications*, Kluwer Academic Publishers.

Kant Shashi and Janaki Alavalapati. 2014. *Handbook of Forest Resource Economics,* Publisher: Routledge.

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.

Sullivan, Gregory M, Susan M Hoke and Jefferson M Fox (editors). 1992. *Financial and Economic Analyses of Agroforestry Systems. Proceedings of a workshop held in Honolulu. Hawaii. USA. July* 1991. Paia, Ill: Nitrogen Fixing Tree Association.

Tejwani KG 1994. *Agroforestry in India* Oxford and IBH publishing Co. Pvt.Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concept of crop productivity. Productivity potential in relation to light, water and nutrients	02
2.	System complementarily, supplementarity, competitiveness, sustainability and management techniques	03
3.	Tree root architecture, reallocation of resources within the plant system	02
4.	Biological yield and harvest index. Growth and yield functions. Land equivalent ratio	03
5.	Water use efficiency, photosynthetic efficiency, radiation balance, canopy transmissivity, canopy management, plant geometry and crop yield	03
6.	Allelopathic effects. Strategies to improve the efficiency and productivity of different land use systems	03
7.	Role of various financing agencies in agroforestry and critical evaluation of different credit systems with emphasis on agroforestry	03
8.	Methodologies for evaluating agroforestry hedonic pricing, PES, LER and LEV	03
9.	Financial, economic and social accounting of agroforestry projects	04
10.	Advances in marketing management of agroforestry products	02
11.	Evaluating combined productivity and profitability of different agroforestry systems *vis-a- vis* other competitive agrobased systems	03
12.	Tree insurance schemes	01
	Total	17

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Techniques for leaf area index, photosynthetically active radiation, soil moisture and leaf water potential and canopy density measurements.	6
	Exercises on developing alternative optimal agroforestry plans under perfect and imperfect knowledge situations.	6
2.	Socio-economic and financial evaluation of agroforestry projects.	4
	Total	16

I. Course Title : Forest Stand Management Techniques

II. Course Code : SAF 605

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about advances in silviculture and silvicultural practice, effect of silvicultural practices on forest stand management and stand development, advances in coppice silviculture.

V. Theory

Unit I

Philosophy of silviculture – advance reproduction methods and their role in silviculture – Judging successful establishment; Analysis of active and passive site preparation – Silviculture with an ecosystem approach.

Unit II

Advances in silvicultural practices; tropical forest, sub-tropical forest and temperate forest.

Unit III

Analysis of different techniques of silviculture in forest stand management, Technique for early stand development; Analysis of thinning methods and its impact on wood yield and quality; Stand protection and health management. Silvicultural use of prescribed fire. Mechanization and role in silviculture.

Unit IV

Advance silviculture techniques for plantation forestry; Case studies of advance silviculture in India and abroad; mixed plantation forestry, Precision silviculture, silviculture of intensively managed plantations, silviculture for climate change mitigation. Sewage silviculture. Silviculture management for watershed and catchment areas. Silviculture for wildlife habitat improvement.

Unit V

Adjusting silviculture to meet industrial demands – silviculture in perspective – Problem solving procedure for silviculture – silviculture in retrospect.

VI. Practical

- Study of components of silvicultural system for sustained yield;
- Management strategies for even aged and uneven aged stands;
- Choice of site preparation methods, Plantation map, Quality planting stock, Planning for tree planting, Release cutting operation;

- Selection of thinning methods, Intensity of thinning;
- Analysis of site quality and biomass production for timber, pulp wood and fuel wood species;
- Problems in silviculture in tropical, subtropical plantation and their solutions.

VII. Suggested Reading

Brang P, Spathelf P, Larsen JB, Bauhus J, Bonèina A and Chauvin C. 2014. *Suitability of Close-To-Nature Silviculture for Adapting Temperate European Forests to Climate Change*. Forestry.

Colak AH, Rotherham ID and Calikoglu M. 2003. *Combining 'Naturalness Concepts' with Close-to-Nature Silviculture*. Forstwiss. Centralbl. 122, 421–431.

Cole DN and Yung L. (eds) 2010. *Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change*. Island Press.

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture*, 2nd edition, McGraw-Hill, 2nd ed.

Fettig CJ, Reid ML, Bentz BJ, Sevanto S, Spittlehouse DL and Wang T. 2013. *Changing climates, changing forests: A western North American perspective*.

Franklin JF. 1989. *Towards a New Forestry*. Am. For.

Holm-Nielsen LB, Nielsen IC and Balsev H. (eds.) 1989. *Tropical Forests*, Academic Press, London.

Pukkala T and Gadow KV. 2012. *Continuous Cover Forestry*. 2nd Edition Springer.

Sairll PS, Evans J, Auclair D and Flack J. 1997. *Plantation Silviculture in Europe*. Oxford University Press.

Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture*: Applied Forest Ecology. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Philosophy of silviculture – Advance reproduction methods and their role in silviculture -judging successful establishment	01
2.	Analysis of active and passive site preparation -silviculture with an ecosystem approach	01
3.	Advances in silvicultural practices; tropical forest, sub-tropical forest and temperate forest	02
4.	Analysis of different techniques of silviculture in forest stand management, technique for early stand development	01
5.	Analysis of thinning methods and its impact on wood yield and quality	01
6.	Stand protection and health management. Silvicultural use of prescribed fire	01
7.	Mechanization and role in Silviculture	01
8.	Advance silviculture techniques for plantation forestry; Case studies of advance silviculture in India and abroad	02
9.	Mixed plantation forestry, Precision Silviculture, Silviculture of intensively managed plantations	01
10.	Silviculture for climate change mitigation. Sewage silviculture	01
11.	Silviculture management for watershed and catchment areas	01
12.	Silviculture for wildlife habitat improvement	01
13.	Adjusting silviculture to meet industrial demands-silviculture in perspective – Problem solving procedure for silviculture -silviculture in retrospect	02
	Total	16

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Study of components of silvicultural system for sustained yield	3
2.	Management strategies for even aged and uneven aged stands	3
3.	Selection of thinning methods, Intensity of thinning	3
4.	Analysis of site quality and biomass production for timber, pulp wood and fuel wood species	3
5.	Problems in silviculture in tropical, subtropical plantation and their solutions	4
	Total	16

I. Course Title : Agroforestry for Ecosystem Services and Environmental Benefits

II. Course Code : SAF 606

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding of students about ecosystem services and environmental benefits and quantification of ecosystem services and their valuation.

V. Theory

Unit I

Multifunctionality of agroforestry. Major ecosystem services and environmental benefits and international conventions and charters on climate change (UNFCCC, UNCCD, agroforestry and climate change negotiations: CoP) and biodiversity conservation (CBD) – an overview.

Unit II

Agroforestry for carbon conservation, sequestration, substitution – role and potentials of various agroforestry systems. Estimates of carbon sequestration potential – measurement – prospects and problems. Factors affecting above and belowground carbon sequestration potential.

Unit III

Agroforestry for soil enrichment – mechanisms – litter and fine root dynamics, rhizo-deposition and other rhizosphere effects, symbiotic and free-living N_2 fixation, mycorrhizal associations. Soil and water conservation benefits.

Unit IV

Agroforestry for biodiversity conservation. Synergy with climate change mitigation. Landscape connectivity for wildlife, supporting the pollinators of plant species. Agroforestry for improved air and water quality. Non-point source pollution in Indian agro-ecosystems. Riparian buffers for alleviating agricultural non-point source pollution.

Unit V

Private profitability vs. social profitability – exclusion or inclusion of social benefits and costs and non-market values, or externalities. Theory of externalities, effect of environmental costs and benefits on the profitability of agroforestry practices.

Valuing environmental services. Profitability of timber-based agroforestry systems. Costs and benefits in agroforestry- valuation of inputs and outputs- environmental outputs.

VI. Suggested Reading

Alavalapati JRR, Shrestha RK, Stainback GA and Matta JR. 2004. *Agroforestry development: An environmental Economic Perspective. Agroforestry Systems.* **61**: 299–310.

Huxley P. 1999. *Tropical Agroforestry*. Blackwell.

IPCC. 2007. "*Climate Change 2007*". *Mitigation of Climate Change*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Jain SK and Singh P. 2000. *Economic Analysis of Industrial Agroforestry: Poplar (Populus deltoides) In Uttar Pradesh (India). Agroforestry Systems.* **49**: 255–273.

Jeffers JNR. 1978. *An Introduction to System Analysis with Ecological Application*. Edward Arnold.

Jose S. 2009. *Agroforestry for Ecosystem Services and Environmental Benefits: An Overview. Agroforestry Systems.* **76**: 1-10.

Lyngbaek AE, Muschler RG and Sinclair FL. 2001. *Productivity and Profitability of Multistrata Organic Versus Conventional Coffee Farms in Costa Rica. Agroforest. Syst.* **53**: 205–213.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer, Netherlands.

Schroth G and Sinclair F. 2003. *Tree Crops and Soil Fertility: Concepts and Research Methods*, CABI, Wallingford, UK.

Young A. 1997. *Agroforestry for Soil Management*. 2nd ed. CABI, Wallingofrd, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Multifunctionality of agroforestry	01
2.	Major ecosystem services and environmental benefits and international conventions and charters on climate change (UNFCCC, UNCCD, agroforestry and climate change negotiations: CoP) and biodiversity conservation (CBD) – an overview	04
3.	Agroforestry for carbon conservation, sequestration, substitution – role and potentials of various agroforestry systems	03
4.	Estimates of carbon sequestration potential – measurement – prospects and problems. Factors affecting above and belowground carbon sequestration potential	04
5.	Agroforestry for soil enrichment – mechanisms – litter and fine root dynamics, rhizo-deposition and other rhizosphere effects, symbiotic and free-living N_2 fixation, mycorrhizal associations. Soil and water conservation benefits	03
6.	Agroforestry for biodiversity conservation. Synergy with climate change mitigation. Landscape connectivity for wildlife, supporting the pollinators of plant species	03
7.	Agroforestry for improved air and water quality. Non-point source pollution in Indian agro-ecosystems. Riparian buffers for alleviating agricultural non-point source pollution	03
8.	Private profitability vs. social profitability – exclusion or inclusion of social benefits and costs and nonmarket values, or externalities	03
9.	Theory of externalities, effect of environmental costs and benefits on the profitability of agroforestry practices	02
10.	Valuing environmental services. Profitability of timber-based agroforestry systems	03

Sr. No	Topic	No. of Lecture(s)
11.	Costs and benefits in agroforestry- valuation of inputs and outputs- environmental outputs	03
	Total	32

I. Course Title : Plantation Forest Productivity
II. Course Code : SAF 607
III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about plantation forest productivity, dynamics of plantation growth, thinning and fertilization of plantation.

V. Theory

Unit I

Plantation forests – scope and perspectives, international and national scenario.

Unit II

Dynamics of plantation growth – site quality, stand density, dynamics of nutrient cycling, thinning, spacing and crown efficiency, nutrient pools and dynamics, biological factors in nutrient supply.

Unit III

Advances in site preparation techniques. Recent trends in fertilization and irrigation of plantations. Tending and cultural operations and plantation productivity – prospects of mechanization in tropical plantations. Reduced impact logging. Clonal forests, their management and productivity comparisons.

Unit IV

Productivity decline in plantation forests – second rotation decline – harvest related resource export – Modern silvicultural interventions.

Unit V

Project formulation, designing and appraisal of different kinds of plantations to meet specific objectives.

VI. Practical

- Plantation productivity analysis – growing stock and MAI assessment – stand density estimation;
- Fertilizers and fertilizer application in plantation;
- Response of plantation to irrigation;
- Productivity of clonal forestry;
- Modern tools in site preparation;
- Weed management methods;
- Management strategies for enhancing plantation productivity.

VII. Suggested Reading

Evans J and Turnbull JW. 2004. *Plantation Forestry in the Tropics: The Role, Silviculture and Use of Planted Forests for Industrial, Social, Environmental and Agroforestry Purposes.* OUP Oxford.

Evans J. 1982. *Plantation Forestry in the Tropics*. Clarendon Press.
Ford ED. 1984. *Nutrition of Plantation Forests*. Academic Press.
Krishnapillay B. 2000. *Silviculture and Management of teak plantations*. *Unasy*. 201. 51:14-21p.
Nambiar EKS, Cossalter C and Tiarks A. 1998. *Site Management and Productivity in Tropical Plantation Forests*. Workshop Proceedings, South Africa.
Sairll PS, Evans J, Auclair D and Flack J. 1997. *Plantation Silviculture in Europe*. Oxford University Press.
Smith DM. 1980. *The Practice of Silviculture*. 8th ed., John Wiley & Sons.
Suzuki K, Ishii K, Sakurai S and Sasaki S. 2006. *Plantation Forestry in the Tropics*. Springer Tokyo.
Zobel BJ, Wyk G and Stahlper P. 1987. *Growing Exotic Forests*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Plantation forests – scope and perspectives, international and national scenario	02
2.	Dynamics of plantation growth – site quality, stand density, dynamics of nutrient cycling, thinning, spacing and crown efficiency, nutrient pools and dynamics, biological factors in nutrient supply	03
3.	Advances in site preparation techniques. Recent trends in fertilization and irrigation of plantations	02
4.	Tending and cultural operations and plantation productivity – prospects of mechanization in tropical plantations	02
5.	Reduced impact logging	01
6.	Clonal forests, their management and productivity comparisons	02
7.	Productivity decline in plantation forests – second rotation decline – harvest related resource export – Modern silvicultural interventions	02
8.	Project formulation, designing and appraisal of different kinds of plantations to meet specific objectives	03
	Total	17
	Practical	
1.	Plantation productivity analysis – growing stock and MAI assessment – stand density estimation	3
2.	Fertilizers and fertilizer application in plantation, response of plantation to irrigation	3
3.	Productivity of clonal forestry, modern tools in site preparation	4
4.	Weed management methods	2
5.	Management strategies for enhancing plantation productivity	4
	Total	16

I. Course Title : Restoration Forestry

II. Course Code : SAF 608

III. Credit Hours : 1+0

IV. Aim of the course

To develop understanding of students about advances in restoration forestry and forest landscape restoration.

V. Theory

Unit I

Introduction to restoration forestry, scope and opportunities for forest restoration, Natural regeneration, forest and land degradation in the Asia-Pacific region. Forest restoration techniques, tools for prioritization, decision-making and monitoring to enhance restoration success, The Bonn Challenge, The Bonn Challenge in Asia, Africa and Latin America.

Unit II

Forest landscape restoration, environment for natural regeneration in forest and landscape restoration, economic and social aspects for successful integration of natural regeneration in forest landscape restoration, adaptive management for forested landscapes in transformation, measures to improve resilient and genetically diverse forests. Mangrove restoration.

Unit III

Case studies on successful forest landscape restoration.

VI. Suggested Reading

Beatty CR, Cox NA and Kuzee ME. 2018. *Biodiversity Guidelines for Forest Landscape Restoration Opportunities Assessments*. First edition. Gland, Switzerland: IUCN.

Blakesley D and Buckley P. 2016. *Grassland Management and Restoration*. Conservation handbooks. Pelagic Publishing. Food and Agriculture Organization of the United Nations.

Chokkalingam U, Shono K, Sarigumba MP, Durst PB and Leslie R. (eds). 2018. *Advancing the Role of Natural Regeneration in Large-Scale Forest and Landscape Restoration in the Asia-Pacific Region*. FAO and APFNet. Bangkok.

FAO. 2010. *Forests Beneath the Grass*. Proceedings of the Regional Workshop on Advancing The Application of Assisted Natural Regeneration for Effective Low-Cost Forest *Restoration*. Bangkok, FAO.

FAO/ RECOFTC. 2016. *Forest Landscape Restoration in Asia-Pacific Forests*. by Appanah, S. (ed.). Bangkok, Thailand.198p

Prober SM, Byrne M, McLean EH, Steane DA, Potts BM, Vaillancourt RE and Stock WD. 2015. *Climate-Adjusted Provenancing: A Strategy for Climate-Resilient Ecological Restoration*. Frontiers in Ecology and Evolution, 23 June.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction to restoration forestry, scope and opportunities for forest restoration	01
2.	Natural regeneration, forest and land degradation in the Asia Pacific region	02
3.	Forest restoration techniques	02
4.	Tools for prioritization, decision-making and monitoring to enhance restoration success, The Bonn Challenge, The Bonn Challenge in Asia, Africa and Latin America.	03
5.	Forest landscape restoration, environment for natural regeneration in forest and landscape restoration, economic and social aspects for successful integration of natural regeneration in forest landscape restoration, adaptive management for forested landscapes in transformation	03

Sr. No	Topic	No. of Lecture(s)
6.	Measures to improve resilient and genetically diverse forests	02
	Mangrove restoration	01
7.	Case studies on successful forest landscape restoration	03
	Total	17

I. Course Title : Regeneration Silviculture

II. Course Code : SAF 609

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about advances in regeneration silviculture, forest continuum, advancement in artificial regeneration.

V. Theory

Unit I

Planning for regeneration, setting the objectives for regeneration, principles and methodologies of forest regeneration, ecological basis of natural regeneration techniques.

Unit II

Basic Concepts in forest regeneration, importance of different combinations of light, moisture, soil in determining success or failure of regeneration. Factors affecting natural and artificial regeneration- kinds, extent and quality of sites.

Unit III

Techniques of canopy manipulation and forest continuum in regular and irregular forests canopy, light pattern and regeneration establishment. Regeneration survey and methodology. Major silvicultural systems of tropical and temperate parts of the world. Continuous cover forestry. Advances in coppice silviculture. Silviculture in a changing world.

Unit IV

Advances in artificial regeneration techniques, advances in vegetative propagation techniques like mini and micro-cutting techniques, production technology for quality planting stock, carbon enrichment techniques for production of quality planting stock. Integrated nutrient management in nursery production. Plant quality assessment tools. Nursery production system of important timber and Non-Timber Forest Products, NTFP's yielding species in the region.

Unit V

Sustainable site establishment practices, Novel tree establishment techniques. Regeneration problems of important conifers and broad leaved species-case studies.

VI. Practical

- Factors affecting natural and artificial regeneration;
- Advances in vegetative propagation techniques like mini and micro-cutting techniques;
- Production technology for quality planting stock;

- Carbon enrichment techniques for production of quality planting stock;
- Integrated nutrient management in nursery production;
- Novel tree establishment techniques. Modern approaches in containerized seedling production.

VII. Suggested Reading

Colak AH, Rotherham ID and Calikoglu M. 2003. *Combining 'naturalness concepts' with close-to-nature silviculture*. Forstwiss. Centralbl. 122, 421–431.

Sairll PS, Evans J, Auclair D and Flack J. 1997. *Plantation Silviculture in Europe*. Oxford University Press.

Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture*: Applied Forest Ecology. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Planning for regeneration, setting the objectives for regeneration, principles and methodologies of forest regeneration, ecological basis of natural regeneration techniques	03
2.	Basic concepts in forest regeneration, importance of different combinations of light, moisture, soil in determining success or failure of regeneration	03
3.	Factors affecting natural and artificial regeneration- kinds, extent and quality of sites	02
4.	Techniques of canopy manipulation and forest continuum in regular and irregular forests canopy, light pattern and regeneration establishment	03
5.	Regeneration survey and methodology	02
6.	Major Silvicultural systems of tropical and temperate parts of the world. Continuous cover forestry	02
7.	Advances in coppice Silviculture. Silviculture in a changing world	02
8.	Advances in artificial regeneration techniques, advances in vegetative propagation techniques like mini and micro-cutting techniques, production technology for quality planting stock, carbon enrichment	02
9.	Techniques for production of quality planting stock. Integrated nutrient management in nursery production	02
10.	Plant quality assessment tools	04
11.	Nursery production system of important timber and Non-Timber Forest Products, NTFP's yielding species in the region	02
12.	Sustainable site establishment practices, Novel tree establishment techniques	02
13.	Regeneration problems of important conifers and broad leaved species-case studies	03
	Total	32
	Practical	
1.	Factors affecting natural and artificial regeneration,	2
2.	Advances in vegetative propagation techniques like mini and micro-cutting techniques,	3

Sr. No	Topic	No. of Practical(s)
3.	Production technology for quality planting stock,	3
4.	Carbon enrichment techniques for production of quality planting stock,	2
5.	Integrated nutrient management in nursery production.	2
6.	Novel tree establishment techniques.	2
7.	Modern approaches in containerized seedling production.	2
	Total	16

I. Course Title : Forest Soil Management

II. Course Code : SAF 610

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about advances in forest soil management, forest soils and vegetation management.

V. Theory

Unit I

Forest soils and vegetation development. Physical properties of forest soils. Forest soil classification. Soils of the major forest biomes – soils under different forest types – tropical rainforest soils – moist deciduous forests – dry deciduous. Soils and plant roots.

Unit II

Soil chemistry and nutrient uptake. Soil organic matter – maintenance and buildup. Biology of forest soils – role of microorganisms in ameliorating soils; N and C cycles. Forest biogeochemistry. Micorrhizae. Role of forests in conserving soils.

Unit III

Nutrient transformation in soils. Nitrogen fixation in tropical forest plantations: N_2 fixation process, species, rates of N_2 fixation, factors influencing N_2 fixation; nutrient cycling – comparison of plantation productivity – case studies. Nutrition management: nutrient limitations, fertilization. Soil carbon sequestration – processes and mechanisms.

Unit IV

Soil management for reforestation of salt affected soils, acid soils, coastal soils. Effects of fire on soils and their properties.

Unit V

Management of long term soil productivity – soil compaction and erosion – harvest removal and nutrient budgeting – harvest effect on water quality – strategies for future management.

VI. Practical

- Nutrient budgeting for different plantation systems;
- Quantification of physical and chemical soil constraints in plantation and agroforestry systems;
- Evolving new strategies for soil and site development.

VII. Suggested Reading

Binkley D and R. Fisher. 2012. *Ecology and Management of Forest Soils* (4^{th} Edition), John Wiley & Sons Singapore Pte. Ltd., Singapore.

Fisher RF, Binkley D and Pritchett WL. 2000. *Ecology and Management of Forest Soils*. 3^{rd} Ed.John Wiley & Sons Inc., New York.

Havlin *et al*. 2014. *Soil Fertility and Fertilizers: An Introduction to Nutrient Management* (8^{th} Edition), PHI Learning Pvt. Ltd., Delhi.

Khan TO. 2013 *Forest Soils: Properties and Management*, Springer International Publishing, Switzerland.

Pritchett and Fisher RF 1987. *Properties and Management of Forest Soils*. John Wiley, New York.

Reddy MV. 2001. *Management of Tropical Plantation Forests and Their Soil Litter System-Litter, Biota and Soil Nutrient Dynamics*. Science Publishers, U.S.

Sadanandan Nambiar EK and Grown AG. (Eds.). 1997. *Management of Soil, Nutrients and Water in Tropical Plantation Forests*. ACIAR, CSIR and CIFOR, Australia.

Schulte A and Ruhiyat D. 1998. *Soils of Tropical Forest Ecosystems*: *Characteristics, Ecology, and Management*. Springer Verlag,Berlin, New York.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest soils and vegetation development	01
2.	Physical properties of forest soils, Forest soil classification	01
3.	Soils of the major forest biomes – soils under different forest types – tropical rainforest soils – moist deciduous forests – dry deciduous	01
4.	Soils and plant roots, Soil chemistry and nutrient uptake	01
5.	Soil organic matter – maintenance and buildup	01
6.	Biology of forest soils – role of microorganisms in ameliorating soils; N and C cycles	01
7.	Forest biogeochemistry. Micorrhizae. Role of forests in conserving soils	01
8.	Nutrient transformation in soils	01
9.	Nitrogen fixation in tropical forest plantations: N_2 fixation process, species, rates of N fixation, factors influencing N_2 fixation	01
10.	Nutrient cycling – comparison of plantation productivity – case studies	01
11.	Nutrition management: nutrient limitations, fertilization	01
12.	Soil carbon sequestration – processes and mechanisms	01
13.	Soil management for reforestation of salt affected soils, acid soils, coastal soils	01
14.	Effects of fire on soilsand their properties	01
15.	Management of long term soil productivity – soil compaction and erosion – harvest removal and nutrient budgeting	01
16.	Harvest effect on water quality – strategies for future management	01
	Total	16
	Practical	
1.	Nutrient budgeting for different plantation systems,	5
2.	Quantification of physical and chemical soil constraints in plantation and agroforestry systems,	6
3.	Evolving new strategies for soil and site development	5
	Total	16

I. Course Title : Agroforestry For Sustainable Agriculture

II. Course Code : SAF 611

III. Credit Hours : 1+0

Aim of the course

To develop understanding of students about the role of agroforestry in sustainable agriculture, current agricultural scenario, role of trees in enhancing productivity of agricultural land on sustainable basis.

IV. Theory

Unit I

Current Agricultural scenario in India. Sustainable agriculture: issues and challenges. Land use changes- agroforestry: an opportunity for sustainability and rainfed agriculture.

Unit II

Agroforestry options for sustainable agriculture: integration of perennial components in agriculture. Role of trees in enhancing the productivity of traditional agriculture. Strategies on integration of trees suitable for different cropping systems for important agro-ecological regions. Tree management for productivity optimization.

Unit III

Agroforestry for different land holdings. Integrated farming systems. Agroforestry strategies for short term and long term returns.

Unit IV

Processing, value addition and marketing of agroforestry products.

V. Suggested Reading

Chin K Ong, Colin Black and Julia Wilson. 2015. *Tree-Crop Interactions*, 2nd Edition: Agroforestry in a Changing Climate. CAB International ICRAF.

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer, Netherlands.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*.

Schroth G and Sinclair F. 2003. *Tree Crops and Soil Fertility: Concepts and Research Methods*. CABI, Wallingford, UK.

Snelder DJ and Lasco RD. 2008. *Smallholder Tree Growing for Rural Development and Environmental Services*. Springer Science, Amsterdam.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Current Agricultural scenario in India. Sustainable agriculture: Issues and challenges and land use changes	02
2.	Agroforestry: An opportunity for sustainability and rainfed agriculture	02
3.	Agroforestry options for sustainable agriculture: Integration perennial components in agriculture	02
4.	Role of trees in enhancing the productivity of traditional agriculture	01
5.	Strategies on integration of trees suitable for different cropping systems for important agro-ecological regions. Tree management for productivity optimization	03

Sr. No	Topic	No. of Practical(s)
6.	Agroforestry for different land holdings. Integrated farming systems	02
7.	Agroforestry strategies for short term and long term returns	02
8.	Processing, value addition and marketing of agroforestry products	03
	Total	17

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry

– Forest Biology and Tree Improvement

Course Title with Credit Load M.Sc. (Forestry) in Forest Biology and Tree Improvement

Course Code		Course Title	Credit Hours
		Major Courses	
FBT 501 *	I	Applied Forest Tree Improvement	2+1
FBT 502	II	Forest Ecology and Biodiversity Management	2+1
FBT 503*	I	Breeding Methods in Forest Trees	2+1
FBT 504	II	Reproductive Biology of Forest Trees	2+1
FBT 505	I	Tree Seed Orchards	2+1
FBT 506*	II	Quantitative Genetics in Forest Tree Breeding	2+1
FBT 507	I	Forest Genetic Diversity and Conservation	3+0
FBT 508*	II	Biotechnology in Forestry	2+1
FBT 509	I	Clonal Forestry	2+0
FBT 510	II	Forest Ecophysiology	2+1
FBT 511	I	Physiology of Woody Plants	2+1
FBT 512	II	Breeding for Insect Pest and Disease Resistance in Trees	2+1
FBT 513	I	Tree Seed Technology	2+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Products and Utilization	08
		Supporting Courses	
FOR 511*	I	General Statistical Methods and Computer Applications	2+1
		Any other course relavent to MSc research problem	03
		Common Courses	
		Library and Information Services	1+0
		Technical Writing and Communications Skills	1+0
		Intellectual Property and its management in Agriculture	1+0
		Basic Concepts in Laboratory Techniques	1+0
		Agricultural Research, Research Ethics and Rural Development Programmes	1+0
FBT 591*	I/ II	Master's Seminar	1+0
		ii) Thesis Research	
FBT 599		Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Forest Biology and Tree Improvement

I. Course Title : Applied Forest Tree Improvement

II. Course Code : FBT 501

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students about general principles of tree breeding with examples of important trees.

V. Theory

Unit I

General concept of forest tree breeding, tree improvement and forest genetics.

Unit II

Reproduction in forest trees, dimorphism, pollination mechanism. Pollen dispersal, pollinators. Attractants for pollinators.

Unit III

Variation in trees, importance and its causes. Natural variations as a basis for tree improvement. Geographic variations – Ecotypes, clines, races and land races.

Unit IV

Selective breeding methods- mass, family, within family, family plus within family. Plus tree selection for wood quality, disease resistance and agroforestry objectives. Selection strategies and choice of breeding methods and progress in selective breeding in forest trees.

Unit V

Seed orchards – type, functions and importance,Genetic testing- mating designs and field designs. Progeny and clone testing estimating genetic parameters and genetic gain, clonal and breeding values. Average performance of half sibs and full-sibs. GxE interaction in trees.

Unit VI

Heterosis breeding: inbreeding and hybrid vigour. Manifestation and fixation of heterosis. Species and racial hybridization. Indian examples – teak, shisham, eucalypts, acacias, poplar, etc.

Unit VII

Polyploidy, aneuploidy and haploidy in soft and hard wood species. Induction of polyploidy.

Unit VIII

Elements of biotechnology in tree improvement.

VI. Practical

- Floral biology, modes of reproduction and modes of pollination in forest trees;

- Estimating pollen viability. Controlled pollination and pollen handling;
- Manipulation of flowering through hormones;
- Identification of ecotypes, races and land-races in natural forest;
- Visit to species, provenance and progeny trials;
- Selection of superior phenotypes;
- Marking of candidate trees, plus trees and elite trees;
- Visit to seed orchards;
- Comparison of parents and their putative hybrids;
- Induction of polyploidy through colchicine treatment;
- *In-vitro* propagation, study of molecular markers.

VII. Suggested Reading

Dutta M and Saini GC. 2009. *Advances in Forestry Research in India*, Vol. XXX. Forest Tree Improvement and Seed Technology. International Book Distributors.

Finkeldey R and Hattemer HH. 2006. *Tropical Forest Genetics*. Springer.

Mandal AK and Gibson GL. (Eds). 1997. *Forest Genetics and Tree Breeding*. CBS.

Sedgley M and Griffin AR. 1989. *Sexual Reproduction of Tree Crops*. Academic Press.

Surendran C, Sehgal RN and Paramathma M. 2003. *Text Book of Forest Tree Breeding*. ICAR.

White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI, UK.

Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.

Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley and Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	General concept of forest tree breeding, tree improvement and forest genetics	1
2.	Reproduction in forest trees – dimorphism, pollination mechanism, pollen dispersal, pollinators, attractants for pollinator	5
3.	Variation in trees importance and its causes. Natural variation as a basis for tree improvement. Geographic variations – ecotypes, clines, races and land races	2
4.	Plus tree selection for wood quality, disease resistance and agroforestry objectives	2
5.	Selective breeding methods- mass, family, within family, family plus within family	2
6.	Selection strategies and choice of breeding methods and progress in selective breeding in forest trees	2
7.	Progeny and clone testing. Estimating genetic parameters and genetic gain Clonal and breeding values	2
8.	Seed orchards – type, functions and importance, Genetic testing-mating designs and field designs	2
9.	Average performance of half sibs and full sibs, GxE interaction in trees	2
10.	Heterosis breeding: inbreeding and hybrid vigour Manifestation and fixation of heterosis. Species and racial hybridization. Indian examples – teak, sal, shisham, eucalypts, acacias, pines and poplars	3
11.	Polyploidy, aneuploidy and haploidy in soft and hard wood species. Induction of polyploidy	2
12.	Mutation breeding	2
13.	Elements of Biotechnology in tree improvement	5
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Floral biology, modes of reproduction and modes of pollination in forest trees	2
2.	Estimating pollen viability. Controlled pollination and pollen handling	2
3.	Manipulation of flowering through hormones	2
4.	Identification of ecotypes, races, and land-races in natural forest	1
5.	Visit to species, provenance and progeny trials	1
6.	Selection of superior phenotypes. Marking of candidate trees, plus trees and elite trees	1
7.	Visit to seed orchards	1
8.	Comparison of parents and their putative hybrids	1
9.	Induction of polyploidy through colchicine treatment	1
10.	*In-vitro* propagation	2
11.	Study of molecular markers	2
	Total	16

I. Course Title : Forest Ecology And Biodiversity Management

II. Course Code : FBT502

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding among students about ecological aspects of forest, conservation of forest resources and biodiversity, consequences of depleting biodiversity and concept of sustainability.

V. Theory

Unit I

Hierarchy issues in ecology and ecosystem.Advanced topics in forest ecology including forest population, forest community dynamics, forest community structure and analysis, forest productivity, ecology of forest landscapes spatial heterogeneity and ecological succession.

Unit II

Conservation of natural resources (hotspot areas, wildlife sanctuaries, national parks, biosphere reserve). Climate change, Global warming and forests. Green house effect and its consequences. Ozone depletion. Conservation laws and acts. Forest genetics resources of India: timber and non timber species. Survey exploration and sampling strategies Phytogeography and vegetation types of India.

Unit III

Documentation and evaluation of forest genetical resources (FGR), *in situ* and *ex situ* conservation of gene resources. Phytodiversity and its significance to sustainable use. Handling and storage of FGR. Intellectual property rights. Quarantine laws and FGR exchange.

VI. Practical

- Study of forest community structure and its successional status;
- Estimation of productivity of forest ecosystem;

- Study tours to different regions of the state to study forest vegetation;
- Collection and preservation of specimen, Methods of vegetation analysis;
- Measurement of biomass and productivity;
- Quantification of litter production and decomposition;
- Visit to national parks, wildlife sanctuaries. Botanical gardens and arboreta.

VII. Suggested Reading

Avery TE and Burkharts H. 2001. *Forest Measurements*. McGraw-Hill Education.

Barnes BV, Zak DR, Denton SR and Spurrs SH. 1998. *Forest Ecology*. Wiley.

Jha BC, Pandey BN, Jaiswal K, Katiha PK, Pandey PN and Sharma AP. 2012. *Biodiversity: Issues Threats and Conservation*. Narendra Publishing House, Delhi.

Kumar Biju. 2013. *Biodiversity and Taxonomy*. Narendra Publishing House, Delhi.

Larocque GR. 2016. *Ecological Forest Management Handbook (Applied Ecology and Environmental Management*). Taylor & Francis.

Mahato B, Pandy BN, Singh LB, Panday PN and Singh RK. 2010. *Text Book of Environmental Pollution*. Narendra Publishing House, Delhi.

Mikusiñski G, Roberge JM and Fuller R. 2018. *Ecology and Conservation of Forest Birds* (*Ecology, Biodiversity and Conservation*). Cambridge University Press.

Pandey PN. 2009. *Biodiversity and Environment Ecology*. Narendra Publishing House, Delhi.

Perry DA, Oren R and Hart SC. 2008. *Forest Ecosystems*. 2nd ed. Baltimore: Johns Hopkins University Press.

Young RA and Giese RL. 2003. *Introduction to Forest Ecosystem Science and Management*. Wiley.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Hierarchy issues in ecology and ecosystem	3
2.	Advanced topics in forest ecology including forest population, forest community dynamics, forest community structure and analysis	3
3.	Forest productivity, ecology of forest landscapes spatial heterogeneity and ecological succession	3
4.	Conservation of natural resources (hotspot areas, wildlife sanctuaries, national parks, biosphere reserve)	3
5.	Climate change, global warming and forests. Green house effect and its consequences	2
6.	Ozone depletion. Conservation laws and acts	2
7.	Forest genetics resources of India: timber and non timber species	3
8.	Survey exploration and sampling strategies Phytogeography and vegetation types of India	2
9.	Documentation and evaluation of forests genetical resources (FGR)	2
10.	*In situ* and *ex situ* conservation of gene resources	3
11.	Phytodiversity and its significance to sustainable use. Handling and storage of FGR	3
12.	Intellectual property rights	2
13.	Quarantine laws and FGR exchange	2
	Total	33
	Practical	
1.	Study of forest community structure and its successional status	2

Sr. No.	Topic	No. of Practical(s)
2.	Estimation of productivity of forest ecosystem	2
3.	Study tours to different regions of the state to study forest vegetation	2
4.	Collection and preservation of specimen	2
5.	Methods of vegetation analysis	2
6.	Measurement of biomass and productivity	2
7.	Quantification of litter production and decomposition	2
8.	Visit to national parks, wildlife sanctuaries, botanical gardens and arboreta	2
	Total	16

I. Course Title : Breeding Methods in Forest Trees

II. Course Code : FBT 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students about the concepts of sub-selection, population structure for breeding and production, genetic testing and making designs.

V. Theory

Unit I

Genetic constitution of tree populations, half-sib, full-sib family in trees. Hardy-Weinberg equilibrium, changes in gene frequency through selection, migration, mutation and population sizes.

Unit II

Long-term and short-term breeding populations. Selective breeding methods- mass, family, within family, family plus within family. Grading system of plus trees in natural stands and plantations selection index, regression systems, mother tree selection and subjective evaluation. Selection for different traits.

Unit III

Genetic testing programmes – mating designs, complete designs – nested designs, factorial, single pair mating, full diallel, half diallel and partial diallel, incomplete pedigree designs – open pollinated mating and polycross mating. Improvement through progeny testing.

Unit IV

Experimental designs in genetic testing. Breeding methods for wood quality, diseases and pest resistance, drought and salt resistance. Testing procedures for genetic advancement. Marker assisted selection.

Unit V

Tree improvement case histories.

VI. Practical

- Half-sib, full-sib family in trees;
- Grading system of plus trees in natural stands;
- Mating designs, complete pedigree designs – nested designs, factorial, single pair

mating, full diallel, half diallel and partial diallel, incomplete pedigree designs – open pollinated mating and polycross mating;
- Selection for biotic and abiotic stresses.

VII. Suggested Reading

Acquaah G. 2012. *Principal of Plant Genetics and Breeding*. John Wiley & Sons, Ltd, UK.
Falconer DS and Mackay TFC. 1995. *Introduction to Quantitative Genetics*. 4th edition. Longman, Essex
Mandal AK and Gibson GL. 2002. *Forest Genetics and Tree breeding*. CBS Publishers
Namkoong G, Kang HC and Brouard JS 1988. *Tree breeding: Principles and Strategies*. Springer Verlag, New York.
Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.
White TL and Hodge GR 1989. *Predicting Breeding Values with Applications in Forest Tree Improvement*. Kluwer Academic Publishers, Boston.
White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI
Wright JW. 1962. *Genetics of Forest Tree Improvement*. Academic Press.
Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.
Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley and Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction	1
2.	Hardy-Weinberg equilibrium, changes in gene frequency through selection, migration, mutation and population sizes	5
3.	Grading system of plus trees in natural stands and plantations regression systems, mother tree selection, subjective evaluation	2
4.	Selective breeding methods- mass, family, within family, family plus within family	2
5.	Long-term and short-term breeding populations	4
6.	Genetic testing programmes – mating designs, Incomplete pedigree designs – open pollinated mating and polycross mating	2
7.	Complete designs (nested designs, factorial, single pair mating, full diallel, half diallel and partial diallel)	2
8.	Experimental designs in genetic testing	2
9.	Marker assisted selection	2
10	Breeding methods for disease resistance	2
11.	Breeding methods for water stress	2
12.	Breeding methods for pest resistance	2
13.	Tree improvement case histories. Breeding strategy for pines and eucalyptus	4
	Total	32
	Practical	
1.	Grading system of plus trees in natural stands, plantation	1
2.	Mating designs	1
3.	Complete designs – nested designs	2
4.	Factorial	4
5.	Single pair mating	2
6.	Full diallel, Half diallel and Partial diallel	4

Sr. No.	Topic	No. of Lecture(s)
7.	Incomplete pedigree designs – open pollinated mating and polycross mating	2
	Total	**16**

I. Course Title : Reproductive Biology of Forest Trees

II. Course Code : FBT 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart the knowledge of reproduction in forest tree species to the students and to make them understand the mechanism of breeding and sex expression.

V. Theory

Unit I

Importance and application of reproductive biology in tree breeding. Crop characteristics-growth and development (both vegetative and reproductive).

Unit II

Floral diversity and pollination. Flower types pollination syndromes and their evolution. Plant – pollinator systems. Diversity of pollination syndromes in selected plant families. Modes of reproduction-sexual, asexual and vegetative and their breeding systems and sex expression, monoecy, dioecy and its evolution.

Unit III

Environmental effects on sex expression. Floral biology. Modes of pollination self and out-crossing. Floral attractants and rewards biology of floral and extrafloral nectaries examples of plant insect interactions involving pollination. Floral characteristics of the main pollination syndromes.

Unit IV

Environmental effects on sex expression. Floral biology initiation and development. Modes of pollination self and out-crossing.

Unit V

Fertilization in hardwood and softwood species. Seed dispersal and gene flow.

VI. Practical

- Sex expression in forest trees;
- Out crossing mechanisms in forest trees;
- Measurement of pollen flow in wind-pollinated and insect-pollinated species;
- Pollen viability and fertility;
- Seed dispersal mechanism.

VII. Suggested Reading

Almeida OJG, Cota K Sánchez JH and Paoli AAS. 2013. *The systematic significance of floral morphology, nectaries and sugar nectar concentration in epiphytic cacti of tribes Hylocereeae and Rhipsalideae* (Cactaceae). Persp. Plant Ecol. Evol. Syst. 15: 255-268.

Barrett SCH. 2006. *Ecology and Evolution of Flowers* [electronic resource]. (Eds.) L.D. Harder SCH. Barrett. Oxford Univ. Press, New York, U.S.A.

Bawa KS and Hadley M. 1990. *Reproductive Ecology of Tropical Forest Plants*. UNESCO Man and Biosphere Series.

Briggs and Walters SM. 1984. *Plant Variation and Evolution*.

Cláudia Inês da Silva and Helena Maura Torezan Silingardi. 2006. *Reproductive Biology of Tropical Plants* – International Commission On Tropical Biology and Natural Resources. Encyclopedia of Life Support Systems (EOLSS)

FAO. 1985. *Forest Tree Improvement,* FAO Publication.

Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.

Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.

Sedgley and Griffin. 1989. *Sexual Reproduction of Tree Crops*.

Spencer C H, Barrett, Robert I, Colautti and Christopher G Eckert. 2007. *Plant Reproductive Systems and Evolution during Biological Invasion*. Wiley Online Library. (https://doi.org/10.1111/ j.1365-294X.2007.03503.x).

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Importance and application of reproductive biology in tree breeding	1
2.	Crop characteristics-growth and development (both vegetative and reproduction)	4
3.	Floral diversity and pollination. Flower types: Pollination syndromes and their evolution; Plant – pollinator systems, Diversity of pollination syndromes in selected plant families	4
4.	Modes of reproduction: sexual, asexual and vegetative and their breeding systems and sex expression, monoecy, dioecy and its evolution	5
5.	Environmental effects on sex expression	3
6.	Floral biology. Initiation and development. Modes of pollination; self and out-crossing	3
7.	Floral attractants and rewards; Biology of floral and extra floral nectarines; Examples of plant insect interactions involving pollination. Floral characteristics of the main pollination syndromes	5
8.	Fertilization in hardwood and softwood species	3
9.	Seed dispersal and gene flow	4
	Total	32
	Practical	
1.	Sex expression in forest trees	2
2.	Out crossing mechanisms in forest trees	3
3.	Measurement of pollen flow in wind-pollinated and insect-pollinated species	3
4.	Pollen viability and fertility	2
5.	Seed dispersal mechanism	3
6.	Study of reproductive biology of Eucalyptus, Pine, Shishum, etc.	3
	Total	16

I. Course Title : Tree Seed Orchards

II. Course Code : FBT 505

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding among students about tree seed orchards.

V. Theory

Unit I

Importance of genetically improved seed in plantation forestry. Status of seed production among major plantation species. Short term supply of superior seed.

Unit II

Selection and delineation of seed stands, seed production areas, seed zones, seed ecological zones.

Unit III

Seed orchard: need, evolving seed orchards, containerized seed, hybrid and research seed orchards; first, second and advanced generation seed orchards. Seed orchard genetics: random mating, gamete exchange and parental balance. Estimation of genetic parameters from seed orchard data. Ortet age and its effect on seed production.

Unit IV

Importance of progeny testing. Establishment of seed orchards, selection and preparation of orchard site, isolation, orchard size, and designs. Seed orchard management: rouging, silvicultural practices to increase seed yield.

Unit V

Pest and disease management. Seed collection and record keeping, seed orchard registration and documentation. Importance of seed orchards in gene conservation.

VI. Practical

- Visits and study of seed orchard designs;
- Estimation of overlap in flowering among genotypes;
- Study of inter and intra-clonal variation in floral, seed characters;
- Effect of girdling on flowering;
- Plant growth regulator application for flower induction;
- Pollen viability/ fertility;
- Assessment of pollen dispersa;.
- Supplemental mass-pollination;
- Effects of foliar application of fertilizers on seed set;
- Estimation of genetic parameters for a few traits;
- Estimation of parental balance.

VII. Suggested Reading

Faulkner R. 1975. *Seed Orchard* Forestry. Commission Bull. No. 34.
Fins L, Friedman ST and Brotschol JV. 1992. *Handbook of Quantitative Forest Genetics*. Kluwer.
Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.
Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.
Nanson A. 2004. *Genetics of Forest Tree Breeding*. Agronomic Press

Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.
Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.
Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Importance of genetically improved seed in plantation forestry	1
2.	Status of seed production among major plantation species	2
3.	Short term supply of superior seed	1
4.	Selection and delineation of seed stands, seed production areas, seed zones, seed ecological zones	4
5.	Seed orchard: need, evolving seed orchards, containerized seed, hybrid and research seed orchards; first, second and advanced generation seed orchard. Seed orchard genetics: random mating, gamete exchange and parental balance	6
6.	Estimation of genetic parameters from seed orchard data. Ortet age and its effect on seed production	3
7.	Importance of progeny testing	2
8.	Establishment of seed orchards, selection and preparation of orchard site, isolation, orchard size, and designs	4
9.	Seed orchard management: rouging, silvicultural practices to increase seed yield. Supplemented mass pollination. Pest and disease management. Seed collection and record keeping, seed orchard registration and documentation	5
10.	Importance of seed orchards in gene conservation	2
12.	Status of seed production among major plantation species	2
	Total	32
	Practical	
1.	Visits and study of seed orchard designs.	2
2.	Estimation of overlap in flowering among genotypes.	2
3.	Study of inter and intra-clonal variation in floral and seed characters.	2
4.	Effect of girdling on flowering.	2
5.	Plant growth regulator application for flower induction.	2
6.	Pollen viability/ fertility.	1
7.	Assessment of pollen dispersal.	2
8.	Supplemental mass-pollination.	2
9.	Effects of foliar application of fertilizers on seed set.	1
	Total	16

I. Course Title : Quantitative Genetics in Forest Tree Breeding

II. Course Code : FBT 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowlewge in the field of biometry as applied to breeding, population, provinces and making experiment in forest genetics and tree breeding.

V. Theory

Unit I

Historical aspects of quantitative genetics. Inheritance of continuously varying characters, Genetic variance and its partitioning, models of gene action. Multiple factor hypothesis (Nilsson-Ehle (1908) and East (1915) experiments.

Unit II

Mating systems, population structure in random mating. Hardy Weinberg law, Effect of selection, mutation, migration, genetic drift; on genes and genotypic frequency.

Unit III

Inbreeding, effects of inbreeding in various populations. Heterosis, causes of heterosis and its utility in various plants.

Unit IV

Significance and estimation of genetic variance components. Heritability, its estimation by various methods and significance.

Unit V

Natural selection, fundamental theorem of natural selection (Fisher 1930). Selection responses. Correlation and its utility. Partitioning of correlation into direct and indirect effects.

Unit VI

Mating design, combining ability, general and specific combining ability and methods of its estimation.

Unit VII

Genotypic x environment interaction, its significance. Various procedures for the estimation of genotypic x environment interaction.

VI. Practical

- Exercise on polygenic inheritance;
- Proof that quantitative characters are inherited in Mendelian fashion;
- Estimation of genotypic and phenotypic variance in an experiment, estimation of additive and dominance components of variance through various procedures;
- Mating designs and estimation of components of genetic variance;
- Proof of population genetics law;
- Exercise on calculation of gene and genotypic frequency;
- Estimation of heterosis, estimation of heritability (broad sense and narrow sense) by various methods;
- Genotypic and phenotypic correlation coefficients, partitioning of correlation into direct and indirect effects;
- Estimation of general combining ability and specific combining ability;
- Estimation of genotypic x environment interaction.

VII. Suggested Reading

Acquaah G. 2012. *Principal of Plant Genetics and Breeding*. John Wiley & Sons, Ltd, UK. Kute N and Shinde G. 2016. *Principles of Biometrical Genetics*. Daya publishing.

Fins Lauren, Friedman ST and Brotschol JV. (Eds.). 1992. *Handbook of Quantitative Forest Genetics*. Springer, Netherlands.
Gene Namkoong. 1979. *Introduction to Quantitative Genetics In Forestry. Technical Bulletin No. 1588*. Forest Service United States Department of Agriculture Washington,D. C.
Singh RK and Chaudhary BD. 1985. *Biometrical Methods in Quantitative genetical Analysis*. Kalyani Publishers, New Delhi.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Historical aspects of quantitative genetics	1
2.	Genetic variance and its partitioning, models of gene action	3
3.	Inheritance of continuously varying characters	2
4.	Multiple factor hypothesis (Nilsson-Ehle (1908) and East (1915) experiments	2
5.	Mating systems, population structure in random mating	3
6.	Hardy Weinberg law, effect of selection, mutation, migration, genetic drift: on genes and genotypic frequency	3
7.	Inbreeding, effects of inbreeding in various populations	2
8.	Heterosis, causes of heterosis and its utility in various plants	2
9.	Significance and estimation of genetic variance components. Heritability, its estimation by various methods and significance	2
10.	Natural selection, fundamental theorem of natural selection (Fisher 1930)	2
11	Selection responses. Correlation and its utility. Partitioning of correlation into direct and indirect effects	2
12.	Mating designs	3
13.	Combining ability, general and specific combining ability and methods of its estimation	2
14.	Genotypic × environment interaction, its significance. Various procedures for the estimation of genotypic x environment interaction	3
	Total	32

Sr. No.	Topic	No. of Lecture (s)
	Practical	
1.	Polygenic inheritance	2
2.	Proof that quantitative characters are inherited in Mendelian fashion	1
3.	Estimation of genotypic and phenotypic variance in an experiment through various procedures	2
4.	Mating designs and estimation of additive and dominance components of variance components of genetic variance	3
5.	Proof of population genetics law	1
6.	Calculation of gene and genotypic frequency	1
7	Estimation of heterosis, estimation of heritability (broad sense and narrow sense) by various methods	2
8.	Genotypic and phenotypic correlation coefficients, partitioning of correlation into direct and indirect effects	1
9.	Estimation of general combining ability and specific combining ability	1
10.	Estimation of genotypic x environment interaction	2
	Total	16

I. Course Title : Forest Genetic Diversity and Conservation

II. Course Code : FBT 507

III. Credit Hours : 3+0

IV. Aim of the course

To provide the knowledge about the genetic diversity in forest tree species, their distribution, assess and analysis and methodologies of *in-situ* and *ex-situ* conservation.

V. Theory

Unit I

Phytodiversity-concept, levels ecosystem. Genetic diversity and differentiation-definition, characteristics and importance for tree breeding. Genetic erosion. Techniques to assess genetic diversity. Analysis of karyotypic variation.

Unit II

Molecular approaches for assessing genetic diversity. Inventory and monitoring biodiversity: sampling strategies for genetic diversity assessments sufficiency of sampling procedures, neutral allele model and optimal allocation of sampling efforts.

Unit III

Methods of sampling of genetic diversity. Factors influencing levels of genetic diversity in woody plant species. Conservation of genetic diversity Conservation biology and invasive species.

Unit IV

Laws and policies. Methods for maintenance of conservation: gene banks, arboreta, botanical gardens, breeding populations as repositories of gene conservation. Rare, threatened biodiversity, endangered and endemise plants.

Unit V

Techniques for survey and assessment of endangered plants. Rarity patterns and endemism. Concept of island biogeography. Managing corridors and natural habitat fragments.

Unit VI

Monitoring and recovery plans for endangered plants. Plant community reserves. Managing wild flora tourism impacts and eco tourism and urban forestry of rare/ exotic plants. Implications of rarity.

VI. Suggested Reading

Engles JMM, Rao VR Brown AHD and Jackson MT. 2002. *Managing Plant Genetic Diversity*. CABI and IPGRI.

FAO. 1985. *Forest Tree Improvement*, FAO Publication.

Fins L, Friedman ST and Brotschol JV. 1992. *Handbook of Quantitative Forest Genetics*. Kluwer.

IPGRI. 2004. *Forest Genetic Resources Conservation and Management*. Vol. 1, 2 and 3.

Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.

Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.

Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.

Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.

Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley and Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Phytodiversity-concept, levels ecosystem	2
2.	Genetic diversity and differentiation-definition, characteristics and importance for tree breeding	3
3.	Genetic erosion. Techniques to assess genetic diversity	3
4.	Analysis of karyotypic variation	2
5.	Molecular approaches for assessing genetic diversity	3
6.	Inventory and monitoring biodiversity	3
7.	Sampling strategies for genetic diversity assessments sufficiency of sampling procedures	2
8.	Neutral allele model and optimal allocation of sampling efforts	3
9.	Methodsof sampling of genetic diversity	2
10.	Factors influencing levels of genetic diversity in woody plant species	2
11.	Conservation of genetic diversity conservation biology and invasive species	2
12.	Laws and policies	2
13.	Methods for maintenance of conservation: Gene banks, arboreta, botanical gardens, breeding populations as repositories of gene conservation	3
14.	Rare, threatened biodiversity, endangered and endemise plants	1
15.	Techniques for survey and assessment of endangered plants	3
16.	Rarity patterns and endemism	2
17.	Concept of island biogeography. Managing corridors and natural habitat fragments	2
18.	Monitoring and recovery plans for endangered plants	2
19.	Plant community reserves	2
20.	Managing wild flora tourism impacts and eco tourism and urban forestry of rare/ exotic plants	2
21.	Implications of rarity	2
	Total	48

I. Course Title : Biotechnology In Forestry

II. Course Code : FBT 508

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about different aspects of biotechnology in forestry

V. Theory

Unit I

Introduction. Cloning, need for cloning, problems with cloning. Traditional cloning techniques versus micro-propagation, prospects of micro-propagation in forestry. Techniques procedures and problems in micro propagation, case studies. Protocols for micro-propagation.Preconditioning of explants, surface sterilization, nutritional media, other environmental factors controlling micro-propagation, choice of explants for micro-propagation. Micro propagation of juvenile material. Micro propagation of mature trees. *In-vitro* propagation of plants with low sexual reproduction rates, miscellaneous application.

Unit II

Initiation and maintenance of callus. Organogenesis and somatic embryogenesis – factors influencing somatic embryogenesis-applications in forestry, Somatic seeds, encapsulation techniques. Somaclonal variation, genetic and epigenetic variation, exploitation in forestry. Cell suspension cultures. Anther and pollen cultures. Triploids through endosperm culture, embryo culture. Monoploid production by chromosome elimination. Applications of *In-vitro* fertilization, isolation, purification and culture of protoplasts, protoplast fusion and somatic hybridization. Cryopreservation, storage of plant genetic resouces. Production of secondary metabolites by cell cultures. Meristem culture, virus free plants.

Unit III

Genetic engineering – application in forestry Isozymes, restriction fragment length polymorphisms (RFLPs), randomly amplified polymorphic DNAs (RAPDs) and microsatellites. Genetic fingerprinting, Marker assisted selection. Different PCR techniques: their characteristics, with advantages and disadvantages.

Unit IV

Quantification of genetic diversity, genotype verification and delineation. Introduction of genes. Promoters and marker genes. disease resistance, herbicide tolerance and tolerance to salt and other stresses.

VI. Practical

- Introduction to tissue culture lab;
- Micropropagation: Aseptic techniques;
- Preparation of culture media,formulation of different culture media;
- Induction and maintenance of callus, regeneration of plants from callus, regeneration of plants from embryoids;
- Cell suspension culture;
- Anther and pollen culture. Quantification of tissue culture;
- Isolation and culture of protoplasts;
- Marker assisted RFLP in test trees;
- Study of PCR techniques used in tree improvement;
- Application of GENALEX 'bolt on' for excel, arlequin, PopGene and FSTAT for Wright's F-statistics and analysis of molecular variance (AMOVA).

VII. Suggested Reading

Bajaj YPS. 1986. *Biotechnology in Agriculture and Forestry.* Springer Verleg, New York.

Bonga JM and Durjan J. 1987. *Cell and Tissue Culture in Forestry Vol. I & II.* Martinus Nijost Publishers, Dordrecht.

Hainer R. 1996. *Biotechnology in Forest Tree Improvement*. (FAO Bulletin 1994) International Book Distributors. Dehra Dun.

Muchugi A, Kadu C, Kindt R, Kipruto H, Lemurt S, Olale K, Nyadoi P, Dawson I and Jamnadass R. 2008. *Molecular Markers for Tropical Trees, A Practical Guide to Principles and Procedures*. ICRAF Technical Manual no. 9. Dawson I and Jamnadass R. eds. Nairobi: World Agroforestry Centre.

Murphy TM and Thompson WF. 1988. *Molecular Plant Development*. Prentice Hall, Engleward, cliffe, New Jersey.

Russel GE. 1988. *Biotechnology of Higher Plants*. Intercept publishers, Nimborne, Dorset.

Russell Haines. 1994. *Biotechnology in Forest Tree Improvement with Special Reference to Developing Countries*. Food and Agriculture Organization of the United Nations, Rome.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Prospects of micro-propagation in forestry	1
2.	Techniques, procedures and problems in micro propagation – case studies	2
3.	Protocols for micro-propagation, choice of explants for micro-propagation preconditioning of explants, surface sterilization, nutritional media – other environmental factors controlling micro-propagation	2
4.	Micro propagation of juvenile material – Micro propagation of mature trees, *In-vitro* propagation of plants with low sexual reproduction rates, miscellaneous application	2
5.	Initiation and maintenance of callus, organogenesis and somatic embryogenesis, factors influencing somatic embryogenesis-applications in forestry, Somatic seeds, encapsulation techniques.	3
6.	Somaclonal variation, genetic and epigenetic variation, exploitation in forestry	2
7.	Cell suspension cultures, anther and pollen cultures, triploids through endosperm culture, embryo culture	2
8.	Monoploid production by chromosome elimination	1
9.	Applications of *In-vitro* fertilization	1
10.	Isolation, purification and culture of protoplasts, protoplast fusion and somatic hybridization	3
11.	Cryopreservation, storage of plant genetic resources.	1
12.	Production of secondary metabolites by cell cultures	2
13.	Meristem culture – virus free plants	1
14.	Genetic engineering – application in forestry,Isozymes, Restriction Fragment Length Polymorphisms (RFLPs), Randomly Amplified Polymorphic DNAs (RAPDs) and Microsatellites	3
15.	Genetic fingerprinting, marker assisted selection. Different PCR techniques: their characteristics, with advantages and disadvantages.	3
16.	Quantification of genetic diversity, genotype verification and delineation	2
17.	Introduction of genes, Promoters and marker genes. Disease resistance, herbicide tolerance and tolerance to salt and other stresses	2
	Total	33
	Practical	
1.	Introduction to tissue culture lab	1
2.	Micropropagation:Aseptic techniques, Preparation of culture media, Formulation of different culture media, explants inoculation, subculture and *in-vitro* rooting	4
4.	Induction and maintenance of callus, regeneration of plants from callus	
5.	Cell suspension culture	2
6.	Anther and pollen culture	2
7.	Isolation and culture of protoplasts	2
8.	Study of PCR techniques used in tree improvement. Testing of clonal fidelity through molecular markers	3
10.	Application of GENALEX 'bolt on' for Excel, Arlequin, PopGene and FSTAT for Wright's F-statistics and Analysis of Molecular Variance (AMOVA)	2
	Total	16

I. Course Title : Clonal Forestry

II. Course Code : FBT 509

III. Credit Hours : 2+0

IV. Aim of the course

To provide information about genetics, conservation, biotechnological approaches for trees in clonal forestry system for higher biomass/ yield productivity

V. Theory

Unit I

Introduction to Clonal Forestry. History of clonal forestry. Clonal propagation. Clonal planting. Strategies for clonal forestry for higher productive potential.

Unit II

Juvenility and maturation, rejuvenation and maintainance, regulation of phase changes, markers of phase changes. Breeding strategies using vegetative propagation- selection and breeding for extreme genotypes. Physiological research for higher productivity of clonal forest. Field design, testing and evaluation of clones. Genetic gains from breeding with clonal option. Clonal conservation approaches- management of populations for genetic diversity and gain.

Unit III

Biotechnological approaches for clonal forestry, Plant tissue culture, micropropagation, Rejuvenation of tissues from mature trees, Testing of Clonal fidelity using molecular markers.

VI. Suggested Reading

Ahuja MR and Libby WJ. 1993. *Clonal Forestry I Conservation and Application*. Springer
Ahuja MR. 1992. *Micropropagation of Woody Plants*: Volume 41 (Forestry Sciences). Springer
Ahuja MR and Libby WJ. 1993. *Clonal Forestry II Genetics and Biotechnology*. Springer
Mandal AK and Gibson GL. 2002. *Forest Genetics and Tree Breeding*. CBS Publishers, New Delhi

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction to clonal forestry; History of clonal forestry	2
2.	Clonal propagation	4
3.	Clonal planting, strategies for clonal forestry for higher productive potential	2
4.	Juvenility and Maturation, rejuvenation and maintainance, regulation of phase changes, markers of phase changes	3
5.	Breeding strategies using vegetative propagation- selection and breeding for extreme genotypes	4
6.	Physiological research for higher productivity of clonal forestry.	3
7.	Field design, testing and evaluation of clones	3
8.	Genetic gains from breeding with clonal option. Clonal conservation approaches- management of populations for genetic diversity and gain	4

Sr. No.	Topic	No. of Lecture(s)
9.	Biotechnological approaches for clonal forestry-plant tissue culture-micropropagation	3
10.	Rejuvenation of tissues from mature trees	2
11.	Testing of clonal fidelity using molecular markers	2
	Total	**32**

I. Course Title : Forest Ecophysiology

II. Course Code : FBT 510

III. Credit Hours : 2+1

IV. Aim of the course

To under stand dynamics of forest ecosystem and role of stress in forest productivity.

V. Theory

Unit I

Forest environment interactions, Forest ecosystems, Geographic and climatic factors. Environmental factors influencing forest growth and productivity. Sun and shade plants.

Unit II

Influence of temperature, water stress and nutrient availability and disturbance in the forest on tree growth and forest productivity.

Unit III

Dynamics of forest ecosystems, energy, productivity and biomass. Decomposition and nutrient cycling.

Unit IV

Stand structure and micro-climate, energy relationships canopy energy balance. Partitioning absorbed energy. Radiation penetration into and absorption by canopies. Air temperature and humidity in forests. Turbulent transfer process above forests.

Unit V

Transpiration and evapotranspiration from forest canopies. Estimation of ET.

Unit VI

Stress – avoidance and tolerance mechanisms. Temperature stress – low temperature stress – physiology of resistance to frost. Heat stress, heat injury, heat avoidance and tolerance mechanism. Radiation stress, mechanism of shade tolerance, water logging, physiology of resistance to water logging. Drought stress, salt and ion stress.

VI. Practical

- Morphological, anatomical and physiological variations between sun and shade plants;
- Estimation of leaf area, LAI;
- Estimation of biomass production of trees of different species;
- Estimation of microclimatic elements as influenced by stand structure;

- Estimation of evapotranspiration;
- Measurement of radiation in different types of forest and agroforestry systems.

VII. Suggested Reading

Kozlowski TT, Kramer PJ and Pallardy GS. 1991. *The Physiological Ecology of Woody Plants*. Academic Press, New York.

Kramer PJ. 1972. *Plant and Soil Water Relationships*. TMH Edition, Tata McGraw Hill Publ. Co., New Delhi.

Ksenzhek OS and Volkov AG. 1998. *Plant Energetics*. Academic Press, New York.

Lack AJ and Evans DE. 2001. *Plant Biology- Instant Notes*. Vina Books Pvt. Ltd., New Delhi.

Lambers H, Chaplin FS and Pons TL. 1998. *Plant Physiological Ecology*. Springer, New York

Larcher W. 2003. *Physiological Plant Ecology*. 4th edn, Springer-Verlag, Germany

Luttge U. 2008. *Physiological Ecology of Tropical Plants*. Springer-Verlag, Germany

Moore TC. 1989. *Biochemistry and Physiology of Plant Hormones*, 2nd ed. Springer Verlag, Berlin.

Taiz L and Zeiger E. 2007. *Plant Physiology*, 4th ed. Sinauer Associates Inc. Publishers, Sunderland.

Wilkins BM. 1984. *Advanced Plant Physiology*. ELBS/ Longman Pub. Co.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest environment interactions, forest ecosystems, geographic and climatic factors. Environmental factors influencing forest growth and productivity. Sun and shade plants	3
2.	Influence of temperature, water stress and nutrient availability and disturbance in the forest on tree growth and forest productivity	3
3.	Dynamics of forest ecosystems, energy, productivity and biomass. Decomposition and nutrient cycling	3
4.	Stand structure and micro-climate, energy relationships, Canopy energy balance. Partitioning absorbed energy	3
5.	Radiation penetration into and absorption by canopies. Air temperature and humidity in forests. Turbulent transfer process above forests	3
6.	Transpiration and evapotranspiration from forest canopies, Estimation of ET	3
7.	Stress – avoidance and tolerance mechanisms	2
8.	Drought stress	3
9.	Temperature stress, low temperature stress, physiology of resistance to frost	3
10.	Heat stress, heat injury, heat avoidance and tolerance mechanism	3
11.	Radiation stress – mechanism of shade tolerance	1
12.	Water logging, physiology of resistance to water logging	1
13.	Salt and ion stress	2
	Total	**33**
	Practical	
1.	Morphological, anatomical and physiological variations between sun and shade plants	3

Sr. No.	Topic	No. of Lecture(s)
2.	Estimation of leaf area, LAI	2
3.	Estimation of biomass production of trees of different species	3
4.	Estimation of microclimatic elements as influenced by stand structure	3
5.	Estimation of evapotranspiration	2
6.	Measurement of radiation in different types of forest and agroforestry systems	3
	Total	**16**

I. Course Title : Physiology of Woody Plants

II. Course Code : FBT 511

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concepts of physiology for understanding its use in increasing productivity of forest stands.

V. Theory

Unit I

Introduction, Tree physiology. Growth, phases of growth, growth curve, factors affecting growth.- Wood formation.

Unit II

Plant cell as a structural and functional unit. Organization of cells and tissues, morphogenesis.

Unit III

Structure of leaves, stem wood, bark and roots in trees. Functions and process in plant growth and development.

Unit IV

Photosynthesis, structure of photosynthetic tissues and organs, enzyme, energetics and factors influencing photosynthesis. Photorespiration, its mechanisms and significance, factors affecting photorespiration.

Unit V

Respiration, mechanisms, enzymes, energetics and factors influencing respiration. Respiratory quotient.

Unit VI

Water relations of trees, absorption, ascent of sap. Translocation of solutes, phloem loading and phloem transport. Transpiration, mechanisms and factors influencing, regulating transpiration, antitranspirants.

Unit VII

Mineral nutrition. Mineral salt absorption and translocation, deficiency and toxicity of mineral nutrients. Diagnosis of mineral deficiency.

Unit VIII

The enzymes, nomenclature and classification, structure and compositioned. Mode of action. Phytohormones, auxins, GA, cytokinins, ABA, ethlynene. Biosynthesis and biochemical activity of plant hormones. Synthetic plant growth regulators. Growth retardants.

Unit IX

Nitrogen fixing trees, Nitrogen metabolism. N_2 fixation, physical and biological. Nitrogen assimilation, Amino acid and protein synthesis.

Unit X

Fat metabolism. Carbohydrate metabolism.

VI. Practical

- Preparation of growth curves of different tree seedlings;
- Study of structure of leaves;
- Measurement of photosynthesis;
- Observing structure of plant cells and leaves in C3 and C4 species;
- Studying stomata in different tree species and working out stomatal frequency;
- Measurement of stomatal size in different tree species;
- Estimation of transpiration rates in different trees;
- Isolation and estimation of chlorophyll;
- Observing xylem vessel size variation in tree species;
- Estimation of plant water status by different methods;
- Nutrient deficiency symptoms in tree seedlings.

VII. Suggested Reading

Dreyer E. 2011. *Forest Tree Physiology*. University of Minnesota, Elsevier

Kramer PJ and Kozlowsky TT. 1979. *Physiology of Woody Plants*. Academic Press.

Kramer PJ. 1972. *Plant and Soil Water Relationships*. TMH Edition, Tata McGraw Hill Publ. Co., New Delhi.

Ksenzhek OS. and Volkov AG. 1998. *Plant Energetics*. Academic Press, New York.

Lack AJ and Evans DE. 2001. *Plant Biology- Instant Notes*. Vina Books Pvt. Ltd., New Delhi.

Larcher W. 2003. *Physiological Plant Ecology*. 4th edn, Springer-Verlag, Germany

Luttge U. 2008. *Physiological Ecology of Tropical Plants*. Springer-Verlag, Germany

Malik CP and Srivastava. 2015. *Textbook of Plant Physiology*. Kalyani Publishers, Mumbai

Moore TC. 1989. *Biochemistry and Physiology of Plant Hormones*. 2nd ed. Springer-Verlan, Berlin.

Noggle RG. and Fritz GJ. 2010. *Introductory plant physiology*. Sinauer Associates Inc. Publishers, Sunderland

Pallardy HG. 2008. *Physiology of Woody Plants*. Elsevier, Amsterdam

Taiz L and Zeiger E. 2007. *Plant Physiology* 4th ed. Sinauer Associates Inc. Publishers, Sunderland.

Zimmerman MH and Brown CL. 1971. *Tree structure and Function*, Springer Verlag.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction, Tree physiology, growth, phases of growth, growth curve factors affecting growth, wood formation	3
2.	Plant cell as a structural and functional unit. Organization of cells and tissues morphogenesis	2

Sr. No.	Topic	No. of Lecture(s)
3.	Structure of leaves, stem wood, bark and roots in trees. Functions and process in plant growth and development	4
4.	Photosynthesis, structure of photosynthetic tissues and organs, enzyme, energetics and factors influencing photosynthesis. Photorespiration, its mechanisms and significance, factors affecting photorespiration	4
5.	Respiration, mechanisms, enzymes, energetics and factors influencing respiration. Respiratory quotient	3
6.	Water relations of trees, absorption, ascent of sap. Translocation of solutes – Phloem loading and phloem transport. Transpiration, Mechanisms and factors influencing,regulating transpiration, antitranspirants	4
7.	Mineral nutrition, Mineral salt absorption and translocation, deficiency and toxicity of mineral nutrients. Diagnosis of mineral deficiency	3
8.	The enzymes, nomenclature and classification, structure and composition – Mode of action. Phytohormones – auxins, GA, cytokinins, ABA, ethlynene biosynthesis and biochemical activity of Plant hormones. Synthetic plant growth regulators. Growth retardants	3
9.	Nitrogen fixing trees, Nitrogen metabolism. N_2 fixation, physical and biological. Nitrogen assimilation, Amino acid and protein synthesis.	3
10.	Fat metabolism. Carbohydrate metabolism	3
	Total	32

Practical

1.	Preparation of growth curves of different tree seedlings	2
2.	Study of structure of leaves. Observing structure of plant cells and leaves in C3 and C4 species	2
3.	Measurement of photosynthesis	2
4.	Studying stomata in different tree species and working out stomatal frequency and size	1
5.	Estimation of transpiration rates in different trees	2
6.	Isolation and estimation of chlorophyll	1
7.	Observing xylem vessel size variation in tree species	1
8.	Estimation of plant water status by different methods	3
9.	Nutrient deficiency symptoms in tree seedlings	2
	Total	**16**

I. Course Title : Breeding for Insect Pest and Disease Resistance in Trees

II. Course Code : FBT 512

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about mechanisms of disease and insect pest resistance in trees, breeding methodology to incorporate disease and insect pest resistance.

V. Theory

Unit I

Need for disease resistance in forest trees, Process of infection. Variability in plant pathogens. Types of resistance. Inheritance of resistance. Disease resistance mechanisms in trees, Clonal resistance. Disease resistance breeding techniques. Techniques of isolating resistant genes; developing disease resistant transgenic plants.

Unit II

History and importance of insect pest resistance, types and mechanism of resistance. Insect-tree relationships. Basis of resistance: Induced resistance and acquired resistance. Defense mechanisms against insects. Factors affecting tree pest resistance. Breeding for insect resistance.

VI. Practical

- Disease progression in relation to resistance, disease resistance in clonal plantations and seed orchards, hypersensitivity and its mechanisms, disease resistance screening;
- Screening for insect pest resistance; chemical and morphological characterization of susceptible/ resistance tree species;
- Defence strategies of woody plants.

VII. Suggested Reading

Dube HC. 2014. *Modern Plant Pathology*, Second Edition. Agribios, Jodhpur (India).

Harsh NS. 2012. *Disease Resistance in Genetic Material in Tree Improvement Programme*. Lambert Acad. Publications.

Heybroek HM, Stephan BR and Weissenberg KV. 1990. *Resistance to Diseases and Pests in Forest Trees*. IBD, Dehra Dun (India).

Nair KSS, Sharma JK and Varma RV. 1996. *Impact of Diseases and Insect Pest in Forest Trees*.

Parker J. 2008. *Molecular Aspects of Plant Disease Resistance*. Ann. Pl. Rev.,. 34. Blackwell Publications UK.

Ross Wylie F and Martin R Speight. 2012. *Insect Pests in Tropical Forestry* (2nd Ed.). CABI *Tropical Forests*.

Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press Inc., New York.

Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press Inc., New York.

Willium M Ciesla. 2010. *Forest Entomology-A Global Perspective*. Wiley-Blackwell.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Need for disease resistance in forest trees	1
2.	Process of infection, variability in plant pathogens	3
3.	Inheritance of resistance	3
4.	Disease resistance mechanisms in trees	2
5.	Clonal resistance	1
6.	Disease resistance breeding techniques	3
7.	Types of resistance techniques of isolating resistant genes	3
8.	Developing disease resistant transgenic plants	2
9.	History and importance of insect pest resistance	1

Sr. No.	Topic	No. of Lecture(s)
10.	Types and mechanism of resistance	2
11.	Insect-tree relationships	3
12.	Basis of resistance: Induced resistance and acquired resistance. Defence mechanisms against insects	4
13.	Factors affecting tree pest resistance	2
14.	Breeding for insect resistance	2
	Total	32

Practical

1.	Disease progression in relation to resistance	3
2.	Disease resistance in clonal plantations and seed orchards	2
3.	Hypersensitivity and its mechanisms	2
4.	Disease resistance screening	3
5.	Screening for insect pest resistance	2
6.	Chemical and morphological characterization of susceptible/ resistance tree species	2
7.	Defence strategies of woody plants	2
	Total	16

I. Course Title : Tree Seed Technology

II. Course Code : FBT 513

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and develop understanding about tree seed development, harvesting, processing, storage, dormancy, germination of tropical, sub-tropical and temperate species, their testing and certification.

V. Theory

Unit I

Trends and development in tropical, sub-tropical and temperate forestry and their influence on seed demand. Seed problems, limiting factors in tree propagation and afforestation.

Unit II

Ecological fruit and seed types – seasonality and periodicity of flowering and fruiting. Seed structure and chemical composition development and maturation germination breakdown of storage products endogenous hormonal regulation effect of stimulators and inhibitors. Dormancy its causes and breakage specific problems of seeds of woody plants.

Unit III

Determining optimal harvest maturity indices. Methods of seed collection and processing. Storage methods – loss of viability during storage. Dormancy and pre-treatment and seed testing techniques.

Unit IV

Quality seed production technologies – Seed stand/ seed production area, pollen management in seed orchards. Seed transfer guidelines. Seed certification and legislation.

Unit V

Factors affecting seed longevity. Pre-storage treatment. Physiological change during ageing. Viability and vigor. Storage of orthodox, recalcitrant and pre-storage intermediate seeds, Fumigation and seed treatment.

Unit VI

Seed fortification. Seed pelleting.

VI. Practical

- Identification of forest seed;
- Seed sampling, Seed quality testing- purity, viability and germination;
- Collection and processing of seeds/ fruit. Different storage methods;
- Pretreatment of seed;
- Seed fortification;
- Seed pelleting.

VII. Suggested Reading

Dutta M and Saini GC. 2009. *Advances in Forestry Research in India*, Vol. XXX. *Forest Tree Improvement and Seed Technology*. International Book Distributors.
Khullar P, Thapliyal RC, Beniwal BS, Vakshasya and Sharma A. 1991. *Forest Seeds. ICFRE.*
Lars H Schmidt. 2000. *Guide to Handling of Tropical and Subtropical Forest Seeds*. Danida Forest Seed Centre.
Mema NP. 1989. *Principles of Seed Certification and Testing*. Allied Publ.
Negi SS. 2008. *Forest Tree Seeds*. International Book Distributers
Ram Prasad and Kandya RK. 1992. *Handling of Forestry Seeds in India.*Associated Publ.
Vanangamudi K. 2007. *Advances in Seed Science and Technology*, Volume IV. Agrobios (India).
Vanangamudi K. 2013. *Advances in Seed Science and Technology*, Volume III. Agrobios (India).
William RL. 1985. *A Guide to Forest Seed Handling with Reference to the Tropics*. FAO.
Zobel B and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Trends in seed demand. Seed problems, limiting factors in tree propagation and afforestation	1
2.	Ecological fruit and seed types – seasonality and periodicity of flowering and fruiting	3
3.	Seed structure and chemical composition – development and maturation	2
4.	Germination – breakdown of storage products endogenous hormonal regulation	2
5.	Effect of stimulators and inhibitors dormancy – its causes and breakage	2
6.	Determining optimal harvest maturity indices	2
7.	Methods of seed collection and processing, storage methods loss of viability during storage	2
8.	Dormancy and pre-treatment	2

Sr. No.	Topic	No. of Lecture(s)
9.	Seed testing techniques	2
10.	Quality seed production technologies seed stand/ seed production area	2
11.	Pollen management in seed orchards	2
12.	Seed transfer guidelines	2
13.	Seed certification and legislation	2
14.	Factors affecting seed longevity. Pre-storage treatment. Physiological change during ageing. Viability and vigor	3
15.	Storage of orthodox, recalcitrant and pre-storage intermediate seeds, Fumigation and seed treatment	2
16.	Seed fortification, seed pelleting	2
	Total	33

Practical

1.	Identification of forest seed	1
2.	Collection and processing of seeds/ fruit, different storage methods	2
3.	Seed sampling. Seed quality testing- purity, viability and germination	7
4.	Pretreatment of seed	2
5.	Seed fortification	2
6.	Seed pelleting	2
	Total	16

Course Title with Credit Load Ph.D. (Forestry) in Forest Biology and Tree Improvement

Course Code		Course Title	Credit Hours
		Major Courses	
FBT 601*	I	Special Topics in Tree Improvement	2+1
FBT 602	II	Forest Genetics and Tree Breeding	2+0
FBT 603*	I	Biometrical Genetics	2+1
FBT 604	II	Forest Tree Reproduction	2+1
FBT 605	I	Molecular Genetics of Forest Trees	2+1
FBT 606	II	Genetics of Forest Ecosystems and Conservation Biology	3+0
FBT 607	I	Tree Physiology and Forest Productivity	1+1
FBT 608	II	Tree Seed Management	2+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Products and Utilization	06
		Supporting Courses	
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
FBT 691*	I/ II	Doctoral Seminar	1+0
FBT 692*	I/ II	Doctoral Seminar	1+0
	ii)	Thesis Research	
FBT 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Forest Biology and Tree Improvement

I. Course Title : **Special Topics in Tree Improvement**

II. Course Code : **FBT 601**

III. Credit Hours : **2+1**

IV. Aim of the course

To develop understanding among students in application of Mendelian principles to forest trees and integration of physiological and molecular techniques for tree improvement programmes.

V. Theory

Unit I

Mendelian concepts as applied to forest trees. Cytological and chromosomal systems of forest trees. Cytoplasmic inheritance in trees. Colchiploid and mutation breeding for forest trees.

Unit II

Tree domestication for small-scale farmers: needs, criteria and selection methods. Choosing the right tree. Participatory rural appraisal approaches. Ethnobotanical methods. Species priority setting procedures. Value chain analysis. Participatory tree domestication approach.

Unit III

Physiological basis of tree improvement. Pollution responses of trees. Pollen handling and hybridization techniques in forest trees. Tissue culture of trees.

Unit IV

Molecular genetics as applied to forest trees, recent trends in tree improvement, somatic hybrids, transformation, gene sequencing. Inheritance of monoterpene composition in conifers.

Unit V

Indirect selection for improvement of desired traits, molecular markers. Juvenile traits and their role in genetic evaluation in tree improvement programmes.

Unit VI

Geographic variation in trees, evolution and gene flow. Exploration and conservation of gene resources of trees. Dioecism and moneocism in trees.

VI. Practical

- Cytology of pine root tips, kryotypic analysis;
- Mutagenic treatments with colchicine and MH;
- Tissue culture of organs and transformation experiments, resin tapping;
- Observation of trees for menoecium and dioecium.

VII. Suggested Reading

Ramawat KG, Merillon JM and Ahuja MR. 2014. *Tree Biotechnology*. CRC Press.
Schnell RJ and Pridarshan PM. 2012. *Genomics of Tree Crops*, Springer.
White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction	1
2.	Mendelian concepts as applied to forest trees	1
3.	Tree domestication, selection methods, ethnobotanical methods	2
4.	Value chain analysis, Participatory tree domestication approach	2
5.	Cytological and chromosomal systems of forest trees	2
6.	Cytoplasmic inheritance in trees	1
7.	Colchiploid and mutation breeding for forest trees	2
8.	Pollen handling and hybridization techniques in forest tree	1
9.	Physiological basis of tree improvement	2
10.	Pollution responses of trees	2
11.	Tissue culture of trees	2
12.	Somatic hybrids	1
13.	Genetic transformation	2
14.	Gene sequencing	2
15.	Inheritance of monoterpene composition in conifers	1
16.	Indirect selection for improvement of desired traits, molecular markers. Juvenile traits and their role in genetic evaluation in tree improvement programmes	4
17.	Geographic variation in trees	1
18.	Evolution and gene flow	1
19.	Exploration and conservation of gene resources of trees	1
20.	Dioecism and moneocism in trees	2
	Total	33
	Practical	
1.	Cytology of softwood/ harwood spps	4
2.	Mutagenic treatments with colchicine and MH	3
3.	Tissue culture of organs and transformation experiments	7
4.	Observation of trees for monoecium and dioecium	2
	Total	16

I. Course Title : Forest Genetics and Tree Breeding

II. Course Code : FBT 602

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding among students about methodologies involved in the study of gene flow of forest tree through pollen, seed, development of hybrids and molecular breeding.

V. Theory

Unit I

Taxonomy and phylogenetic studies. Assessment of genetic diversity, gene conservation, breeding populations: long term and short term, pollen collection storage, extension, theories of pollen dispersal, mating designs. Polygenic inheritance, genetics of heterosis, overcoming incompatibility, hybrid embryo rescue and studies in hybrid development in forest trees.

Unit II

Molecular breeding- constructing molecular map. Integrating genetic, physical and molecular maps. Diversity assessment and phylogenetic analysis. Molecular tagging of genes/ traits. Selected examples on marker assisted selection of qualitative and quantitative traits. Application of molecular markers and genomic tools for the genetic enhancement.

VI. Suggested Reading

Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.

Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.

Nanson A. 2004. *Genetics of Forest Tree Breeding*. Agronomic Press.

Schnell RJ and Pridarshan PM. 2012. *Genomics of Tree Crops*, Springer.

Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.

Suzuki D, Gryfiths AJF, Miller JH and Lewontin RC. 1986. *An Introduction to Genetic Analysis*.

Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Taxonomy and phylogenetic studies	3
2.	Assessment of genetic diversity and gene conservation	3
3.	Breeding populations: long term and short term	3
4.	Pollen collection storage, extension, theories of pollen dispersal	3
6.	Polygenic inheritance	4
7.	Genetics of heterosis	2
8.	Overcoming incompatibility, hybrid embryo rescue and studies in hybrid development in forest trees	2
9.	Molecular breeding- constructing molecular map. Integrating genetic, physical and molecular maps	5
11.	Molecular tagging of genes/ traits	3
12.	Application of molecular markers and genomic tools for the genetic enhancement	2
13.	Selected examples on marker assisted selection of qualitative and quantitative traits	2
	Total	**32**

I. Course Title : Quantitative Forest Genetics

II. Course Code : FBT 603

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of principles of biometrical genetics and utility of various biometrical techniques in tree improvement programmes.

V. Theory

Unit I

Concepts inquantitative genetics, quantitative inheritance, historical aspects, Galton (1869) methods for studying quantitative traits, qualitative and quantitative traits and their inheritance, property of nuclear born genes (segregation and linkages). Linkage between major gene and polygenes. Evidence that quantitative trait is inherited in Mendalian Fashion. Nilsson Ehle (1908) multiple factor hypothesis. East (1916) experiment on *Nicotiana longifera*.

Unit II

Genetic components of continuous variation gene models (additive, dominance, epistasis) features of additive gene action, features of non-additive gene action, genetic variance in F_2 population in various gene models. Important principles established by NCSU (North Carolina State University) for forest Tree Improvement, Origin of variation, estimation of hereditary parameters, variance derivation in F_2 and backcrosses. Genotype X environment interaction, its measurement and significance. Concepts of heritablility and genetic advance. Random mating in forest trees, their population structure and response to selection.

Unit III

Quantitative genetics in relation to efficient breeding methodology – partitioning of means and variances, simple scaling and joint scaling tests. Line X tester analysis and diallel analysis mating designs in tree improvement, incomplete pedigree design and complete pedigree design.

Unit IV

Usefulness of biometrical techniques. Assessment of variability, variance analysis, metroglymph analysis, D^2. Statistic. Aids to selection correlation, path analysis, discriminant function. Aids to choice of parents: Assessment of adaptability, stability analysis, software in forest genetic analysis and their interpretation.

Unit V

Molecular diversity analysis, methods for mapping QTL.

VI. Practical

- Genotypic and phenotypic variance in forest trees;
- Detection of linkage in coupling;
- Proof that gene and genotypic frequencies remain constant in random mating populations;
- Stability analysis- Eberhart and Russel Model (1966)- Perkins and Jinks Model (1971);
- Problems on demonstrating the effects of selection, mutation, migration and genetic drift in random mating population through graphs. Simple scaling tests. Joint scaling tests;
- Heritability estimation (Analysis of variance, parent offspring correlation and regression).Heritability in narrow sense estimation;
- Line X Tester analysis;
- Diallel analysis.
- Calculation of genotypic and phenotypic correlations;

- Path analysis;
- Discriminant function. D^2 Statistics;
- Principal component analysis;
- Diversity analysis based on RAPD/ SSR.

VII. Suggested Reading

Mather K and Jinks JL. 1971. *Biometrical Genetics*. Champman and Hall, London.

Singh RK and Chaudhary BD. 1985. *Biometrical Methods in Quantitative Genetical Analysis*. Kalyani Publishers, New Delhi.

White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concepts inquantitative genetics, quantitative inheritance, historical aspects	1
2.	Galton (1869) methods for studying quantitative traits, qualitative and quantitative traits and their inheritance, property of nuclear born genes (segregation and linkages)	2
3.	Linkage between major gene and polygenes. Evidence that quantitative trait is inherited in Mendalian Fashion. Nilsson Ehle (1908) multiple factor hypothesis. East (1916) experiment on *Nicotiana longifera*	2
4.	Genetic components of continuous variation gene models (additive, dominance, epistasis) features of additive gene action, features of non-additive gene action, genetic variance in F_2 population in various gene models	3
5.	Important principles established by NCSU (North Carolina State University) for forest Tree Improvement, Origin of variation, estimation of hereditary parameters, variance derivation in F_2 and backcrosses. Genotype X environment interaction, its measurement and significance	3
6.	Concepts of heritablility and genetic advance.Random mating in forest trees, their population structure and response to selection	1
7.	Quantitative genetics in relation to efficient breeding methodology – partitioning of means and variances, simple scaling and joint scaling tests	2
8	Incomplete pedigree design and complete pedigree design. Line X tester analysis and diallel analysis mating designs in tree improvement	2
9.	Usefulness of biometrical techniques. Assessment of variability, variance analysis	2
10.	metroglymph analysis	2
11.	D^2. Statistic	2
12.	Aids to selection correlation, path analysis, discriminant function	2
13.	Aids to choice of parents: Assessment of adaptability	2
14.	Stability analysis	2
15.	Software in forest genetic analysis and their interpretation	2
16.	Molecular diversity analysis, methods for mapping QTL	2
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Genotypic and phenotypic variance in forest trees	1
2.	Detection of linkage in coupling. Eberhart and Russel Model (1966)-Perkins and Jinks Model (1971	1
3.	Proof that gene and genotypic frequencies remain constant in random mating populations	1
4.	Stability analysis-	1
5.	Problems on demonstrating the effects of selection, mutation, migration and genetic drift in random mating population through graphs	2
6.	Simple scaling tests. Joint scaling tests	1
7.	Heritability estimation (Analysis of variance, parent offspring correlation and regression).Heritability in narrow sense estimation	1
8.	Line X Tester analysis	1
9.	Diallel analysis	1
10.	Calculation of genotypic and phenotypic correlations	1
11.	Path analysis	1
12.	Discriminant function.D^2 Statistics	1
13.	Principal component analysis	1
14.	Diversity analysis based on RAPD/ SSR	2
	Total	16

I. Course Title : Forest Tree Reproduction

II. Course Code : FBT 604

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about phenology, phenodynamics breeding behaviour pollination biology and breeding systems in forest trees.

V. Theory

Unit I

Reproductive biology of gymnosperms and angiosperms, Reproduction and population genetic structure, population dynamics. Floral morphology, floral initiation and breeding systems. Flowering manipulation. Reproductive abnormalities.

Unit II

Pollination, biology, pollination ecology of tropical and temperate forest tree species, plant-pollination interactions. Pollinator energetic and nectar production.

Unit III

Genetic consequences of variation in reproductive biology. Pollen biotechnology for improved production.

Unit IV

Gene expression during pollen development. Pollination efficiency of insects. Self-incompatibility.

VI. Practical

- Phenological studies in forest trees;
- Nectar collection and analysis;
- Pollination trapling distances;
- Foraging behaviour;
- Pollinator identification and visitation.

VII. Suggested Reading

Barrett SCH. 2006. *Ecology and Evolution of Flowers*. [electronic resource]. (Eds.) L.D. Harder SCH. Barrett. Oxford Univ. Press, New York, U.S.A.

Bawa KS and Hadley M. 1990. *Reproductive Ecology of Tropical Forest Plants*. UNESCO Man and Biosphere series.

Briggs and Walters S. 1984. *Plant Variation and Evolution*.

Cláudia Inês da Silva and Helena Maura Torezan Silingardi. 2006. *Reproductive Biology of Tropical Plants*. International Commission on Tropical Biology and Natural Resources. Encyclopedia of Life Support Systems (EOLSS).

FAO. 1985. *Forest Tree Improvement,* FAO Publication.

Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.

Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.

Sedgley M and Griffin AR. 1989. *Sexual Reproduction of Tree Crops*. Academic Press.

Spencer CH, Barrett, Robert I, Colautti and Christopher G Eckert. 2007. *Plant Reproductive Systems and Evolution during Biological Invasion*. Wiley Online Library.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Reproductive biology of gymnosperms and angiosperms	2
2.	Reproduction and population genetic structure, population dynamics	2
3.	Floral morphology, floral initiation and breeding systems	4
4.	Flowering manipulation	2
5.	Reproductive abnormalities	2
6.	Pollination, biology, pollination ecology of tropical and temperate forest tree species, plant-pollination interactions	5
7.	Pollinator energetic and nectar production	2
8.	Genetic consequences of variation in reproductive biology	2
9.	Pollen biotechnology for improved production	2
10.	Gene expression during pollen development	2
11.	Pollination efficiency of insects	2
12.	Self-incompatibility	2
	Total	32
	Practical	
1.	Phenological studies in forest trees.	4
2.	Pollination trapling distances.	2
3.	Nectar collection and analysis.	4
4.	Foraging behaviour.	3
5.	Pollinator identification and visitation.	3
	Total	16

I. Course Title : Molecular Genetics of Forest Trees

II. Course Code : FBT 605

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding among students about molecular markers, biochemical markers, gene mapping, transgenics in forest trees.

V. Theory

Unit I

Biochemical markers (Isozymes and Monoterpenes). Molecular markers – Non-PCR based (RFLP) and PCR based (RAPD, ISSR, SSR, AFLP, SNP, etc.). Application in forestry – quantification of genetic diversity. Marker assisted selection. Genetic maps of selected forest trees.

Unit II

DNA sequencing. Structural genomics. Functional genomics. Transcriptomics. Proteomics. Metabolomics.

Unit III

Recombinant DNA Technology, Transgenics, Vectors,. Gene transfer strategies – direct and indirect. Molecular characterization of transformants. Application of transgenics in forestry.

VI. Practical

- Isolation of DNA, RNA from forest tree species;
- Isozyme analysis;
- Use of molecular markers and RAPD and RFLP for clonal identification;
- *Agrobacterium* mediated gene transfer;
- Preparation of linkage maps.

VII. Suggested Reading

Brown CM, Campbell I and Preist FG. 2005. *Introduction to Biotechnology*. Panama Publishers.
Chawla HS. 2004. *Introduction to Plant Biotechnology*. Kalyani Publishers.
Kole C 2007. *Genome Mapping and Molecular Breeding in Plants*. Springer.
Schnell RJ and Pridarshan PM. 2012. *Genomics of Tree Crops*. Springer.
Singh BD. 2006. *Biotechnology – Expanding Horizons*. Kalyani Publishers.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Biochemical markers (Isozymes and Monoterpenes)	2
2.	Molecular markers – Non-PCR based (RFLP) and PCR based (RAPD, ISSR, SSR, AFLP, SNP, etc.)	5
3.	Application in forestry – quantification of genetic diversity	2
4.	Marker assisted selection. Genetic maps of selected forest trees	4
5.	DNA sequencing	2
6.	Structural genomics, functional genomics	4
7.	Transcriptomics, proteomics, metabolomics	4
8.	Recombinant DNA Technology, Transgenics, Vectors	4

Sr. No.	Topic	No. of Lecture(s)
9.	Gene transfer strategies – direct and indirect	3
10.	Molecular characterization of transformants. Application of transgenics in forestry	2
	Total	32

Practical

1.	Isozyme analysis	2
2.	Isolation of DNA, RNA from forest tree species	2
3.	Use of molecular markers and RAPD, SSR and RFLP for clonal identification	6
4.	*Agrobacterium* mediated gene transfer	4
5.	Preparation of linkage maps	2
	Total	16

I. Course Title : Genetics of Forest Ecosystems and Conservation Biology

II. Course Code : FBT 606

III. Credit Hours : 3+0

IV. Aim of the course

To make the students understand about the ecological genetics, markers and sampling in ecological genetics, genetic diversity and differentiation, gene flow and mating system, forest ecosystems, physiology of woody plants and forests as biological community.

V. Theory

Unit I

What is ecological genetics, uses of ecological genetics, markers and sampling in ecological genetics, genetic diversity and differentiation, gene flow and mating system, intraspecific phylogenies and phylogeography, speciation and hybridization.

Unit II

The ecological niche, adaptations, genetic systems, adaptive strategies, forest ecosystems, how man affects forest ecosystems manmade forest ecosystems.

Unit III

Carbon sequestration consumption and export – carbon balance in trees – canopy photosynthesis – Transport and partitioning. Factors influencing net photosynthesis in trees. Relationship between the CO_2 compensation point and carbon fixation efficiency in trees. Physiology of formation of early and late woods-resource sharing in mixed agroforestry system.

Unit IV

Evapo-transpiration – factors affecting evapo-transpiration potential evapo-transpiration. Moisture stress – osmotic adjustment stomatal response to moisture stress water use efficiency drought tolerance.

Unit V

Forest as biological community, Amplification of conceptual and quantitative models of variation in trees.Changes in gene frequencies genetics and theory of selections adaptations and conservation. Gene flow and genetic drift, polymorphism. Population structure and migration.

Unit VI

Conservation biology: Introduction, Conservation biology—past and present. Biodiversity. Defining and measuring biological diversity. Threats to biodiversity. Computing biological diversity. Biological hot spots. Social value and the role of people in conservation. Ecosystem functions and services. Habitat destruction. Habitat fragmentation and landscape changes. Over harvesting. Invasive species impacts. Climate change. Population viability analysis. Application of population ecology to conservation biology for fauna and flora. Population and conservation genetics practical examples in conservation of plants and animals. Landscape ecology and conservation practices. Conservation planning and priorities. Single and Multi species conservation strategies. Endangered species management. Restoration and species recovery planning. Community biodiversity management. Strategic species concepts (Keystone species, Indicator species, Umbrella and flagship species) concept of sustainable development.

VI. Suggested Reading

Klaus Stern and Laurence Roche. 1974.*Genetics of Forest Ecosystems*.New York a.o. Springer-Verl.

Kozlowski TT. 1971. *Growth and Development of Trees*. Vol. I. Academic Press.

Kramer PJ and Kozlowshi TT. 1979. *Physiology of Woody Plants*. Academic Press.

Larcher W. 1980. *Physiological Plant Ecology*. Springer-Verlag.

Lowe A, Harris S and Ashton P. 2004. *Ecological Genetics: Design, Analysis and Application* Oxford: Blackwell Publishing.

Raghavendra AS. 1991. *Physiology of Trees*. John Wiley & Sons.

Weathers. 2013. *Fundamentals of Ecosystem Science*. M/s. International Books and Periodicals Supply Service, Pitampura, Delhi.

Zimmerman RH. 1972. *Juvenility and Flowering in Woody Plants: A Review. Hort. Science* 7(5): 447-455.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Ecological genetics, uses of ecological genetics, markers and sampling in ecological genetics	2
2.	Genetic diversity and differentiation, gene flow and mating system	2
3.	Intraspecific phylogenies and phylogeography, speciation and hybridization	2
4.	The ecological niche, adaptations.	1
5.	Genetic systems, adaptive strategies, forest ecosystems	2
6.	How man affects forest ecosystems manmade forest ecosystem	1
7.	Carbon sequestration consumption and export – carbon balance in trees	2
8.	Canopy photosynthesis – Transport and partitioning	1
9.	Factors influencing net photosynthesis in trees	1
10.	Relationship between the CO_2 compensation point and carbon fixation efficiency in trees	1

Sr. No.	Topic	No. of Lecture(s)
11.	Physiology of formation of early and late woods	2
12.	Resource sharing in mixed agroforestry system	2
13.	Evapo-transpiration, factors affecting evapo-transpiration, Potential evapo-transpiration	2
14.	Moisture stress, osmotic adjustment, stomatal response to moisture stress	2
15.	Water use efficiency, drought toleranc	1
16.	Forest as biological community	1
17.	Amplification of conceptual and quantitative models of variation in trees	1
18.	Changes in gene frequencies, genetics and theory of selections, adaptations and conservation	1
19.	Gene flow and genetic drift, polymorphism, population structure and migration	1
20.	Introduction, Conservation biology, past and present	1
21.	Biodiversity concepts. Measuring biological diversity. Threats to biodiversity	2
22.	Computing biological diversity. Biological hot spots	1
23.	Social value and the role of people in conservation	1
24.	Ecosystem functions and services	1
25.	Habitat destruction. Habitat fragmentation and landscape changes. Over harvesting. Invasive species impacts	2
26.	Climate change. Population viability analysis	1
27.	Application of population ecology to conservation biology: for fauna and flora	2
28.	Population and conservation genetics: practical examples in conservation of plants and animals	1
29.	Landscape ecology and conservation practices. Conservation planning and priorities	2
30.	Single and Multi species conservation strategies. Endangered species management	2
31.	Restoration and species recovery planning. Community biodiversity management	1
32.	Strategic species concepts (Keystone species, Indicator species, Umbrella and flagship species)	1
33.	Concept of sustainable development	1
	Total	47

I. Course Title : Tree Physiology and Forest Productivity

II. Course Code : FBT 607

III. Credit Hours : 2+1

IV. Aim of the course

To make the students understand the physiological factors responsible for the tree growth and how CO_2 fixation and consumption lead to growth.

V. Theory

Unit I

Introduction, tree forms in relation to environmental factors mechanism responsible for differences in tree forms stand structure and micro-climate.

Unit II

Carbon fixation by tree canopies, leaf area, interception of solar radiation and tree growth. Leaf area index and dry matter production. Radiation attenuation through canopies strategies for maximising solar energy utilization, stomatal conductance.

Unit III

Carbon consumption and export, carbon balance in trees, canopy photosynthesis. Transport and partitioning. Factors influencing net photosynthesis in trees. Relationship between the CO_2 compensation point and carbon fixation efficiency in trees. Physiology of formation of early and late woods. Resource sharing in mixed agroforestry system.

Unit IV

Evapo-transpiration factors affecting evapo-transpiration. Potential evapo-transpiration. Moisture stress, osmotic adjustment stomatal response to moisture stress. Water use efficiency drought tolerance.

Unit V

Biochemical and molecular aspects, water logging, physiology of resistance to water logging. Salt and ion stress.

Unit VI

Avoidance and tolerance mechanisms. Temperature stress, low temperature stress,physiology of resistance to frost. Heat stress, heat injury, heat avoidance and tolerance mechanism, Radiation stress, mechanism of shade tolerance, Physiological basis of pollution stress, Ozone injury Acid rain, Heavy metals.

VI. Practical

- Chlorophyll stability index;
- Leaf water potential by pressure bomb technique – porometry steady state porometer;
- Leaf temperature, transpiration rate;
- Stomatal resistance and conductance;
- Seed germination test for drought, tolerance and pre-treatment of seeds for drought tolerance;
- Water use efficiency;
- Measurement of photosynthesis.

VII. Suggested Reading

Kozlowski TT. 1971. *Growth and Development of Trees. Vol. I.* Academic Press.

Kramer PJ and Kozlowshi TT. 1979. *Physiology of Woody Plants*.Academic Press.

Ksenzhek OS and Volkov AG. 1998. *Plant Energetics*. Academic Press, New York.

Lack AJ and Evans DE. 2001. *Plant Biology- Instant Notes*. Vina Books Pvt. Ltd., New Delhi.

Larcher W. 2003. *Physiological Plant Ecology*. 4th edn, Springer-Verlag, Germany.

Luttge U. 2008. *Physiological Ecology of Tropical Plants*. Springer-Verlag, Germany Mandal AK and Gibson GL. 1997. *Forest Genetics and Tree Breeding*. CBS.

Raghavendra AS. 1991. *Physiology of Trees*. John Wiley & Sons.

Taiz L and Zeiger E. 2007. *Plant Physiology* 4t h Ed. Sinauer Associates Inc. Publishers, Sunderland.

Zimmerman RH. 1972. *Juvenility and Flowering in Woody Plants: A Review*. Hort. Science 7(5): 447-455.

Zimmermann MH and Brown CL. 1971. *Trees Structure and Function*. Springer Verlag.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1	Introduction, tree forms in relation to environmental factors mechanism responsible for differences in tree forms stand structure and micro-climate	2
2	Carbon fixation by tree canopies, leaf area, interception of solar radiation and tree growth	2
3.	Leaf area index and dry matter production. Radiation attenuation through canopies, strategies for maximising solar energy utilisation stomatal conductance	4
4.	Carbon consumption and export carbon balance in trees	2
5.	Canopy photosynthesis. Transport and partitioning. Factors influencing net photosynthesis in trees. Relationship between the CO2 compensation point and carbon fixation efficiency in trees	2
6.	Physiology of formation of early and late woods-Resource sharing in mixed agroforestry system	3
7.	Evapo-transpiration factors affecting evapo-transpiration	2
8.	Potential evapo-transpiration. Moisture stress, osmotic adjustment	2
9.	Stomatal response to moisture stress, water use efficiency, drought tolerance	2
10.	Biochemical and molecular aspects water logging physiology of resistance to water logging	2
11.	Salt and ion stress	2
12.	Avoidance and tolerance mechanisms – temperature stress – low temperature stress physiology of resistance to frost. Heat stress – heat injury, heat avoidance and tolerance mechanism	3
13.	Radiation stress mechanism of shade tolerance	2
14.	Physiological basis of pollution stress, Ozone injury Acid rain. Heavy metals	2
	Total	32
	Practical	
1.	Chlorophyll stability index	2
2.	Leaf water potential by pressure bomb technique	2
3.	Porometry, steady state porometer leaf temperature transpiration rate stomatal resistance and conductance	2
4.	Seed germination test for drought tolerance and pre-treatment of seeds for drought tolerance	3
5.	Water use efficiency	3
6.	Measurement of photosynthesis	4
	Total	16

I. Course Title : Tree Seed Management

II. Course Code : FBT 608

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding among students in the concept of seed maturity, dormancy, stratification, seed storage and forest seed management.

V. Theory

Unit I

Concepts, classification, seed fortification, use of adjuvants, diluents, stickers, encapsulation materials, dyes, chemicals, pesticides, fungicides, animal repellents, biological materials, antibiotic and growth regulators, biofertilizers, minerals salts, bioactive substances.

Unit II

Seed infusion and involvement in synergistic factors dormancy and stratification, Physical treatment with abrasives, hot and cold temperature, radio, frequency waves, UV rays, X-rays and gamma rays.

Unit III

Methods of application and their effects on germination, seed hardening, osmotic priming in relation to stress management.

Unit IV

Seed pelleting, use of bio-fertilizers, mineral salts, growth regulators, hydrophilic substances, seed-coat polymers in stress management, sequences in seed inoculation.

Unit V

Planting value determination and storage potential evaluation, aerial seeding and its implication, use of IDS for separation of viable seed from non viable seeds mid-storage correction treatment.

VI. Practical

- Influence of seed fortification with different treatments on germination and vigour of seeds;
- Studies on seed infusion effects on germination. Vigour and planting value;
- Use of physical treatment of seeds on seed germination and vigour. Seed hardening treatments and their influence on the planting value of seeds;
- Studies on osmotic priming on stress tolerance of seedlings. Seed pelleting studies in tree seeds. Evaluation of pelletted seeds for survival percentage both in laboratory and field. Determination of storage potential of pelleted seeds;
- Use of organic solvents for seed infusion and their influence on the seed quality. Standardization of IDS method to separate viable seeds from non-viable seeds in tree species. Evaluation of effectiveness of separation by IDS method by germination test, cutting test radiographic analysis. Studies on the evaluation of mid-storage correction treatments on the viability and vigour of seeds in storage by accelerated aging test.

VII. Suggested Reading

Dutta M and Saini GC. 2009.*Advances in Forestry Research in India*, Vol. XXX. *Forest Tree Improvement and Seed Technology*. International Book Distributors.

Khullar P, Thapliyal RC, Beniwal BS, Vakshasya and Sharma A. 1991. *Forest Seeds. ICFRE.*

Lars H Schmidt. 2000. *Guide to Handling of Tropical and Subtropical Forest Seed*s. Danida Forest Seed Centre.

Mema NP. 1989. *Principles of Seed Certification and Testing*. Allied Publ.

Negi SS. 2008. *Forest Tree Seeds*. International Book Distributers.

Ram Prasad and Kandya R K. 1992. *Handling of Forestry Seeds in India*.Associated Publ.

Vanangamudi K. 2007. *Advances in Seed Science and Technology*, Volume IV. Agrobios (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Concepts, classification, seed fortification, use of adjuvants, diluents, stickers, encapsulation materials, dyes, chemicals, pesticides, fungicides, animal repellents, biological materials, antibiotic and growth regulators, biofertilizers, minerals salts, bioactive substances	3
2.	Seed infusion and involvement in synergistic factors, dormancy and stratification	3
3.	Physical treatment with abrasives, hot and cold temperature, radio – frequency waves, UV rays, X-rays and gamma rays	4
4.	Methods of application and their effects on germination, seed hardening, osmotic priming in relation to stress management	3
5.	Seed pelleting, use of bio-fertilizers, mineral salts, growth regulators, hydrophilic substances, seed-coat polymers in stress management, sequences in seed inoculation	3
6.	Planting value determination and storage potential evaluation	1
7.	Aerial seeding and its implication	1
8.	Use of IDS for separation of viable seed from non viable seeds mid-storage correction treatment	2
	Total	20
	Practical	
1.	Influence of seed fortification with different treatments on germination and vigour of seeds	3
2.	Studies on seed infusion effects on germination.Vigour and planting value	3
3.	Use of physical treatment of seeds on seed germination and vigour. Seed hardening treatments and their influence on the planting value of seeds	3
4.	Studies on osmotic priming on stress tolerance of seedlings. Seed pelleting studies in tree seeds. Evaluation of pelletted seeds for survival percentage both in laboratory and field. Determination of storage potential of pelleted seeds	4
5.	Use of organic solvents for seed infusion and their influence on the seed quality. Standardization of IDS method to separate viable seeds from non-viable seeds in tree species. Evaluation of effectiveness of separation by IDS method by germination test, cutting test radiographic analysis. Studies on the evaluation of mid-storage correction treatments on the viability and vigour of seeds in storage by accelerated aging test	4
	Total	17

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry
– Forest Products and Utilization

Course Title with Credit Load
M.Sc. (Forestry) in Forest Products and Utilization

Course Code		Course Title	Credit Hours
		Major Courses	
FPU 501*	I	Non Wood Forest Products Management	2+1
FPU 502	II	Applied Wood Technology	2+1
FPU 503	I	Pulp and Paper Technology	2+1
FPU 504	II	Composite Wood Technology	2+1
FPU 505*	I	Forest Products Laboratory Techniques	0+2
FPU 506*	II	Agro-techniques of Medicinal and Aromatic Crops	2+1
FPU 507	I	Breeding Techniques and Improvement of Medicinal and Aromatic Crops	2+1
FPU 508	II	Chemistry and Processing of Medicinal and Aromatic Plants	2+1
FPU 509*	I	Wood Identification	0+2
FPU 510*	II	Chemistry of Forest Products and Industries	2+1
FPU 511	I	Wood Chemistry	1+1
FPU 512	II	Wood Physics	1+1
FPU 513	I	Wood Seasoning and Preservation	2+1
FPU 514	II	Production of Medicinal and Aromatic Crops	1+1
FPU 515	I	Medicinal and Aromatic Plants in Health Care Systems	2 +0
FPU 516	II	Pharmacognosy of Medicinal and Aromatic Plants	1+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Biology and Tree Improveemnt	08
		Supporting Courses	
FOR 511*	I	General Statistical Methods and Computer Applications	2+1
		Any other course relavent to MSc research problem	03
		Common Courses	
		Library and Information Services	1+0
		Technical Writing and Communications Skills	1+0
		Intellectual Property and its management in Agriculture	1+0
		Basic Concepts in Laboratory Techniques	1+0
		Agricultural Research, Research Ethics and Rural Development Programmes	1+0
FPU 591*	I/ II	Master's Seminar	1+0
	ii)	Thesis Research	
FPU 599		Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Forest Products and Utilization

I. Course Title : Non Wood Forest Products Management

II. Course Code : FPU 501

III. Credit Hours : 2+1

IV. Aim of the course

To make students to understand and learn about the different non wood Forest Products and their scientific extraction, processing and disposal.

V. Theory

UNIT I

Classification of non wood forest products like gums and resins, katha, dyes, tannins, oils, raw drugs, bamboos, canes and other products.

UNIT II

Technologies for extraction of gums, resins, katha, dyes, tannins, oils, raw drugs and other products.

UNIT III

Utilization of various non wood forest products and their scientific management for processing, value addition, marketing and disposal.

UNIT IV

Quality assessment of important products and their methods for storage. Important industries based on non wood forest products and their management.

VI. Practical

- Extraction of resins, gums, katha, dyes, tannins, oils raw drugs, bamboos, canes and other products;
- Value addition techniques for these products;
- Visit to non wood forest products based industries.

VII. Suggested Reading

Linskens HF and Jackson JF. 1991. *Essential Oils and Waxes* (Ed.). Springer-Verlag Berlin Heidelberg.

Mathe A. 2015. *Medicinal and Aromatic Plants of the World-Scientific, Production, Commercial and Utilization Aspects.* Springer Netherlands.

Panda H. 2005. *Hand Book on Specialty Gums, Adhesive, Oils, Rosin And Derivatives, Resins, Oleoresins, Katha, Chemicals with others Natural Products.* Asia Pacific business press. Inc.

Panshin AJ, Harrer ES and Bethel JS. *Forest Products, their Sources, Production and Utilization.*

Shackleton S, Shackleton C and Shanley P. 2011. *Non-Timber Forest Products in the Global Context* (Ed.). Springer, Verlag Berlin Heidelberg.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Classification of non wood forest products like; gums and resins, katha, dyes, tannins, oils, raw drugs and other products	9
2.	Technologies for extraction of gums, resins, katha, dyes, tannins, oils, raw drugs and other products	8
3.	Utilization of various non wood forest products and their scientific management for processing, value addition and disposal	6
4.	Quality assessment of important products and their methods for storage	6
5.	Important industries based on non wood forest products and their management	3
	Total	32
	Practical	
1.	Extraction of resins, gums, katha, dyes, tannins, oils, raw drugs and other products	8
2.	Value addition techniques resins, gums, katha, dyes, tannins, oils, raw drugs and other products	5
3.	Visit to non wood forest products based industries	3
	Total	16

I. Course Title : Applied Wood Technology

II. Course Code : FPU 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with various aspects of wood technology and their role in different applications.

V. Theory

UNIT I

Physical properties of wood-wood density, specific gravity and methods of their determination. Effect of growth on density of wood. Moisture content and its measurement. Effect of sound on wood resonance. Color of wood, phosphorescence, fluorescence and residual luminescence. Thermal properties-conductivity and diffusivity. Electrical properties-conductivity, dielectric constant and current resistivity. Wood permeability.

UNIT II

Mechanical properties-elastic constants, plasticity, Hook's Law, Poisson's ratio, elastic constants, modulus of elasticity, factors affecting strength properties, elastic theory of bending, shear stresses in simple beams, supported beams and cantilevers carrying concentrated and uniformly distributed loads, direct and bending safe working stresses and their evaluation.

UNIT III

Standard tests of timber specimen's-compression, tensile strength. Mechanics and Rheology of wood, abrasion, brittleness and hardness. Suitability coefficient and indices of different wood species. Vibration properties.

UNIT IV

Effect of environment on mechanical properties of wood. Effect of radiations on strength of wood.

VI. Practical

- Determination of density, specific gravity, strength, hardness, modulus of elasticity, mechanical properties, thermal conductivity, electrical resistivity and dielectric constant of important domestic and imported timber species.

VII. Suggested Reading

Bodig J and Benjamin AJ. 1993. *Mechanics of Woods and Woods Composites*. Krieger Publish Company.

Brown HP. 1925. *An Elementary Manual on Indian Wood technology*. Central Publication Branch, Government of India, Calcutta.

Brown HP. 1985. *Manual of Indian Wood Technology*. International Books and Periodicals Supply Service, New Delhi.

Hill CAS. 2006. *Wood Modification: Chemical, Thermal and other Processes*. John Wiley and Sons Ltd.

Hoadley B. 2000. *Understanding Wood: A Craftsman's Guide to Wood Technology*. Taunton Press. Newtown, USA.

Kollmann FFP and Cote WAJ. 1968. *Principle of Wood Science and Technology*. Vol I, Solid wood. George Allen and Unwin Ltd London, Springer-Verlag, Berlin, Heidelberg, New York.

Panshin AJ and De ZC. 1980. *Textbook of Wood Technology*, 4th Ed. McGraw-Hill. New York.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Physical properties of wood-wood density, specific gravity and methods of determination	4
2.	Effect of growth on density of wood. Moisture content and its measurement. Effect of sound on wood resonance. Phosphorescence, fluorescence and residual luminescence	4
3.	Thermal properties-conductivity and diffusivity	2
4.	Electrical properties-conductivity, dielectric constant and current resistivity. Wood permeability	3
5.	Mechanical properties-elastic constants, plasticity, Hook's Law, Poisson's ratio, elastic constants, modulus of elasticity, factors affecting strength properties, elastic theory of bending, shear stresses in simple beams, supported beams and cantilevers carrying concentrated and uniformly distributed leads, direct and bending safe working stresses in simple and their evaluation	8
6.	Standard tests of timber specimen's-compression, tensile strength, Mechanics and Rheology of wood, abrasion, brittleness and hardness.	5
7.	Suitability coefficient and indices of different wood species. Vibration properties	3
8.	Effect of environment on mechanical properties of wood. Effect of radiations on strength of wood	3
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Determination of density, strength, hardness modulus of elasticity of wood and mechanical properties of important domestic and imported timber species	9
2.	Determination electrical resistivity and dielectric constant of important domestic and imported timber species	7
	Total	16

I. Course Title : Pulp and Paper Technology

II. Course Code : FPU 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with the resources and processes for making pulp and paper.

V. Theory

UNIT I

Raw material used in pulp and paper industries, characteristics and handling.

UNIT II

Pulping process, mechanical, chemical, semi-chemical and biopulping. Pulp bleaching, pulp treatment, defibering, de-knotting, brown stock washing, screening, cleaning, thickening, etc.

UNIT III

Recycled fibers, supplementary pulp treatment and additives. Paper making, paper drying, reeling, external sizing, coating, calendaring, etc.

UNIT IV

Structure of paper, its characterization and measuring strength method, optional and structural properties of paper, Type of paper: coated paper, corrugated containers, printing quality of paper, ageing of paper. Rayon industry.

VI. Practical

- Visit to pulp and paper industry;
- Study of raw materials, techniques and pulp yield, making of paper and its quality determination.

VII. Suggested Reading

Asuncion J. 2003. *The Complete Book of Paper Making*. Lark books, New York.

Bajpai P. 2018. *Biermann's Handbook of Pulp and Paper*. Vol. 1st:Raw material and pulp making. Elsevier Science, UK.

Biermann C. 1996. *Handbook of Pulping and Paper Making*. 2nd Ed. Academic Press San Diego, New York, Boston, London, Sydney, Tokyo, Toronito.

Britt KW. 1970. *Handbook of Pulp and Paper Technology*. 2nd Ed. Van Nostrand Reinhold Company, New York.

Lavigne JR. 1979. *Instrumentation Applications for the Pulp and Paper Industry*. Miller Freeman Publications.

Rao KP. 2007. *Pulp and Paper Technology: Technology, Testing and Applications*. CBS Publishing and Distributors, New Delhi.

Sjostrom E and Alen R (Eds). 1999. *Analytical Methods in Wood Chemistry Pulping and Paper Making*. Springer Series in Wood Science.

Viikari L and Lantto R. 2002. *Progress in Biotechnology*. Vol. 21st. Biotechnology in the pulp and paper industry. 1st Ed. ICBPPI. Elsevier Science.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Raw materials used in pulp and paper industries, characteristics and handling	6
2.	Pulping process, mechanical, chemical, semi-chemical and biopulping. Pulp bleaching, pulp treatment, defibering, de-knotting, brown stock washing, screening, cleaning, thickening, etc.	8
3.	Recycled fibers, supplementary pulp treatment and additives. Paper making, paper drying, reeling, external sizing, coating, calendaring, etc. Structure of paper, its characterization and measuring strength method	10
4.	Optional and structural properties of paper, Type of paper: coated paper, corrugated containers, printing quality of paper, ageing of paper	6
5.	Rayon industry	2
	Total	32
	Practical	
1.	Visit to pulp and paper industry	6
2.	Study of raw materials, techniques and pulp yield, making of paper and its quality determination	10
	Total	16

I. Course Title : Composite Wood Technology

II. Course Code : FPU 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge regarding the scope and processes for developing composite and modified woods.

V. Theory

UNIT I

Introduction to wood modification, its need and scope.Chemical modification of wood (acetylation, reaction with isocyanates, acetates, ethers, epoxides, etc.) Wood impregnation and compregnation, heat stabilization, wood densification.

UNIT II

Modern trends in composite wood. Wood adhesives – types, characteristics and application.

UNIT III

Plywood, laminated wood and inorganic wood composites- their manufacture, characteristics and application.

VI. Practical

- Use of different adhesives in plywood;
- Study of composite boards, study of anti-shrink efficiency of wood treated with different chemicals;
- Impregnation and compregnation of wood with chemicals.

VII. Suggested Reading

Ansell MP. 2015.*Wood Composites*. Elsevier, Science and Technology.

Hill CAS. 2006. *Wood Modification: Chemical, Thermal and Other Processes*. John Wiley and Sons Ltd.

Pizzi A and Mittal KL. 2011. *Wood Adhesives*. CRC Press, New York.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press, New York.

USDA (U.S. Department of Agriculture). 1999. *Wood Handbook: Wood as an Engineered Material*. US Department of Agriculture, Forest Service. Forest Products Laboratory, Madison, WI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction to wood modification, its need and scope	4
2.	Chemical modification of wood (acetylation, reaction with isocyanates, acetates, ethers, epoxides, etc.)	6
3.	Wood impregnation and compregnation, heat stabilization, wood densification	6
4.	Modern trends in composite wood	4
5.	Wood adhesives – types, characteristics and application	4
6.	Plywood, laminated wood and inorganic wood composites- their manufacture, characteristics and application	8
	Total	32
	Practical	
1.	Use of different adhesives in plywood	4
2.	Study of composite boards, study of anti-shrink efficiency of wood treated with different chemicals	6
3.	Impregnation and compregnation of wood with chemicals	6
	Total	16

I. Course Title : Forest Products Laboratory Techniques

II. Course Code : FPU 505

III. Credit Hours : 0+2

IV. Aim of the course

To expose the students to the practical aspects of laboratory techniques employed in forest products.

V. Practical

- Wood and non-wood product sampling, drying and storage. Estimation of extraneous components of wood. Analysis of volatile compounds;
- Estimation of chemical composition of wood samples (hardwoods, softwood and other lignocellulosic material) and ash;
- Separation of components by column, paper, and thin layer chromatography. HPLC techniques;
- Determination of strength properties of paper and wood composites.

VI. Suggested Reading

Meyland BA and Butterfield BG. 1972. *Three-Dimensional Structure of Wood: A Scanning Electron Microscope Study*. Syracuse University Press.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press, New York.

Skaar C. 1988. *Wood-Water Relations*. Springer Series in Wood Science.

Snyder LR, Kirkland JJ and Glajch JL. 2012. *Practical HPLC Method Development*. 2nd Ed. John Wiley & Sons.

Lecture Schedule

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Wood and non-wood products sampling, drying and storage	4
2.	Estimation of extraneous components of wood. Analysis of volatile compounds	6
3.	Estimation of chemical composition of wood samples (hardwoods, softwood and other lignocellulosic material) and ash	10
4.	Separation of components by column, paper, and thin layer chromatography. HPLC techniques	6
5.	Determination of strength properties of paper and wood composites	6
	Total	32

I. Course Title : Agro-techniques of Medicinal and Aromatic Crops

II. Course Code : FPU 506

III. Credit Hours : 2+1

IV. Aim of the course

To equip the student with the conventional and commercial production techniques of medicinal and aromatic plant species.

V. Theory

UNIT I

Importance of medicinal and aromatic plants in human health, national economy and related industries. Need of cultivation of medicinal and aromatic plants as agricultural crops. Concept of organic farming, GACP and GAP in medicinal and aromatic crops production. Quality concern in plant based drugs.

UNIT II

Introduction and importance, climate and soil requirements, cultural practices, harvesting and yield, important constituents of medicinal plants – Mulhathi, Senna, *Gloriosa superba*, *Valeriana jatamansi, Swertia chirayita,* Isabgol, *Rauwolfia serpentina, Withania sominifera,* Opium Poppy, *Aloe vera*, Satavar, *Stevia rebaudiana,* Safed Musli, Kalmegh and other important species of the region.

UNIT III

Introduction and importance, climate and soil requirements; cultural practices; harvest and yield; important constituents of aromatic plants – Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, *Tagetes minuta*, Lavender, Rosemary, Patchouli, Geranium and other important species of the region.

VI. Practical

- Morphological identification of listed plants and their economic parts, maturity indices;
- Preparation and layout of nursery and field, methods of seed sowing/ transplantation, cultural operations in MAP crops;
- Raising and harvesting of at least one crop grown in the region;
- Visit to government and private Pharmaceutical units/ Institutes in adjoining areas;
- Visit to large scale herb growing and processing units engaged in commercial cultivation and preparation of purified phytochemical/ standardized extracts;
- Visit to nearby marketing/ trade centres.

VII. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization Of Medicinal Plants*. RRL, CSIR, Jammu-Tawi.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publishing House.

Chopra AK. 2007. *Medicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN. Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants*. CSIR, New Delhi.

EIRI Board. 2007. *Handbook of Medicinal and Aromatic Plants: Cultivation, Utilization and Extraction Processes*. Engineers India Research Institute, New Delhi.

Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.

Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.

Muralia S. 2006. *Medicinal and Aromatic Plants* 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Importance of medicinal and aromatic plants in human health, national economy and related industries. Need of cultivation of Medicinal and aromatic plants as agricultural crops	2
2.	Concept of organic farming, GACP and GAP in medicinal and aromatic crop production. Quality concern in plant based drugs	3
3.	Introduction and importance, botanical features, climate and soil requirements, cultural practices, harvesting and yield and important constituents of medicinal plants – Mulhathi, Senna, *Gloriosa superba*, *Valeriana jatamansi, Swertia chirayita,* Isabgol, *Rauwolfia serpentina, Withania somnifera,* Opium Poppy, *Aloe vera*, Satavar, *Stevia rebaudiana,* Safed Musli, Kalmegh and other important species of the region	15

Sr. No.	Topic	No. of Lecture(s)
4.	Introduction and importance, climate and soil requirements; cultural practices; harvest and yield; important constituents of aromatic plants - Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, *Tagetes minuta*, Lavender, Rosemary, Patchouli, Geranium and other important species of the region	12
	Total	32

Practical

1.	Morphological identification of listed plants and their economic parts, maturity indices	3
2.	Preparation and layout of nursery and field, methods of seed sowing/ transplantation, cultural operations in MAP crops	4
3.	Raising and harvesting of at least one crop grown in the region	3
4.	Visit to government and private Pharmaceutical units/ Institutes in adjoining areas. Visit to large scale herb growing and processing units engaged in commercial cultivation and preparation of purified phytochemical/ standardized extracts	4
5.	Visit to nearby marketing/ trade centres	2
	Total	16

I. Course Title : Breeding Techniques and Improvement of Medicinal and Aromatic crops

II. Course Code : FPU 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the breeding techniques and quality improvement of medicinal and aromatic crops.

V. V.Theory

UNIT I

Plant biodiversity, Major objectives of breeding of medicinal and aromatic crops. Plant introduction, domestication and germplasm conservation. Modes of pollination, male sterility, self incompatibility and apomixis. Production and maintenance of pure seeds of medicinal and aromatic plants.

UNIT II

Principles of plant breeding for self pollinated and cross pollinated crops. Selection, Hybridization-techniques and consequences. Hetersosis and inbreeding depression. Different plant breeding methods for self pollinated, cross pollinated and asexually propagated crops. Mutation and polyploidy breeding. Distinctiveness, uniformity, stability testing in medicinal and aromatic crops.

UNIT III

Breeding for quality parameters in medicinal and aromatic crops. Achievements and prospects in breeding of important medicinal and aromatic crops- *Rauvolfia* *serpentina, Plantago ovata, Cassia angustifolia, Ocimum* spp., *Withania somnifera, Valeriana* spp., *Opium poppy, Gloriosa superb, Andrographis paniculata, Mentha* spp., *Geranium, Cymbopogon* spp., and other important crops.

UNIT IV

Legislation in conservation of medicinal and aromatic plants- IPR issues in medicinal and aromatic plants.

VI. Practical

- Identification based on morphological features;
- Pollen viability and germination testing;
- Stigma receptivity;
- Field practice in emasculation, selfing and crossing in different medicinal and aromatic crops;
- Determination of mode of pollination and hybridization in different medicinal and aromatic crops.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture.* Vol. XI. Medicinal and aromatic plants. Malhotra Publishing House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*. ICMR.

Johnson CB and Franz C. 2005. *Breeding Research on Aromatic and Medicinal Plants*. International Book Distributor.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publishing.

Singh BD. 2010. *Plant Breeding- Principles and Methods*. Kalyani Publishers.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Plant biodiversity, Major objectives of breeding of medicinal and aromatic crops. Plant introduction, domestication and germplasm conservation	3
2.	Modes of pollination, male sterility, self incompatibility and apomixis. Production and maintenance of pure seeds of medicinal and aromatic plants	3
3.	Principles of plant breeding for self pollinated and cross pollinated crops	3
4.	Selection, Hybridization-techniques and consequences	2
5.	Hetersosis and inbreeding depression	3
6.	Different plant breeding methods for self pollinated, cross pollinated and asexually propagated crops	5
7.	Mutation and polyploidy breeding	2
8.	Distinctiveness, uniformity, stability testing in medicinal and aromatic crops	3
9.	Breeding for quality parameters in medicinal and aromatic crops	2
10.	Achievements and prospects in breeding of important medicinal and aromatic crops- *Rauvolfia serpentina, Plantago ovata, Cassia angustifolia, Ocimum* sp., *Withania somnifera, Valeriana* sp., *Opium poppy, Gloriosa superba, Andrographis paniculata, Mentha* sp., *Geranium, Cymbopogon* sp., and other important crops	5

Sr. No	Topic	No. of Practical(s)
11.	Legislation in conservation of medicinal and aromatic plants-IPR issues in medicinal and aromatic plants	1
	Total	32

Practical

1.	Identification based on morphological features	3
2.	Pollen viability and germination testing	3
3.	Stigma receptivity	2
4.	Field practice in emasculation	2
5.	Selfing and crossing in different medicinal and aromatic crops	4
6.	Determination of mode of pollination and hybridization in different medicinal and aromatic crops	2
	Total	16

I. Course Title : Chemistry and Processing of Medicinal and Aromatic Plants

II. Course Code : FPU 508

III. Credit Hours : 2+1

IV. Aim of the course

To understand the chemistry of phytopharmaceuticals and their processing as industrial products.

V. Theory

UNIT I

Organic compounds and their classification such as aliphatic, aromatic, alkaloids, steroids, terpenoids, glycosides, phenolic compounds, heterocyclic compounds and carbohydrates.

UNIT II

Primary and Secondary plant metabolites and theurapeutical uses of phytoconstituents such as anthraquinones, steroidal and triterpenoidal glycosides, phenolic compounds, lipids, alkaloids and terpenoids.

UNIT III

Basic principles and extraction techniques of different phytoconstituents. Analysis of active principles using TLC, HPLC, Gas chromatography, etc. Quality standards in herbal products. Drug descriptors for medicinal and aromatic plants.

UNIT IV

Postharvest processing-drying, grading and storage. Extraction techniques of essential oils and their quality analysis.

VI. Practical

- Use of thin layer and column chromatography during extraction and purification of phytopharmaceuticals;

- Preparation of active constituent enriched extracts;
- Extraction of Essential oils and their quality evaluation;
- Preparation of concretes and absolutes. Use of HPLC and GC in quality evaluation.

VII. Suggested Reading

Bedi S, Singh T and Vyas SP. 2012. *A Handbook of Aromatic and Essential Oil Plants: Cultivation, Chemistry, Processing and Uses*. Agrobios (India).

Finar IL. 2002. *Organic Chemistry*. Vol. I & II. *Pearson Education* India.

Raaman N. 2006. *Phytochemical Techniques*. New India Publishing Agency, N. Delhi.

Singh MP and Panda H. 2005. *Medicinal Herbs with their Formulations*. Vol-1st. Daya Publishing House.

Singh S. 2009. *Essentials of Pharmacology*. 2nd Ed. New Age International Publisher.

Wagner H and Bladt S. 2009. *Plant Drug Analysis- A Thin Layer Chromatography Atlas*. Springer (India) Pvt. Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Organic compounds and their classification such as aliphatic, aromatic, alkaloids, steroids, terpenoids, glycosides, phenolic compounds, heterocyclic compounds and Carbohydrates	9
2.	Primary and secondary plant metabolites	4
3.	Theurapeutical uses of phytoconstituents such as anthraquinones, steroidal and triterpenoidal glycosides, phenolic compounds, lipids, alkaloids and terpenoids	6
4.	Basic principles and extraction techniques of different . phytoconstituentsAnalysis of active principles using TLC, HPLC, Gas chromatography, etc. Quality standards in herbal products	4
5.	Drug descriptors for medicinal and aromatic plants	2
6.	Postharvest processing-drying, grading and storage	4
7.	Extraction techniques of essential oils and their quality analysis	3
	Total	32
	Practical	
1.	Use of thin layer and column chromatography during extraction and purification of phytopharmaceuticals	3
2.	Preparation of active constituent enriched extracts	3
3.	Extraction of Essential oils and their quality evaluation	2
4.	Preparation of concretes and absolutes	2
5.	Use of HPLC and GC in quality evaluation	6
	Total	16

I. Course Title : Wood Identification

II. Course Code : FPU 509

III. Credit Hours : 0+2

IV. Aim of the course

The course deals with the use of anatomical features of wood in timber identification and classification.

V. Practical

- Study of planes of wood, gross features and physical characteristics of important woods;
- Identification of different types of cells and tissues;
- Anatomical studies of soft and hard woods. Anatomical studies of reaction wood;
- Classification of timber using dichotomous key;
- Modern timber identification techniques.

VI. Suggested Reading

Agarwal VK and Upadhaya SD. 2006. *Agrotechniques of Medicinal and Aromatic Plants.* Satish Serial Publishing House.

Anoop EV. 1971. *Timber Identification Manual.* Forest Research Institute, Dehradun.

Dutta JC. 1964. *Botany for Degree Students.* Oxford University Press, Bombay-Calcutta-Madras.

Govil JN, Pandey J, Shivakumar BG and Singh VK. 2004. *Crop Improvement, Production Technology, Trade Commerce.*

Lakshman HC and Inchal RF. 2012. *Indigenous Medicinal Plants and their Practical Utility.*

Meier E. 2015. *Wood Identifying and Using Hundreds of Woods Worldwide.* Wood database.

Porter T. 2004. *Wood Identification and Use.* Guild of Master Craftsman, UK.

Purkayastha SK. 1982. *Indian Woods: Their Identification Properties and Uses.* Controller of Publication.

Rao R and Juneja KDS. 1971. *A Handbook for Field Identification of Fifty Important Timbers of India.* Manager of Publications.

Vashishta PC. 1985. *A Text Book of Botany.* S. Chand Publishing Company, New Delhi.

Lecture Schedule

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Study of planes of wood,gross features and physical characteristics of important woods	6
2.	Identification of different types of cells and tissues	5
3.	Anatomical studies of soft and hard woods. Anatomical studies of reaction wood	10
4.	Classification of timber using dichotomous keys	6
5.	Modern timber identification techniques	5
	Total	32

I. Course Title : Chemistry of Forest Products and Industries

II. Course Code : FPU 510

III. Credit Hours : 2+1

IV. Aim of the course

The course will equip the students regarding forest based industries and their impact on the economy of the country. To support the studies on the role of various products such as pulp, paper, composite wood, furniture match boxes, sports, pencil making, resins and gums, katha, tannins and various types of other non- timber and wood products either produced or processed in these industries. Practicals will make them aware regarding extraction and processing methods of different forest products.

V. Theory

UNIT I

Importance of forest based industries in relation to Indian economy. Role of Chemistry in relation to forest products.

UNIT II

Classification and description of different forest based industries – pulp and paper, composite wood, furniture, bamboo, sports goods, pencil making, match box and splint making. Use of lesser known wood species for commercial purposes.

UNIT III

Cell wall constituents. Chemistry of cellulose, starch, hemicelluloses and lignin. Extraneous components of wood – water and organic solvent soluble.

UNIT IV

Chemical composition of oleoresin from major pine species. Structural difference among different gums (arabic, ghatti, tragacanth, etc.).

UNIT V

Chemical nature and uses of volatile oils, tannins, katha and cutch and important forest based dyes and pigments.

VI. Practical

- Estimation of cell wall constituents – Hemicelluloses and lignin;
- Extraction of essential oils, resins and tannins;
- Wood pulping. Acetylation of wood;
- Visit to nearby forest based industries.

VII. Suggested Reading

Bowyer JL, Shmulsky R and Haygreen JG. 2003. *Forest Products and Wood Science: An Introduction*. 4th Ed. Blackwell Publishing.

Chung and Deborah DL. 2003. *Composite Materials-Functional Materials for Modern Technologies*. Springer,Verlag London.

David AT. 2013. *Forest Products: Advanced Technologies and Economic Analyses*. Elsevier.

Eriksson KEL, Blanchette RA and Ander P. 1990. *Microbial and Enzymatic Degradation of Wood and Wood Components*. Springer,Verlag Berlin Heidelberg.

Linskens HF and Jackson JF. 1991. *Essential Oils and Waxes* (Ed.). Springer-Verlag Berlin Heidelberg.

Panda H. 2005. *Hand Book on Specialty Gums, Adhesive, Oils, Rosin And Derivatives, Resins, Oleoresins, Katha, Chemicals with Others Natural Products*. Asia Pacific business press. Inc.

Rojas OJ. 2016. *Cellulose Chemistry and Properties: Fibers, Nanocelluloses and Advanced Materials (Ed.).* Springer International Publishing.

Rowell RM. 2013. *Hand Book of Wood Chemistry and Wood Composites.* CRC press, Taylor and Francis group.

Shackleton S, Shackleton C and Shanley P. 2011. *Non-Timber Forest Products in the Global Context (Ed.).* Springer, Verlag Berlin Heidelberg.

Sharma LC. 2012. *Development of Forests and Forest Based Industries*. M/s Bishen Singh Mahendra Pal Singh.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Importance of forest based industries in relation to Indian economy	1
2.	Role of chemistry in relation to forest products	1
3.	Classification and description of different forest based industries – pulp and paper and composite wood	6
4.	Classification and description of different forest based industries like; Furniture, bamboo, sports goods, pencil making, match box and splint making	5
5.	Use of lesser known wood species for commercial purposes	2
6.	Cell wall constituents. Chemistry of cellulose, starch, hemicelluloses and lignin	4
7.	Extraneous components of wood – water and organic solvent soluble	2
8.	Chemical composition of oleoresin from major pine species	3
9.	Structural difference among different gums (arabic, ghatti, tragacanth, etc.)	2
10.	Chemical nature and uses of volatile oils, tannins, katha and cutch	3
11.	Chemical nature and uses of important forest based dyes and pigments	3
	Total	**32**
	Practical	
1.	Estimation of cell wall contents – Hollocellulose and lignin	5
2.	Extraction of essential oils	2
3.	Extraction of resins and tannins	3
4.	Wood pulping	2
5.	Acetylation of wood	2
6.	Visit to nearby forest based industries	2
	Total	16

I. Course Title : Wood Chemistry

II. Course Code : FPU 511

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge about the chemical properties of wood, cell wall constituents and wood extractions.

V. Theory

UNIT I

Chemical composition of wood: Cell wall constituents- cellulose, lignin, hemicellulose, peptic substances, etc.

UNIT II

Volatile oils and extractives, cellulose derivatives and their applications.

UNIT III

Hydrolysis and fermentation of lignocellulosic materials. Pyrolysis and gasification of wood.

VI. Practical

- Extraction of cellulose, hemicellulose, lignin, extractives and ash content of wood.

VII. Suggested Reading

Coppen JJW. 1995. *Gums, Resin and Latex of Plant Origin*. Food and Agriculture Organizations, Rome.

Rowe JW. 1989. *Natural Products of Woody Plants.* Springer Series in Wood Science.

Rowell RM. 1984. *The Chemistry of Solid Wood (Advances in Chemistry Series).* American Chemical Society.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites.* 2nd Ed. CRC Press.

Singh A. 1967. *Plant Physiology*. Readers in Botany, Allahabad University.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Chemical composition of wood: Cell wall constituents- cellulose, lignin, hemicellulose, peptic substances, etc.	5
2.	Volatile oils and extractives, cellulose derivatives and their applications	4
3.	Hydrolysis and fermentation of lignocellulosic materials	4
4.	Pyrolysis and gasification of wood	3
	Total	16
	Practical	
1.	Extraction of cellulose	3
2.	Extraction of Hemicellulose	3
3.	Extraction of lignin	4
4.	Extraction of wood extractives	3
5.	Extraction of ash content of wood	3
Total	16	

I. Course Title : Wood Physics

II. Course Code : FPU 512

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint with the physical characteristics and strength properties of wood.

V. Theory

UNIT I

Wood density, thermal, electrical and acoustic properties of wood. Mechanics and Rheology of wood, elasticity, plasticity and creep (tensile compression and bending strength)

UNIT II

Toughness, torsion, shear, hardness and abrasion strength. Acoustic and acousto-ultrasonics based non-destructive evaluation technique.

VI. Practical

- Determination of wood density;
- Study of thermal, electrical and acoustic properties of wood;
- Determination of tensile and bending properties of wood.

VII. Suggested Reading

Brown HP. 1925. *An Elementary Manual on Indian Wood Technology*. Central Publication Branch Government of India.

Dutta AC. 1964. *Botany for Degree Students*. Oxford University Press.

Franz FP, Kollmann and Wilfred AJC. 1968. *Principle of Wood Science and Technology*. Vol I. Solid wood. George Allen and Unwin Ltd London, Springer-Verlag, Berlin, Heidelberg.

Franz FP, Kollmann, Kuwnzi E and Stamm AJ. 1975. *Principle of Wood Science and Technology*. Wood based material. Vol. II Springer-Verlag, Berlin, Heidelberg.

Meyland BA and Butterfield BG (Eds). 1972. *Three-Dimensional Structure of Wood: A Scanning Electron Microscope Study*. Syracuse University Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Wood density, thermal, electrical and acoustic properties of wood.	4
2.	Mechanics and Rheology of wood, elasticity, plasticity and creep (tensile compression and bending strength)	5
3.	Toughness, torsion, shear, hardness and abrasion strength	4
4.	Acoustic and acousto-ultrasonics based non-destructive evaluation technique	3
	Total	16
	Practical	
1.	Determination of wood density,	7
2.	Study of thermal, electrical and acoustic properties of wood	5
3.	Determination of tensile and bending properties of wood	4
	Total	16

I. Course Title : Wood Seasoning and Preservation

II. Course Code : FPU 513

III. Credit Hours : 2+1

IV. Aim of the course

To understand the importance of wood seasoning and preservation for utilizing secondary timber for multipurpose use.

V. Theory

UNIT I

Wood water relationship, absorption behaviour and wood drying, Refractory and non refractory behaviour of wood, Wood seasoning, types- air, kiln and special seasoning methods like steaming, chemical, high temperature drying, vacuum drying and water conditioning.

UNIT II

Defects of timber- natural, seasoning defects, defects due to external agencies, machining defects. Effect of defects on utilization.

UNIT III

Detection and diagnosis of discolouration and decay in wood: decaying agencies- fungi, insects, borer, etc.

UNIT IV

Wood preservation: preservatives and treatment processes. Advantages and safety concern of wood preservatives, fire retardants. Graveyard test and anti-fungal activity of wood. Bio-preservation.

VI. Practical

- Determination of moisture content and swelling coefficients of different woods;
- Comparative studies on air and kiln dried woods;
- Analysis of decayed wood for physical and chemical parameters;
- Treatment of wood with different types of preservatives. Graveyard test.

VII. Suggested Reading

FAO. 2007. *Wood Preservation Manual*. International Book Distributor.

Hunt GM. 1967. *Wood Preservation* 3rd Ed. Mc GRAW-HILL Book Company.

Pandey CN and Jain VK. 1992. *Wood Seasoning Technology*. FRI, Dehradun.

Purushotham A, Pande JN and Jadhav. 1959. *Wood Preservation In India*. Manager of Publications.

Winn W. 1919. *Timbers and their Uses*. London George Rotledge & Sons Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Wood water relationship, absorption behaviour and wood drying	4
2.	Refractory and non refractory behaviour of wood	4
3.	Wood seasoning, types- air, kiln and special seasoning methods like steaming, chemical, high temperature drying, vacuum drying and water conditioning	6
4.	Defects of timber- natural, seasoning defects, defects due to external agencies, machining defects	4
5.	Effect of defects on utilization	2
6.	Detection and diagnosis of discolouration and decay in wood: decaying agencies- fungi, insects, borer, etc.	4
7.	Wood preservation: preservatives and treatment processes	2
8.	Advantages and safety concern of wood preservatives, fire retardants	2
9	Graveyard test and anti-fungal activity of wood. Bio-preservation	4
	Total	32

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Determination of moisture content and swelling coefficients of different woods	3
2.	Comparative studies on air and kiln dried woods	3
3.	Analysis of decayed wood for physical and chemical parameters	4
4.	Treatment of wood with different types of preservatives. Graveyard test	6
	Total	16

I. Course Title : Production of Medicinal and Aromatic Crops

II. Course Code : FPU 514

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with the plant production techniques.

V. Theory

UNIT I

Modes of reproduction in MAP crops and their relevance in maintaining genetic purity of crops. Concept of quality seed production and maintenance.

UNIT II

Soil fertility, essential nutrient elements- functions, deficiency symptoms, availability and factors affecting their availability. Soil micro-organisms and their role in organic matter decomposition. Importance of pH and C:N ratio in plant nutrition. Concept of bio-fertlizers and their potential for use in medicinal and aromatic crops.

UNIT III

Essentials of nursery production, criteria of site selection, and types of nursery, establishment of a model nursery. Nursery raising of medicinal plants. Tissue culture technique and *in-vitro* propagation of important MAPs.

UNIT IV

Plant protection measures in medicinal and aromatic crops, Quality parameters of seedlings and nursery stock.

VI. Practical

- Asexual/ vegetative reproduction techniques- cutting, budding, layering, etc.;
- Methods of seed collection and storage techniques;
- *In-vitro* propagation techniques;
- Determination of pH, organic matter and N,P,K from soil.

VII. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization of Medicinal Plants.* RRL, CSIR, Jammu-Tawi.

Chopra AK. 2007. *Medicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN. Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants*. CSIR, New Delhi.

EIRI Board. 2007. *Handbook of Medicinal and Aromatic Plants: Cultivation, Utilization and Extraction Processes*. Engineers India Research Institute, New Delhi.
Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.
Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.
Muralia S. 2006. *Medicinal and Aromatic Plants* 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Modes of reproduction in crop plants and their relevance in maintaining genetic purity of crops. Concept of quality seed production and maintenance	2
2.	Soil fertility, essential nutrient elements- functions, deficiency symptoms, availability and factors affecting their availability. Soil micro-organisms and their role in organic matter decomposition. Importance of pH and C:N ratio in plant nutrition. Concept of bio-fertlizers and their potential for use in medicinal and aromatic crops	5
3.	Essentials of nursery production, criteria of site selection, and types of nursery, establishment of a model nursery. Nursery raising of medicinal plants. Mode of plant propagation techniques. Tissue culture technique and *in-vitro* propagation of important MAPs	6
4.	Plant protection measures in medicinal and aromatic crops, Quality parameters of seedlings and nursery stock	3
	Total	16
	Practical	
1.	Asexual/ vegetative reproduction techniques-cutting, budding, layering, etc.	5
2.	Methods of seed collection and storage techniques	2
3.	*In-vitro*-propagation techniques	3
4.	Determination of pH, Organic matter and N,P,K from soil	6
	Total	16

I. Course Title : Medicinal and Aromatic Plants in Health Care Systems

II. Course Code : FPU 515

III. Credit Hours : 2 + 0

IV. Aim of the course

To acquaint the student with the importance of plants used in modern and AYUSH methods of treatment.

V. Theory

UNIT I

Concept of Health Care systems

UNIT II

Brief introduction to Ayurveda, Unani, Sidha, Homeopathy, Allopathy, Naturopathy, Electrohomoeopathy, etc.

UNIT III

Important medicinal plants used in treating various diseases in modern and complementary systems.

UNIT IV

Biological activity of selected medicinal plants. Methods of preparing poultices, decoctions, powders, tinctures, active content rich extracts.

VI. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu-Tawi.

Chopra AK. 2007. M*edicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN. Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants*. CSIR, New Delhi.

Cunningham A. 2014. *Applied Ethnobotany: "People, Wild Plant Use and Conservation*". Taylor & Francis.

Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.

Jain SK. 1968. *Medicinal Plants*. National book trust, New Delhi. Oxford & IBH, New Delhi.

Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.

Maheshwari JK. 2000. *Ethnobotany and Medicinal Plants of Indian Subcontinent*. Scientific Publishers,Jodhpur, India.

Muralia S. 2006. *Medicinal and Aromatic Plants* 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concept of Health Care systems	2
2.	Brief introduction to Ayurveda, Unani, Sidha, Homeopathy, Allopathy, Naturopathy, Electrohomoeopathy, etc.	10
3.	Important medicinal plants used in treating various diseases in modern and complementary systems.	6
4.	Biological activity of selected medicinal plants.	6
5.	Methods of preparing poultices, decoctions, powders, tinctures, active content rich extracts	8
	Total	32

I. Course Title : Pharmacognosy of Medicinal and Aromatic Plants

II. Course Code : FPU 516

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding about microscopical, macroscopical and chemical methods of drug identification.

V. Theory

UNIT I

History and scope of pharmacognosy, Pharmaceutical products. Classification of natural drugs. Chemical nature of drugs. Pharmacognostic analysis of drug plants based on botanical, chemical and histological features.

UNIT II

Evaluation based on pharmacopoeial standards for both single drugs and compound formulations most commonly used in different systems of medicines.

UNIT III

Pharmacognostic features of Sarpagandha, Jatamansi, Ashwagandha, Turmeric, Punarnava, *Ephedra, Gymnema*, Senna, Amla, Gokhru, Isabgol, Black pepper, Banafsha, Arjun or any other commercially species specific to the region.

VI. Practical

- Identification of drugs by morphological characters;
- Physical and chemical tests for evaluation of drugs;
- Gross anatomical studies of Ginger, Ashwagandha, Senna, *Gentiana*, Kalmegh, Sarpagandha, Mulhathi, *Aconitum* species or any other important species relevant to the region.

VII. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization of Medicinal Plants*.RRL, CSIR, Jammu-Tawi.

Chopra AK. 2007. *Medicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN, Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants*. CSIR, New Delhi.

Cunningham A. 2014. *Applied Ethnobotany: "People, Wild Plant Use and Conservation*". Taylor & Francis.

Cupp J and Tracy TS. 2003. *Dietary Supplements: Toxicology and Clinical Pharmacology*. Humana Press.

Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.

Gupta K, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Jain SK. 1968. *Medicinal Plants*. National book trust, New Delhi. Oxford & IBH, New Delhi.

Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.

Maheshwari JK. 2000. *Ethnobotany and Medicinal Plants of Indian Subcontinent*. Scientific Publishers,Jodhpur, India.

Muralia S. 2006. *Medicinal and Aromatic Plants*. 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	History and scope of pharmacognosy	1
2.	Pharmaceutical products. Classification of natural drugs. Chemical nature of drugs	3
3.	Pharmacognostic analysis of drug plants based on botanical, chemical and histological features	4
4.	Evaluation based on pharmacopoeial standards for both single drugs and compound formulations most commonly used in different systems of medicines	3
5.	Pharmacognostic features of Sarpagandha, Jatamansi, Ashwagandha, Turmeric, Punarnava, Ephedra, Gymnema, Senna, Amla, Gokhru, Isabgol, Black pepper, Banafsha, Arjun or any other commercially species specific to the region	5
	Total	16

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Identification of drugs by morphological characters	3
2.	Physical and chemical tests for evaluation of drugs	6
3.	Gross anatomical studies of Ginger, Ashwagandha, Senna, Gentiana, Kalmegh, Sarpagandha, Mulhathi, *Aconitum* species or any other important species relevant to the region	7
	Total	16

Course Title with Credit Load
Ph.D. (Forestry) in Forest Products and Utilization

Course Code		Course Title	Credit Hours
		Major Courses	
FPU 601*	I	Developments in Wood and Non-Wood Forest Products	3+0
FPU 602	II	Energy and Chemicals from Wood	2+0
FPU 603	I	Wood and Wood Technology	2+1
FPU 604*	II	Analytical Techniques in Forest Products	1+2
FPU 605	I	Chemistry of Medicinal and Aromatic Plants	2+1
FPU 606	II	Processing Technology of Forest Products	2+1
FPU 607	I	Value Addition and Marketing of Forest Products	2+1
FPU 608	II	Modern Trends in Wood Modification	2+1
FPU 609	I	Development in Pulp and Paper Technology	2+0
FPU 610	II	Application of Traditional Knowledge	2+0
FPU 611	I	Production of Quality Planting Material of Medicinal and Aromatic Plants	2+1
FPU 612	II	Processing Technology of Medicinal and Aromatic Plants	2+1
FPU 613	I	Biosynthesis of Secondary Metabolites	3+0
FPU 614	II	Value Additions and Marketing of Medicinal and Aromatic Plants	2+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Biology and Tree Improvement	06
		Supporting Courses	
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
FPU 691*	I/ II	Doctoral Seminar	1+0
FPU 692*	I/ II	Doctoral Seminar	1+0
		ii) Thesis Research	
FPU 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Forest Products and Utilization

I. Course Title : Developments in Wood and Non-wood Forest Products

II. Course Code : FPU 601

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint the students regarding updated and advance technology of timber mechanics, wood derivatives, export and import potential of non timber forest produce and computer applications in various forest products.

V. Theory

UNIT I

Mechanics of wood and wood composites, Application of orthotropic and non-linear constitutive relations, Laminate theory and failure criterion in the prediction of mechanical properties of solid woods; Wood-polymer; Hybrid composite processing.

UNIT II

Principles of industrial wood processes, products derived from wood by chemical processes and value added wood products, properties of construction, Wood polymers and surface chemistry, fundamentals of adhesion and fracture in adhesively bonded wood, adhesive systems used for wood with emphasis in wood based composites.

UNIT III

Methods of extraction, chemistry, processing, import and export potential of gums, resins, tannins, dyes, essential oils, fixed oils, cutch and katha, drugs, spices, poisons, insecticides, pesticides, wild edible fruits, etc.

UNIT IV

Computer application system in forest products, Use of information technologies to integrate material, quality and market fluctuations.

VI. Suggested Reading

Arnason JT, Rachel M and Romeo JT. 1995. *Phytochemistry of Medicinal Plants*. Springer, US.

Bowyer JL, Shmulsky R and Haygreen JG. 2003. *Forest Products and Wood Science: An Introduction. 4th Ed.* Blackwell Publishing.

Chung and Deborah DL. 2003. *Composite Materials-Functional Materials for Modern Technologies*. Springer,Verlag London.

David AT. 2013. *Forest Products: Advanced Technologies and Economic Analyses*. Elsevier.

Linskens HF and Jackson JF. 1991. *Essential Oils and Waxes (Ed.)*. Springer-Verlag Berlin Heidelberg.

Mathe A. 2015. *Medicinal and Aromatic Plants of the World-Scientific, Production, Commercial and Utilization Aspects*. Springer Netherlands.

Panda H. 2005. *Hand Book on Specialty Gums, Adhesive, Oils, Rosin and Derivatives, Resins, Oleoresins, Katha, Chemicals with others Natural Products*. Asia Pacific business press. Inc.

Rojas OJ. 2016. *Cellulose Chemistry and Properties: Fibers, Nanocelluloses And Advanced Materials (Ed.)*. Springer International Publishing.

Rowell RM. *Hand Book of Wood Chemistry and Wood Composites*. 2013. CRC press, Taylor and Francis group.

Shackleton S, Shackleton C and Shanley P. 2011. *Non-Timber Forest Products in the Global Context (Ed.)*. Springer, Verlag Berlin Heidelberg.

Sharma LC. 2012. *Development of Forests and Forest Based Industries*. M/s Bishen Singh Mahendra Pal Singh.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Mechanics of wood and wood composites	4
2.	Application of orthotropic and non-linear constitutive relations	2
3.	Laminate theory and failure criterion in the prediction of mechanical properties of solid woods	3
4.	Wood-polymer; Hybrid composite processing	4
5.	Principles of industrial wood processes, products derived from wood by chemical processes and value added wood products, properties of construction	6
6.	Wood polymers and surface chemistry	4
7.	Fundamentals of adhesion and fracture in adhesively bonded wood, adhesive systems used for wood with emphasis in wood based composites	3
8.	Methods of extraction, chemistry and processing of gums, resins, tannins, dyes, essential oils, fixed oils, cutch and katha, drugs, spices, poisons, insecticides, pesticides, wild edible fruits, etc.	8
9.	Import and export potential of gums, resins, tannins, dyes, essential oils, fixed oils, cutch and katha, drugs, spices, poisons, insecticides, pesticides, wild edible fruits, etc.	7
10.	Computer application system in forest products	2
11.	Use of information technologies to integrate material, quality and market fluctuations	2
	Total	45

I. Course Title : Energy and Chemicals from Wood

II. Course Code : FPU 602

III. Credit Hours : 2+0

IV. Aim of the course

To make students conversant with wood as a source of energy and utilization of wood residues and chemicals for different purposes.

V. Theory

UNIT I

Energy and its measurements. Wood as sources of energy and its comparison with other sources. Criteria for evaluation of different fuel wood species for energy.

UNIT II

Utilization of wood waste material as fuel. Gasification, pyrolysis and briquetting of lignocellulosic material. Production of chemicals from forest biomass cellulose, lignin and hemicelluloses. Important wood extractives

UNIT III

Wood refinery techniques. Chemicals produced as by product in pulp industry.

UNIT IV

Destructive distillation of wood. Future of wood chemical industry.

VI. Suggested Reading

Dimitris SA. 2007. *Materials, Chemicals, and Energy from Forest Biomass*. American Chemical Society.

Klass DL. 1998. *Biomass for Renewable Energy, Fuels and Chemicals*. Academic Press.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press.

Sjostrom E. 1993. *Wood Chemistry: Fundamentals and Applications*. 2nd Ed. Gulf Professional Publishing, Texas.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Energy and its measurements	2
2.	Wood as sources of energy and its comparison with other sources	3
3.	Criteria for evaluation of different fuel wood species for energy	3
4.	Utilization of wood waste material as fuel	4
5.	Gasification, pyrolysis and briquetting of lignocellulosic material	3
6.	Production of chemicals from forest biomass cellulose, lignin and hemicelluloses. Important wood extractives	6
7.	Wood refinery techniques	4
8.	Chemicals produced as by product in pulp industry	3
9.	Destructive distillation of wood. Future of wood chemical industry	4
	Total	32

I. Course Title : Wood and Wood Technology

II. Course Code : FPU 703

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about advances in wood technology

V. Theory

UNIT I

Ultrastructure and composition of softwoods and hardwoods.

UNIT II

Transverse, volumetric and longitudinal shrinkages in wood.

UNIT III

Biopulping, enzyme pulp bleaching, biotechnological production of wood composites, bioremediation of wood treated with preservatives, bioactive wood polymer composites, non-conventional wood bonding, wood degradation by chemicals, treatment of pulp effluents.

VI. Practical

- Study of major cell types of softwoods and hardwoods;
- Cell inclusions. Shrinkage and swelling of wood;
- Determination of anti-shrink efficiency of treated wood. Pulping, pulp yield and bleaching.

VII. Suggested Reading

Bowyer JL Shmulsky R and Haygreen JG. 2010. *Forest Products and Wood Science: An Introduction*. 4th Ed. Blackwell Publishing.

David A and Talliman. 1978. *Wood as an Energy Resource*. Academic Press.

Hills WE. 1982. *Heartwood and Tree Exudates*. Springer Verlag.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press,Taylor and Francis Group.

Shmulsky RP and David. 2011. *Forest Products and Wood Science: An Introduction*. 6th Ed. Wiley, Blackwell.

Sjostrom E. 1993. *Wood Chemistry: Fundamentals and Applications*. 2nd Ed. Gulf Professional Publishing.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Ultrastructure and composition of softwoods and hardwoods	6
2.	Transverse, volumetric and longitudinal shrinkages in wood	6
3.	Biopulping, enzyme pulp bleaching	4
4.	Biotechnological production of wood composites	4
5.	Bioremediation of wood treated with preservatives, bioactive wood polymer composites, non-conventional wood bonding	8
6.	Wood degradation by chemicals, treatment of pulp effluents	4
	Total	32
	Practical	
1.	Study of major cell types of softwoods and hardwoods	5
2.	Cell inclusions. Shrinkage and swelling of wood	5
3.	Determination of anti-shrink efficiency of treated wood. Pulping, pulp yield and bleaching	6
	Total	16

I. Course Title : Analytical Techniques in Forest Products

II. Course Code : FPU 604

III. Credit Hours : 1+2

IV. Aim of the course

To develop understanding of students about advances in research methods

V. Theory

UNIT I

Concept of spectroscopy, electromagnetic radiation, Beer-Lambert Law of electromagnetic radiation. Chemical analysis of spectrophotometery. Different spectrophotometric methods in chemical analysis. Principle and utilization of different instruments based on spectrophotomeric methods- atomic absorption, spectrophotometer, IR, UV, NMR, Mass spectrophotometer, etc. Chromatography and various chromatographic techniques in chemical analysis of plant samples. Principle and utilization of various chromatographic techniques and instruments- TLC, HPLC, Gas chromatography, etc.

UNIT II

Principle and utilization of CHN analyzer. Physico-chemical analysis of pulp and Paper.

VI. Practical

- Estimation of volatile and non volatile chemical constituents of plants through various techniques and instruments;
- Estimation of different elements in plant samples. Chemical analysis of pulp;
- Determination of physico-chemical analysis of pulp and Paper;
- Preparation of research project. Writing of research report.

VII. Suggested Reading

Harborne JB. 1998. *Phyto-Chemical Method*s. 3rd Ed. Springer Publication, New York.

Moore WE and Johnson DB. 1967. *Procedure for Chemical Analysis of Wood and Wood Products*. Forest Products Laboratory, Forest Service US Dept of Agriculture.

Raaman N. 2006. *Phytochemical Techniques*. New India Publishing Agency, New Delhi.

Rao KP. 2003. *Pulp and Technology*. CBS Publishing and Distributors, New Delhi.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press, New York.

Rydholm SA. 1965. *Pulping Process*. Inter-science Publishers.

Snyder LR, Kirkland JJ and Glajch JL. 1997. *Practical HPLC Method Development*. 2nd Ed. John Wiley & Sons.

Wilde KD and Engewald W. 2014. *Practical Gas Chromatography: A Comprehensive Reference*. Springer, Berlin.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concept of spectroscopy, electromagnetic radiation, Beer-Lambert Law of electromagnetic radiation. Chemical analysis of spectrophotometery. Different spectrophotometric methods in chemical analysis.	3
2.	Different spectrophotometric methods in chemical analysis. Principle and utilization of different instruments based on spectrophotomeric methods- atomic absorption, spectrophotometer, IR, UV, NMR, Mass spectrophotometer, etc.	5
3	Chromatography and various chromatographic techniques in chemical analysis of plant samples. Principle and utilization of various chromatographic techniques and instruments- TLC, HPLC, Gas chromatography, etc.	3
3.	Principle and utilization of CHN analyzer	2
4.	Determination of physico-chemical analysis of pulp and Paper	3
	Total	16

Practical

Sr. No	Topic	No. of Practical(s)
1.	Estimation of volatile and non volatile chemical constituents of plants through various techniques and instruments	8
2.	Estimation of different elements in plant samples	4
3.	Determination of physico-chemical analysis of pulp and Paper	6
4.	Preparation of research project. Writing of research report	14
	Total	32

I. Course Title : Chemistry of Medicinal and Aromatic Plants

II. Course Code : FPU 605

III. Credit Hours : 2+1

IV. Aim of the course

To expose the students on different aspects related to medicinal plants research and its application.

V. Theory

UNIT I

Detail study of biosynthetic pathways of terpenoides, steroids, alkaloids, phenolic compounds and amino acids.

UNIT II

Chemical studies of important insecticidal compounds of plant origin. Chemical conversion of some plant products to useful drugs.

UNIT III

Nature of postharvest degradation of active principles.

VI. Practical

- Extraction, purification, separation and structural determination of some important active principles of plants by various physical and chemical techniques;
- Structural determination of some important active principles of plants by various physical and chemical techniques.

VII. Suggested Reading

Chauhan NS. 1999. *Medicinal and Aromatic Plants of Himachal Pradesh*. Indus Publishing.

Mathe A. 2015. *Medicinal and Aromatic Plants of the World: Scientific, Production, Commercial and Utilization Aspects*. Springer.

Zohara Y and Bachrach U. 2005. *Handbook of Medicinal Plants*. CRC Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Detail study of biosynthetic pathways of terpenoides, steroids, alkaloids, phenolic compounds and amino acids	10
2.	Chemical studies of important insecticidal compounds of plant origin	6
3.	Chemical conversion of some plant products to useful drugs	8

Sr. No	Topic	No. of Practical(s)
4.	Nature of postharvest degradation of active principles	8
	Total	32

Practical

1.	Extraction, purification and separation of some important active principles of plants by various physical and chemical techniques	9
2.	Structural determination of some important active principles of plants by various physical and chemical techniques	7
	Total	16

I. Course Title : Processing Technology of Forest Products

II. Course Code : FPU 606

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about nutritional and post harvest aspects

V. Theory

UNIT I

Identification of harvesting period based on active content of drugs. Harvesting method of underground parts, leaves, stem, bark, wood, fruits, flowers, etc.

UNIT II

Processing of harvested crops of various forest products (*e.g.* Gums, Resin, Katha, Cutch, Tans, Dyes and fixed oil). Storage and value addition. Deterioration degradation of active principles during storage and their control.

UNIT III

Isolation of major bioactive compounds. Preparation of active content enriched extracts.

UNIT IV

Latest methods of extraction of volatile and fixed oil.

VI. Practical

- Harvesting, drying, grading and packaging of various forest products;
- Assessment of deterioration of active principles during storage and their control;
- Preparation of active content enriched extracts of important forest products.

VII. Suggested Reading

Bedi S, Singh T and Vyas SP. 2012. *A Handbook of Aromatic and Essential Oil Plants: Cultivation, Chemistry, Processing and Uses.* Agrobios (India).

Dawn CPA, Annamalai M and Naik R. 2016. *Leafy Medicinal Herbs: Botany, Chemistry, Postharvest Technology and Uses.* CABI.

Serdar O and Milan M. 2014. *Medicinal and Aromatic Crops: Harvesting, Drying and Processing.* CRC Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Identification of harvesting period based on active content of drugs	3
2.	Harvesting method of underground parts, leaves, stem, bark, wood, fruits, flowers, etc.	4
3.	Processing of harvested crops of various forest products (*e.g.* Gums, Resin, Katha, Cutch, Tans, Dyes and fixed oil)	5
4.	Storage and value addition	4
5.	Deterioration degradation of active principles during storage and their control	4
6.	Isolation of major bioactive compounds	5
7.	Preparation of active content enriched extracts	4
8.	Latest methods of extraction of volatile and fixed oil	3
	Total	32
	Practical	
1.	Harvesting, drying, grading and packaging of various forest products.	5
2.	Assessment of deterioration of active principles during storage and their control	5
3.	Preparation of active content enriched extracts of important forest products	6
	Total	16

I. Course Title : Value Additions and Marketing of Forest Products

II. Course Code : FPU 607

III. Credit Hours : 2+1

IV. Aim of the course

This course will educate students, methods of harvesting of yieldable plant/ plant parts of herb shrub, trees, etc. to increase the value of product, post harvest technology and will make them aware about instruments/ equipments used to extract essential oil and also operation of machines for preparation of tablets, mixture, tinctures, etc.

V. Theory

UNIT I

Value addition – concepts and procedures. Drying and grading of various forest products. Preparation of powders, aqueous and alcoholic extracts essences, etc. Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging.

UNIT II

Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector. Village and regional markets, state, national and international market of forest products. Internet marketing practices for latest market value and other pattern of fluctuations for high value forest products. Concept of e-market and quality standards.

VI. Practical

- Visit to nearby pharmaceutical concern for understanding value addition processes;
- Visit to local market and data collection of sale and sale procedure – organized and unorganized. Internet surfing for latest market value of high value forest products.

VII. Suggested Reading

Govil JN, Arunachalam C and Singh VK. 2006. *Recent Progress in Medicinal Plants*. Volume11: drug development from molecules. Studium Press LLC.

Sharma AK and Singh VK, Govil JN and Goyal NK. 2006. *Recent Progress in Medicinal Plants*. Volume 12: Globalization Of Herbal Health. Studium Press LLC.

Singh MP and Somadey. 2015. *Indian Medicinal Plants*. Satish Serial Publishing House.

Singh VK, Govil JN and Singh G. 2002. *Ethnomedicine and Pharmacognosy*. Science Technology, Publishing LLC.

Syamal MM. 2008. *Production Technology of Medicinal and Aromatic Plants*. IBDC Publishers.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Value addition – concepts and procedures	3
2.	Preparation of powders, aqueous and alcoholic extracts, essences, etc.	5
3.	Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging	6
4.	Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector	5
5.	Village and regional markets, state, national and international market of herbs and herbal forest products	5
6.	Internet marketing practices for latest market value and other pattern of fluctuations for high value forest products	6
7.	Concept of e-market and quality standards	2
	Total	32
	Practical	
1.	Visit to nearby pharmaceutical concern for understanding value addition processes	6
2.	Visit to local market and data collection of sale and sale procedure – organized and unorganized. Internet surfing for latest market value of high value forest products	10
	Total	16

I. Course Title : Modern Trends in Wood Modification

II. Course Code : FPU 608

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about advances in wood modification.

V. Theory

UNIT I

Engineered wood products. Wood polymer hybrid composites. Stabilization of wood preservatives.

UNIT II

Testing of biological performance of modified wood products. Degradation of cellular structure of wood during use.

UNIT III

Environmental issues related to wood modification.

VI. Practical

- Different preservative treatments of wood;
- Chemical modification of wood;
- Testing of biological performance of modified wood;
- Treated wood finishing.

VII. Suggested Reading

Ansell MP. 2015. *Wood Composites*. Elsevier-Science-Technology.

FAO. 2007. *Wood Preservation Manual*. International Book Distributor, Dehradun.

Hill CAS. 2006. *Wood Modification: Chemical, Thermal and Other Processes*. John Wiley and Sons Ltd.

Pizzi A and Mittal KL. 2011. *Wood Adhesives*. CRC Press.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press.

USDA. 1999. *Wood Handbook – Wood as an Engineered Material*. US Department of Agriculture, Forest Service. Forest Products Laboratory, Madison.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Engineered wood products	5
2.	Wood polymer hybrid composites	7
3.	Stabilization of wood preservatives	5
4.	Testing of biological performance of modified wood products	6
5.	Degradation of cellular structure of wood during use	5
6.	Environmental issues related to wood modification	4
Total	32	
	Practical	
1.	Different preservative treatments of wood	5
2.	Chemical modification of wood	5
3.	Testing of biological performance of modified wood. Treated wood finishing	6
	Total	16

I. Course Title : Development in Pulp and Paper Technology

II. Course Code : FPU 609

III. Credit Hours : 2+0

IV. Aim of the course

To impart advanced knowledge related to different aspects of pulp and paper technology.

V. Theory

UNIT I

Historical development of the pulp and paper industry. Chemistry of fibrous raw material – raw material preparation.

UNIT II

Advances in pulping processes for softwood, hardwoods and other fibrous material. Recent trends in Bio-pulping, Chorine free bleaching, organo solve pulping.

UNIT III

Nenotechnology in pulp and paper making. Substation of wood with recycled fibers.

UNIT IV

Reduction in water utilization and effluent discharge.

VI. Suggested Reading

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites.* 2nd Ed. CRC Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Historical development of the pulp and paper industry	3
2.	Chemistry of fibrous raw material – raw material preparation	4
3.	Advances in pulping processes for softwood, hardwoods and other fibrous material	6
4.	Recent trends in Bio-pulping, Chorine free bleaching, organo solve pulping	7
5.	Nenotechnology in pulp and paper making	4
6.	Substation of wood with recycled fibers	4
7.	Reduction in water utilization and effluent discharge	4
	Total	32

I. Course Title : Application of Traditional Knowledge

II. Course Code : FPU 610

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding of students about application of traditional knowledge.

V. Theory

UNIT I

Traditional remedies for treating specific diseases like cardiovascular disease, mental disorders, rheumatic arthritis, diabetes, cough and asthma, fatigue, liver diseases, kidney and bladder stones, wounds stomach disorders, etc. Traditional therapies *vis-a-vis* modern therapies.

UNIT II

Scientific validation of traditional systems of medicines/ remedies – case studies. Important herbs used in traditional medicines. Integration of herbal remedies with allopathic system of medicine. Allopathic drugs based on medicines herbs.

UNIT III

National and international research and other institutions involved in scientific validation of traditional knowledge eg. CDRI, CIMAP, RRL's, CCRAS, WHO, etc., their role and major achievements.

UNIT IV

Composition of major herbal formulations e.g. Chavanprash, Vasavaleha, Arjunarishta, Pachakchurna, etc. Major herbal pharmaceutical companies and their products like Dabur, Zandhu, Baidyanath, Himalayan Drug Company, Charak Pharmaceuticals, etc. Role of local health traditions in primary health care.

VI. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Johnson CB and Franz C. 2005. *Breeding Research on Aromatic and Medicinal Plants*. International Book Distr.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Traditional remedies for treating specific diseases like cardiovascular disease, mental disorders, rheumatic arthritis, diabetes, cough and asthma, fatigue, liver diseases, kidney and bladder stones, wounds stomach disorders, etc.	5
2.	Traditional therapies *vis-a-vis* modern therapies	3
3.	Scientific validation of traditional systems of medicines/ remedies – case studies	4
4.	Important herbs used in traditional medicines. Integration of herbal remedies with allopathic system of medicine	4
5.	Allopathic drugs based on medicines herbs	2
6.	National and international research and other institutions involved in scientific validation of traditional knowledge eg. CDRI, CIMAP, RRL's, CCRAS, WHO, etc., their role and major achievements	3
7.	Composition of major herbal formulations e.g. Chavanprash, Vasavaleha, Arjunarishta, Pachakchurna, etc.	4

Sr. No.	Topic	No. of Lecture(s)
8.	Major herbal pharmaceutical companies and their products like Dabur, Zandhu, Baidyanath, Himalayan Drug Company, Charak Pharmaceuticals, etc.	5
9.	Role of local health traditions in primary health care	2
	Total	32

I. Course Title : Production of Quality Planting Material of Medicinal and Aromatic Plants

II. Course Code : FPU 611

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about production of quality planting material.

V. Theory

UNIT I

Concept of quality in the context of medicinal and aromatic plants. Quality parameters of different medicinal and aromatic plants.

UNIT II

Role of genotype and environment in affecting quality. Selection and development of hybrids in medicinal and aromatic plants.

UNIT III

Breeders seed, foundation seed and certified seed. Marker assisted breeding. Authentication of nursery produce for quality parameters. Different approaches including biotechnological tools for production of quality planting material.

VI. Practical

- Production of inbred seed of commercially important species;
- Selection of superior genotypes on the basis of agronomical characters from an existing population of medicinal and aromatic plants;
- Evaluation of germplasm for yield attributes.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Johnson CB and Franz C. 2005. *Breeding Research on Aromatic And Medicinal Plants*. International Book Distr.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publications.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Concept of quality in the context of medicinal and aromatic plants	2
2.	Quality parameters of different medicinal and aromatic plants	7
3.	Role of genotype and environment in affecting quality	4
4.	Selection and development of hybrids in medicinal and aromatic plants. Breeders seed, foundation seed and certified seed	6
5.	Marker assisted breeding	3
6.	Authentication of nursery produce for quality parameters	5
7.	Different approaches including biotechnological tools for production of quality planting material	5
	Total	32
	Practical	
1.	Production of inbred seed of commercially important species	5
2.	Selection of superior genotypes on the basis of agronomical characters from an existing population of medicinal and aromatic plants	6
3.	Evaluation of germplasm for yield attributes	5
	Total	16

I. Course Title : Processing Technology of Medicinal and Aromatic Plants

II. Course Code : FPU 612

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about nutritional and post harvest aspects of medicinal and aromatic plants.

V. Theory

UNIT I

Identification of maturity indices and harvesting period based on active content. Harvesting method of underground parts, leaves, stem, bark, fruits, flowers, etc.

UNIT II

Processing of harvested crops of medicinal and aromatic plants. Storage and value addition. Deterioration/ degradation of active principles during storage and their control.

UNIT III

Isolation of major bioactive compounds from medicinal plants, preparation of active content enriched extracts.

UNIT IV

Advances in extraction of essential oil.

VI. Practical

- Harvesting, drying, garbling, grading and packaging of medicinal and aromatic plants;
- Assessment of deterioration of active principles during storage and their control;
- Preparation of active content enriched extracts of important medicinal plants.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture.* Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Mann J 1994. *Chemical Aspects of Biosynthesis*. Oxford Chemistry Primers.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Identification of maturity indices and harvesting period based on active content	4
2.	Harvesting method of underground parts, leaves, stem, bark, fruits, flowers, etc.	4
3.	Processing of harvested crops of medicinal and aromatic plants	5
4.	Storage and value addition.	4
5.	Deterioration/ degradation of active principles during storage and their control	3
6.	Isolation of major bioactive compounds from medicinal plants, preparation of active content enriched extracts	8
7.	Advances in extraction of essential oil	4
	Total	32
	Practical	
1.	Harvesting, drying, garbling, grading and packaging of medicinal and aromatic plants	5
2.	Assessment of deterioration of active principles during storage and their control	6
3.	Preparation of active content enriched extracts of important medicinal plants	5
	Total	16

I. Course Title : Biosynthesis of Secondary Metabolites

II. Course Code : FPU 613

III. Credit Hours : 3+0

IV. Aim of the course

To develop understanding of students about biosynthesis of secondary metabolites.

V. Theory

UNIT I

Primary and secondary metabolites. Building blocks for secondary metabolites. Common reactions involved in the biosynthesis of secondary metabolites. Effect of environmental factors on production of secondary metabolites.

UNIT II

Biosynthetic pathways of terpenoids (mono, sesqui, di, tri and tetraterpenoids) and steroids.

UNIT III

Biosynthesis of alkaloids of phenylethylamine. Pyrrolidine piperidine, pyrrolidine – pyridine, tropane, quinoline, isoquinoline and phenanthrene groups.

UNIT IV

Biosynthesis of flavonoids, lignans (podophyllotoxin) and Vitamins E and K.

VI. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta K and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Mann J 1994. *Chemical Aspects of Biosynthesis*. Oxford Chemistry Primers.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Primary and secondary metabolites	4
2.	Building blocks for secondary metabolites	4
3.	Common reactions involved in the biosynthesis of secondary metabolites	7
4.	Effect of environmental factors on production of secondary metabolites	4
5.	Biosynthetic pathways of terpenoids (mono, sesqui, di, tri and tetraterpenoids) and steroids	8
6.	Biosynthesis of alkaloids of phenylethylamine. Pyrrolidine piperidine, pyrrolidine – pyridine, tropane, quinoline, isoquinoline and phenanthrene groups	10
7.	Biosynthesis of flavonoids, lignans (podophyllotoxin) and Vitamins E and K	8
	Total	45

I. Course Title : Value Additions and Marketing of Medicinal and Aromatic Plants

II. Course Code : FPU 614

III. Credit Hours : 2+1

IV. Aim of the course

This course will educate students, methods of harvesting of yieldable plant/ plant parts of herb, shrub, trees, climber, lianas and ephipytes. To increase the value of product, post harvest technology will be known to them, practical classes will make them aware about instruments/ equipments used to extract essential oil and also operation of machines for preparation of tablets, mixture, tinctures, etc.

V. Theory

UNIT I

Value addition for higher economic returns. Concepts and procedures. Preparation of powders, aqueous and alcoholic extracts, essences, etc. Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging of medicinal and aromatic plants.

UNIT II

Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector. Village and regional markets, state, national and international market of herbs and herbal products. Internet marketing practices for latest market value and other pattern of fluctuations for high value medicinal and aromatic plants/ plant parts and products. Concept of e-market and quality standards.

VI. Practical

- Visit to nearby pharmaceutical concern for understanding value addition processes;
- Visit to local market and data collection on sale and sale procedure – organized and unorganized;
- Internet surfing for latest market value of high value of medicinal and aromatic plants.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta K and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Mann J 1994. *Chemical Aspects of Biosynthesis*. Oxford Chemistry Primers.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Value addition for higher economic returns. Concepts and procedures	4
2.	Preparation of powders, aqueous and alcoholic extracts, essences, etc.	5
3.	Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging of medicinal and aromatic plants	5
4.	Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector	5
5.	Village and regional markets, state, national and international market of herbs and herbal products	5
6.	Internet marketing practices for latest market value and other pattern of fluctuations for high value medicinal and aromatic plants/ plant parts and products	6
7.	Concept of e-market and quality standards	2
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Visit to nearby pharmaceutical concern for understanding value addition processes	6
2.	Visit to local market and data collection on sale and sale procedure – organized and unorganized. Internet surfing for latest market value of high value of medicinal and aromatic plants	10
	Total	16

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry
– Forest Resource Management

Course Title with Credit Load
M.Sc. (Forestry) in Forest Resource Management

Course Code	Course Title		Credit Hours
	Major Courses		
FRM 501*	I	Forest Biometry and Management	2+1
FRM 502	II	Ecology and Management of Forest Soils	2+1
FRM 503*	I	Remote Sensing and Geographical Information System in Natural Resource Management	2+1
FRM 504	II	Land Use Planning and Watershed Management	2+1
FRM 505*	I	Forest Resource Economics	1+1
FRM 506*	II	Forest Ecosystem Services and Valuation	2+1
FRM 507	I	Environmental Impact Assessment and Auditing	1+1
FRM 508*	II	Forest Policy, law and International Conventions	2+0
FRM 509	I	Global Climate Change Impact, Mitigation and Adaptation	2+0
FRM 510*	II	Participatory Approaches in Forest Resource Management	1+1
FRM 511	I	Management of Tree Insect-Pests and Diseases	2+1
FRM 512	II	Forest Ecology, Biodiversity and Management	2+1
	Minor Courses		
		Courses from Silviculture and Agroforestry or Forest Biology and Tree Improveemnt or Forest Products and Utilization	08
	Supporting Courses		
FOR 511*	I	General Statistical Methods and Computer Applications	2+1
		Any other course relavent to MSc research problem	03
	Common Courses		
		Library and Information Services	1+0
		Technical Writing and Communications Skills	1+0
		Intellectual Property and its management in Agriculture	1+0
		Basic Concepts in Laboratory Techniques	1+0
		Agricultural Research, Research Ethics and Rural Development Programmes	1+0
FRM 591*	I/ II	Master's Seminar	1+0
		ii) Thesis Research	
FRM 599		Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Forest Resource Management

I. Course Title : Forest Biometry and Management

II. Course Code : FRM 501

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge about forest management, ecosystem management, site quality evaluation, stand density and forest valuation, tree measurements, forest inventory and yield concepts

V. Theory

Unit I

Measurement of tree parameters. Estimation of volume, growth and yield of individual tree and forest stands. Preparation of volume tables and its application, yield and stand tables.

Unit II

Forest inventory, Sampling methods adopted in forestry, Use of GPS in forest inventory. Measurement of stand density. Simulation techniques.

Unit III

Principles of forest management; scope and object of forest management, ecosystem management, development of forest management in India. Site quality evaluation and importance. Stand density measurement.

Unit IV

Forest valuation and appraisal in regulated forests.

Unit V

Growth and yield prediction models – their preparation and applications.

VI. Practical

- Calculations of volume of felled as well as standing trees;
- Volume table preparation;
- Application of sampling procedures;
- Handling of GPS;
- Preparation of yield and stand table.

VII. Suggested Reading

Chaturvedi AN and Khanna LS. 1994. *Forest Menstruation*. International Book Distributor.
Davis LS and Johnson KN. 2005. *Forest Management*. Waveland Press.
Husch B, Miller CI and Beers TW. 2003.*Forest Menstruation*. John Wiley.
John AK, Ducey MJ, Beers TW and Husch B. 2017. *Forest Mensuration*. Wiley Blackwel.
Laar A Van and Akca A. 2007. *Forest Mensuration*. Springer, Netherlands.
Loctsch I and Haller KE. 1964. *Forest Inventory* Vol. and Vol II. BLV Verlagsgesellschaft, München, Germany.

Michacl S Philip. 1994. *Measuring Forests and Trees*. CAB International.
Prodan M. 1968. *Forest Biometrics*. Pergamn Press.
Ram Parkash. 1983. *Forest Surveying*. International Book Distr.
Sharpe GW, Hendee CW and Sharpe WE. 1986. *Introduction to Forestry*. McGraw-Hill.
Simmons CE. 1980. *A Manual of Forest Mensuration*. Bishen Singh Mahender Pal Singh, Dehradun.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Measurement of tree parameters. Estimation of volume, growth and yield of individual tree and forest stands	2
2.	Preparation of volume tables and their application	2
3.	Preparations of Yield and stand tables, their application	2
4.	Forest Inventory, Sampling methods adopted in Forestry, Kinds of enumeration, Kinds of sampling Advantages of sampling, Sampling design, Sampling Intensity and Sampling errorsUse of aerial Photography in Forest Inventory	5
5.	Use of GPS in Inventory	2
6.	Principles of forest management, scope and object of forest management	2
7.	Ecosystem management, development of forest management in India	2
	Site quality evaluation and importance: Site Index, Methods of site quality evaluation, Methods of determining past growth of stands Canopy Density, Crown Competition Factor	4
8.	Stand Density Measurement: Measure of stand density, Absolute measures of stand density, Stand density index, Stand density versus stocking	4
9.	Forest Valuation and appraisal in regulated forests	3
10.	Growth and yield prediction models- their preparation and applications	4
11.	Simulation techniques	2
	Total	36
	Practical	
1.	Calculations of volume of felled as well as standing trees	3
2.	Volume table preparation	4
3.	Application of sampling procedures	3
4.	Handling of GPS	2
5.	Preparation of yield and stand table	4
	Total	16

I. Course Title : Ecology and Management of Forest Soils

II. Course Code : FRM 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart information on the soil types and properties of soils under different forest ecosystems, chemical and biological dimensions of soil fertility, and forest soil fertility evaluation and management.

IV. Theory

Unit I

Forest soils – distinguishing features, soils and vegetation development, physical and chemical properties- Types and properties of soils under different forest ecosystems.

Unit II

Forest floor – Organic horizons- litter dynamics- humus – types- organic matter decomposition-mineralization and immobilization of organic matter- nutrient cycling significance of C:N ratio, soil pH.

Unit III

Forest soil biology – soil fauna – nitrogen fixation – rhizobium-tree legume symbiosis *Frankia* x non-legume symbiosis, nitrification and denitrification in forest ecosystems. Micorrhizal associations in forest soils.

Unit IV

Nursery soils, problem soils, mineral nutrition, acidic deposition effects, fire effects and management interventions of forest soils.

VI. Practical

- Study of the soil profile;
- Mechanical analysis;
- Determination of pH;
- Organic C, CEC and available,
- Micro and macro nutrients;
- Manurial schedules for different soils.

VII. Suggested Reading

Brady NC and Weil RR. 2007. *The Nature and Properties of Soils.* 14th Ed., Prentice

Fisher RF and Binkley D. 2000. *Ecology and Management of Forest Soils.* John Wiley & Sons, Inc. New York.

Hall, New Jersey.

Stevenson FJ and cole MA. 1999. *Cycles of soil; Carbon, Nitrogen, Phosphorus, Sulphur, micronutrients.* John Wiley & Sons Inc. New York.

Tisdale LS, Nelson LW and Beaton JD. 1985. *Soil Fertility and Fertilizers.* Macmillan Publishing Company, New York.

Troeh FR and Thompson LM. 2005. *Soils and Soil Ferility.* Black well.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest soils – distinguishing features – soils and vegetation development	3
2.	Physical and chemical properties- Types and properties of soils under different forest ecosystems	3
3.	Forest floor: Organic horizons and litter dynamics	3
4.	Humus – types- organic matter decomposition-mineralization and immobilization of organic matter	4
5.	Nutrient cycling, significance of C:N ratio, soil pH	3
6.	Forest soil biology, soil fauna, nitrogen fixation. Rhizobium-tree legume symbiosis. *Frankia* x non-legume symbiosis	4

Sr. No	Topic	No. of Lecture(s)
7.	Nitrification and denitrification in forest ecosystems. Micorrhizal associations in forest soils	3
8.	Nursery soils, problem soils, mineral nutrition, acidic deposition effects	5
9.	Effect of forest fire and management interventions of forest soils	4
	Total	32
	Practical	
1.	Study of the soil profile	1
2.	Mechanical analysis of soil	3
3.	Determination ofpH, EC, organic carbon	2
4.	Determination ofCEC	2
5.	Determination of availableN, P, K, Ca, Mg and S	3
6.	Determination of micro-nutrients-Cu, Zn, Mn and Fe	2
7.	Manurial schedules for different soils	3
	Total	16

I. Course Title : Remote Sensing and Geographical information System in Forest resource management

II. Course Code : FRM 503

III. Credit Hours : 2+1

IV. Aim of the course

To impart practical knowledge to the students on geomatics and its application in natural resource management

V. Theory

Unit I

Satellite remote sensing and recent developments in geomatics, different satellite missions of India and abroad. Spatial and spectral resolution of different data products and applications.

Unit II

Geo-referencing of topo-sheets and satellite imageries, Satellite Image Interpretation, Digital Image Processing (DIP)-image registration, image enhancement, classification, supervised and unsupervised classification.

Unit III

RS softwares, Application of Remote Sensing in forest resource management-land-use and land cover mapping, vegetation mapping and change detection, forest biomass and carbon mapping and monitoring, forest damage as sessment (pests and diseases, mining, fire), forest fire risk zonation and mapping, Watershed delineation and mapping, wildlife habitat assessment, etc.

Unit IV

GIS for the collection, storage and spatial analysis for geo-referenced forest resources data and information. Integration of spatial data analysis systems with knowledge-based systems and/ or simulation systems for the development of information/ decision support systems for forest management. GIS application in FRM.

VI. Practical

- Thematic layers build up, overlaying and their integration using ERDAS and Arc GIS software package;
- Interpretation of satellite data and digital image processing;
- Preparation of thematic maps;
- Preparation forest biomass and carbon map, fire affected areas assessment, preparation of change detection map, classification of LULC using ERDAS and Arc GIS softwares.

VII. Suggested Reading

A Preliminary Overview. *Journal of Latin American Geography*.

Bolstad P. 2005. *GIS Fundamentals: A first text on Geographic Information Systems, Second Edition*. White Bear Lake, MN: Eider Press.

Buzai GD and Robinson D. 2010. *Geographical Information Systems in Latin America*, 1987-2010.

Campbell JB and Randolph HW. 2011. *Introduction to Remote Sensing*. Fifth Edition, The Guild Press, New York.

Chang K. 2007. *Introduction to Geographic Information System, 4th Edition*. McGraw Hill.

Elangovan N. 2006. *GIS Fundamentals, applications and implementation*. New India Publ.Agncy, New Delhi.

Gurugnanam B. 2009. *Geographic Information System*. New India Publ. Agency, New Delhi.

Harvey and Francis. 2008. *A Primer of GIS, Fundamental geographic and cartographic concepts*. The Guilford Press.

Jackson MJ. 1992. *Integrated Geographical Information Systems*. International Journal of Remote Sensing.

Joseph G. 2005. *Fundamentals of Remote Sensing*, Second edition. Universities Press.

Lillesand TM and Kiefer WR. 1994. *Remote sensing and Image Interpretation*, Fourth edition. John Wiley & Sons, Inc., USA.

Reddy AM. 2014. *Text book of Remote Sensing and Geographic Information System*. 4th edition, BS Publication, Hyderabad.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Remote sensing: Introduction, definition, brief history, fundamental principle of RS, Stages of RS, Classification of RS: Active and Passive RS- based on source of energy and wavelength; Aerial and space remote sensing, Merits and limitations of RS. Recent developments in geomatics. Different satellite missions of India and abroad	6
2.	Remote sensing platforms-ground aerial and space platforms, satellite orbits, Resolution- spatial, spectral, radiometric and temporal; Scanning systems- whisk broom and push broom scanners; Sensor system- MSS, ETM, MSS, LISS, etc.	6
3.	Image analysis: Definition, visual image analysis, digital image analysis, elements of image analysis and steps in digital image processing. Agencies involved in remote sensing	4
4.	Application of RS in forestry: Vegetation cover classification and mapping-NDVI, SAVI, EVI, status and monitoring, species identification, social and agro-forestry applications, growing stock estimation, biodiversity characterization, wildlife habitat	

Sr. No	Topic	No. of Lecture(s)
	suitability mapping, biomass and carbon mapping, etc.	6
5.	Geoinformatics and GIS meaning, objectives, elements of GIS-software, hardware, data ware, human ware, processes involved in GIS, Raster data, vector data, thematic overlay building. Application of GIS to forest resource management	5
6.	GPS: Global Positioning System-meaning, principles, applications, GNSS, IRNS, GAGAN, etc.	3
	Total	30

Practical

1.	Thematic layers build up, overlaying and their integration using ERDAS and ArcGIS Software package	4
2.	Interpretation of satellite data and digital image processing	4
3.	Preparation of thematic maps	3
4.	Preparation forest biomass and carbon map, fire affected areas assessment, preparation of change detection map, classification of LULC using ERDAS and ArcGIS softwares	5
	Total	16

I. Course Title : Land Use Planning and Watershed Management

II. Course Code : FRM 504

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about land use planning and watershed management. Developing sustainable agroforestry systems/ techniques in watershed.

V. Theory

Unit I

Land use Planning: Concepts and techniques; Agro-ecological regions/ sub-regions of India; factors affecting land use; soil and land use survey through remote sensing techniques.

Unit II

Interpretation of soil resource map for land use planning; land evaluation methods and soil-site suitability evaluation for different crops.

Unit III

Watershed management concept- objectives, characterization, planning, execution, community participation and evaluation.

Unit IV

Developing economically and ecologically sustainable agroforestry systems for watersheds; water harvesting and its efficient use; rehabilitation of watersheds. Suitable tree planting techniques in watersheds. Suitable trees/ shrubs and grasses for watershed for different agro-climatic regions.

Unit V

Watershed management cases studies. Drought and flood mapping and its relevance in designing sustainable cropping systems.

VI. Practical

- Study of Agro-ecological regions/ sub-regions of India;
- Soil and land use survey through remote sensing technique;
- Interpretation of soil resource map for land use planning; land evaluation methods and soil-site suitability evaluation for different crops;
- Watershed characterisation, planning, execution, community participation and evaluation.Suitable tree planting techniques in watersheds;
- Suitable trees/ shrubs and grasses for watershed for different agro-climatic regions.
- Watershed management cases studies;
- Drought and Flood mapping and its relevance in designing sustainable cropping systems.

VII. Suggested Reading

Michael AM and Ojha TP. 1966. *Principles of Agricultural Engineering*, Jain Brothers, Jodhpur.

Michael AM. 2008. *Irrigation Theory and Practice*. Vikas Publishing House Pvt Ltd.

Murthy JVS. 1998. *Watershed Management*. New Age International, New Delhi.

Murthy VVN. 1985. *Land and water management engineering*. Kalyani Publishers, New Delhi.

Narayana DVV, G Sastry and US Patnaik. 1997. *Watershed Management*. Indian Council of Agricultural Research, New Delhi.

Narayana DVV. 1993. *Soil and Water Conservation Research in India*, ICAR, New Delhi.

Singh G *et al*. 1988. *Manual of Soil and Water Conservation*. Oxford IBH Publishing Co. New Delhi.

Subramanya K. 2006. *Engineering Hydrology*, Tata McGraw Hill publication.

USDA. 1961. *A Manual on Conservation of Soil and Water*. Oxford and IBH Publishing Company.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Land use Planning: concepts and techniques; Agro-ecological regions/ sub-regions of India	3
2.	Factors affecting land use; soil and land use survey through remote sensing technique	3
3.	Interpretation of soil resource map for land use planning	2
4.	Land evaluation methods and soil-site suitability evaluation for different crops	4
5.	Watershed management concept- objectives, characterization, planning, execution, community participation and evaluation	5
6.	Developing economically and ecologically sustainable agroforestry systems for watersheds; water harvesting and its efficient use; rehabilitation of watersheds	4
7.	Suitable tree planting techniques in watersheds	2
8.	Suitable trees/ shrubs and grasses for watersheds for different agroclimatic regions	2
9.	Watershed management cases studies	4
10.	Drought and flood mapping and its relevance in designing sustainable cropping systems	3
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Study of Agro-ecological regions/ sub-regions of India	2
2.	Soil and land use survey through remote sensing technique	2
3.	Interpretation of soil resource map for land use planning; land evaluation methods and soil-site suitability evaluation for different crops	3
4.	Watershed characterisation, planning, execution, community participation and evaluation. Suitable tree planting techniques in watersheds	3
5.	Suitable trees/ shrubs and grasses for watershed for different agro-climatic regionsWatershed management cases studies	3
6.	Drought and Flood mapping and its relevance in designing sustainable cropping systems	3
	Total	16

I. Course Title : Forest Resource Economics

II. Course Code : FRM 505

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about forest resource management and economics management decisions, forest and environmental resource accounting.

V. Theory

Unit I

Principles of microeconomics and its application in forest resource management. Demand, supply and marketing of forest products. Theory of capital and application in forest resource management.

Unit II

Domestic and international trade in forest products. Impact of soicio-economic variables on forest appraisal and management decisions. Externalities and property rights.

Unit III

Natural and environmental resource accounting –methods and implications. Application of operational research tools in evaluating forest management alternatives in public and private forest planning and valuation.

VI. Practical

- Exercises on estimation of demand and supply functions;
- Biodiversity valuation, valuation of non-marketed forest products;
- Exercises on financial and economic appraisal of forestry projects;
- Exercises on marketing of forest products and international trade competitiveness;
- Computer applications for using programming techniques in evaluating forest management alternatives.

VII. Suggested Reading

FAO. 1986. *Guidelines to Practical Project Appraisal*. Natraj Publ.

Kerr JM, Marothia DK, Singh K, Ramaswamy C and Beritley WR. 1997. *Natural Resource Economics: Theory and Applications in India*. Oxford and IBH.

Nautiyal JC. 1988. *Forest Economics – Principles and Applications*. Natraj Publications, Dehradun.

Sharma LC. 1980. *Forest Economics, Planning and Management*. International Book Distributors, Dehradun.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Principles of microeconomics and its application in forest resource management	3
2.	Demand, supply and marketing of forest products. Theory of capital and application in forest resource management	4
3.	Domestic and international trade in forest products	1
4.	Impact of soicio-economic variables on forest appraisal and management decisions. Externalities and property rights	3
5.	Forest and environmental resource accounting –methods and implications.	3
6.	Application of operational research tools in evaluating forest management alternatives in public and private forest planning and valuation	3
	Total	17
	Practical	
1.	Exercises on estimation of demand and supply functions	4
2.	Biodiversity valuation, valuation of non-marketed forest products	3
3.	Exercises on financial and economic appraisal of forestry projects Exercises on marketing of forest products and international trade competitiveness	6
4.	Computer applications for using programming techniques in evaluating forest management alternatives	3
	Total	16

I. Course Title : Forest Ecosystem Services and Valuation

II. Course Code : FRM 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge ecosystem services, natural capital, natures contribution to people, global science perception on ecosystem services, quantification and valuation tools, governance, challenges and policy issues. To develop an understanding of students on the concepts of Ecological-Economics and importance of Green Economy.

V. Theory

Unit I

Ecosystem Services (ES) basics, importance, history of ES and natural capital, classification of ES-provisioning, regulating, supporting and cultural services and their status and changes, drivers of change of ecosystem services, international conventions and charters on ES-Inter-governamental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) and Millennium Ecosystem Services (MEA) Assessment– an overview. Linkages among biodiversity, ecosystem services and human well being.

Unit II

Quantification of ecosystem services-direct and indirect approaches. Ecological Economics: Valuation of ES, need for valuation. Use values and Non-Use values-direct value, indirect value, optional value, bequest value, existence value. Valuation methods-Market price based approach such as stumpage value method, productivity and cost based approaches such as replacement cost method and surrogate market and stated preference approaches such as stumpage value method, Hedonic Pricing Method, Contingent Valuation Method, Travel Cost Method, etc., Case studies in India and abroad. Challenges in valuation of ES.

Unit III

Governance and policy issues in ecosystem services, Payment for ecosystem services (PES), mechanisms of benefit sharing, eco-certification, Geographic Indications, Forest Stewardship Council, Landscape labelling. National and International initiatives in PES and on-going programs.

VI. Practical

- IPBES and MEA assessment;
- Valuation methods- direct and indirect;
- Case studies of PES in India and Abroad;
- Case studies on certification and geographical indications, FSC.

VII. Suggested Reading

Alavalapati JRR, Shrestha RK, Stainback GA and Matta JR. 2004. *Agroforestry development: An environmental economic perspective*. Agroforestry Systems.

Huxley P. 1999. *Tropical Agroforestry*. Blackwell.

Jain SK and Singh P. 2000. *Economic Analysis of Industrial Agroforestry: Poplar (Populus deltoides) in Uttar Pradesh (India)*. Agroforestry Systems.

Jeffers JNR. 1978. *An Introduction to System Analysis with Ecological Application*. Edward Arnold.

Jose S. 2009. *Agroforestry for Ecosystem Services and Environmental Benefits: an Overview*. Agroforestry Systems.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer, Netherlands.

Paulo ELD and Nunes. 2014. *Handbook on the Economics of Ecosystem and Biodiversity*. E-book.

Sander J, Nicolas D and Hans K. 2014. *Ecosystem Services: Global Issues and Local Practices*. First Edition. Elsevier Publications.

Schroth G and Sinclair F. 2003. *Tree Crops and Soil Fertility: Concepts and Research Methods*, CABI, Wallingford, UK.

Young A. 1997. *Agroforestry for Soil Management*. 2nd ed. CABI, Wallingofrd, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Ecosystem Services (ES) basics, importance, history of ES and natural capital, classification of ES-provisioning, regulating, supporting and cultural services	3

Sr. No	Topic	No. of Lecture(s)
2	Status and changes of ecosystem services, drivers of change of ecosystem services	2
3	International conventions and charters on ES-Inter-governmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) and Millennium Ecosystem Services (MEA) Assessment– an overview	3
4.	Linkages among biodiversity, ecosystem services and human well being	2
5.	Quantification of Ecosystem Services-direct and indirect approaches. Ecological Economics: Valuation of ES, need for valuation	4
6.	Use values and Non-Use values- direct value, indirect value, optional value, bequest value, existence value	2
7.	Valuation methods-Market price based approach such as stumpage value method, productivity and cost based approaches such as replacement cost method and surrogate market and stated preference approaches such as stumpage value method, Hedonic Pricing Method, Contingent Valuation Method, Travel Cost Method, etc.	6
8.	Case studies of valuation of ES in India and abroad. Challenges in valuation of ES	2
9.	Governance and policy issues in ecosystem services	2
10.	Payment for ecosystem services (PES), mechanisms of benefit sharing, eco-certification, Geographic Indications, Forest Stewardship Council, Landscape labelling	3
11.	National and International initiatives in PES and on-going programs	3
	Total	32

Practical

Sr. No	Topic	No. of Practical(s)
1.	IPBES and MEA assessment	3
2.	Valuation methods- direct and indirect	3
3.	Case studies of PES in India and Abroad	4
4.	Case studies on certification and geographical indications, FSC	4
	Total	16

I. Course Title : Environmental Impact Assessments and Auditing

II. Course Code : FRM 507

III. Credit Hours : 1+1

IV. Aim of the course

To provide a detailed knowledge on the environmental inmpact assessment and its importance. Also this course enables the students to know salient features of EIA legislation and other statutory obligations.

V. Theory

Unit I

Origin of EIA and historical perspective, scope and purpose of EIA; Key merits of environmental assessment in regulating the state of environment. Global experience in EIA; Comparative review of EIA systems in different countries and regions. Salient features of EIA legislation and other statutory obligations. · Environmental decision making in India Environmental clearance procedures and national requirements.

Unit II

Flow charts showing key steps; Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening) Scoping (scoping steps, guidance and tools, and stakeholder involvement), Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks).

Unit III

Introduction to various impact assessment methods: checklist, matrices, networks, indices and weight scaling techniques and their scope and limitations · Prediction and assessment of impact on the land, air, water, noise, biological and socioeconomic environments Mitigation: definitions and hierarchy of measures including avoidance, reduction, rectification and compensation enhancement approaches, principles and concepts of offsets, type of offsets.

Unit IV

EIA administration and practice. Cost and benefits of evaluation of EIA; understanding strengths and limitation of EIA. EIA standards; risk assessment; potential impact to water and air pollution.

VI. Practical

- Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening) Scoping (scoping steps, guidance and tools, and stakeholder involvement);
- Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks), EIA of development projects, EIA of restored mine lands, Undertaking an EIA: case studies for agro-industries.

VII. Suggested Reading

Anjanayulu Y. 2002. *EIA Methodologies*. BSP BS publication

Lawrence and Dravid P. 2003. *EIA Practical Solutions to Recurrent problems*.

Morgan RK. 1988. EIA- *A methodological Perspective*. Kluwer Academic Publishers.

Patnaik and Naba Kumar. 2000. *Environmental Audit-A Perspective, Environment Management and Audit*, Deep and Deep Publication Pvt. Ltd., New Delhi.

Pramanik AK. 2002. *Environmental Audit and Indian Scenario, Environmental Accounting and Reporting*, Deep and Deep Publications Pvt. Ltd., New Delhi.

Selvam M. 2002. *The Need for an Environmental Audit, Environmental Accounting and Reporting*, Deep and Deep Publications Pvt. Ltd., New Delhi.

Smith LG. 1993. *Impact Assessment and Sustainable Resource Management*, John Wiley & Sons. New York.

Shrivastava AK. 2003. *Environment Auditing*. APH Publishing.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Origin of EIA and historical perspective, scope and purpose of EIA. Key merits of environmental assessment in regulating the state of environment	1
2.	Global experience in EIA; Comparative review of EIA systems in different countries and regions. Salient features of EIA legislation and other statutory obligations	2
3.	Environmental decision making in India Environmental clearance procedures and national requirements	2
4.	Flow charts showing key steps; Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening	2
5.	Scoping (scoping steps, guidance and tools, and stakeholder involvement), Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks)	2
6.	Introduction to various impact assessment methods: checklist, matrices, networks, indices and weight scaling techniques and their scope and limitations	2
7.	Prediction and assessment of impact on the land, air, water, noise, biological and socioeconomic environments	2
8.	Mitigation: definitions and hierarchy of measures including avoidance, reduction, rectification and compensation enhancement approaches	2
9.	Principles and concepts of offsets, type of offsets	2
	Total	17
	Practical	
1.	Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening) Scoping (scoping steps, guidance and tools, and stakeholder involvement)	8
2.	Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks), EIA of development projects, EIA of restored mine lands, Undertaking an EIA: case studies for agro-industries	8
	Total	16

I. Course Title : Forest Policy, Law and International Conventions

II. Course Code : FRM 508

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding of students about forest policy and laws and international conventions

V. Theory

Unit I

Forest policy – Relevance and scope; National Forest Policy – 1894, 1952 and 1988

Unit II

Forest laws; Indian Forest Act 1927, general provision and detailed study; Forest Conservation Act, 1980, Wildlife Protect Act, 1972 Important Forest Rules and Guidelines; Indian evidence act applied to forestry matters, Legal definitions; objectives of species forest laws.

Unit III

History of environmental policy in India. Constitutional and legislative provisions—constitutional provisions and the environment, Environmental protection and fundamental rights, Digest of environmental *legislation* (Interpretation of environmental statutes, Environmental protection Act, 1986; Biodiversity Act, 2002, Schedules tribes (Recognition of forest rights), Act, 2007. Judicial remedies and procedures, public interest litigations, Intellectual Property Rights (Patents, Copy rights, Trade mark, Trade secrets), freedom of information, and right to know.

Unit IV

Important case studies and landmark judgments. Case studies of different forests divisions/ areas of India. International conventions of forestry issue. e.g. Role of internationaltreaties like CITES, IUCN, RAMSER, CBD, etc.

VI. Suggested Reading

Divan S and Rosencranz A. 2002. *Environmental Law and Policy in India*. Oxford University Press, New Delhi.

Indian Forest Acts (with short notes)1975. Allahabad Law Agency.

Jha LK. 1994. *Analysis and Appraisal of India's Forest Policy*. Ashish Publ. House.

National Forest Policy 1952. Ministry of Food and Agriculture, New Delhi.

National Forest Policy 1988. Ministry of Environment and Forests, New Delhi.

Negi SS. 1985. *Forest Law*. Natraj Publishers.

Saharia VB. 1989. *Wildlife Law in India*. Natraj Publ.The Biodiversity Act,2002.

Wilson B, Van Kooten GC, Vertinsky I, Arthur L. 1998. *Forest policy —International case studies.* CABI publishing, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Forest policy – Relevance and scope,National Forest Policy – 1894, 1952 and 1988	2
2.	Forest laws; Indian Forest Act –1927, general provision and detailed study	3
3.	Forest Conservation Act, 1980	2
4.	Wildlife Protect Act, 1972	2
5.	Important Forest Rules and Guidelines.; Indian evidence act applied to forestry matters, Legal definitions; objectives of species forest laws	2
6.	History of environmental policy in India	1
7.	Constitutional and legislative provisions—constitutional provisions and the environment,	2

Sr. No	Topic	No. of Practical(s)
8.	Environmental protection and fundamental rights, Digest of environmental *legislation*(Interpretation of environmental statutes,	2
9.	Environmental protection Act, 1986	2
10.	Biodiversity Act, 2002	2
11.	Schedules tribes (Recognition of forest rights), Act,2007	1
12.	Judicial remedies and procedures, public interest litigations, Intellectual Property Rights (Patents, Copy rights, Trade mark, Trade secrets), freedom of information, and right to know	4
13.	Important case studies and landmark judgments. Case studies of different forests divisions/ areas of India	3
15.	International conventions of forestry issue. e.g. Role of international treaties like CITES, IUCN, RAMSER, CBD, etc.	3
	Total	32

I. Course Title : Global Climate Change Impact, Mitigation and adaptation

II. Course Code : FRM 509

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge on climate change and different mitigation and adaptation strategies and also on international initiatives on climate change.

V. Theory

Unit I

Definition and concept of climate change and variability; global warming and dimming; science and politics of climate change and international conventions; evidence, scenario and causes of climate change. Greenhouse gases and mechanism of their production and emission from various agro-ecosystems, source and sinks of GHG; warming potential and contribution of greenhouse gases to global warming, greenhouse effect; monitoring of greenhouse gases.

Unit II

Impact assessment of rise in atmospheric temperature and CO_2 on growth, physiological processes, productivity and quality of different vegetation types, soil health, water availability, insect pest dynamics, crop production, milk and inland and marine fish production; climate change and loss of biodiversity; spatial and temporal changes in forest and plantation productivity and agricultural production in context of climate change.

Unit III

Adaptation and mitigation options to climate change; carbon sequestration; modeling climate change and its impact on forests. International summit, conferences, protocols and negotiations on climate change; clean development mechanism; carbon trading, credits, footprints and govt. strategies and policies on climate change management.

Unit IV

Recent techniques for assessing the impact of high temperature on tree species and crops, recent techniques for assessing the impact of CO_2 fertilization on productivity, recent techniques for assessing the impact of elevated CO_2 on tree species.

VI. Suggested Reading

Climate Change: Challenges To Sustainable Development in India. 2008. Research Unit (Larrdis) Rajya Sabha Secretariat, New Delhi.

Reddy KR and Hodges HF. *Greenhouse Gas Emission from Agricultural System*, Published by IPCC- USEPA *Climate change and global crop productivity* Ed. CABI Publishing.

IPCC Assessment Report. 2007. *Climate Change Journal Climate Change: Source, Impact and Policy*, Proceeding of 2nd World Climate Conference. Ed. by J Jager and HL. Ferguson, Cambridge University Press.

Houghton J. *Global Warming* (4th), Cambridge Press.

Robert M, Clausen and Henry L Gholz. *Carbon and Forest Management*. School of Forest Resources and Conservation. University of Florida, Gainesville, FL 32611, USA.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Definition and concept of climate change and variability; global warming and dimming	2
2.	Science and politics of climate change and international conventions; evidence, scenario and causes of climate change. Greenhouse gases and mechanism of their production and emission from various agro-ecosystems, source and sinks of GHG	4
3.	Warming potential and contribution of greenhouse gases to global warming, greenhouse effect; monitoring of greenhouse gases	4
4.	Impact assessment of rise in atmospheric temperature and CO_2 on growth, physiological processes, productivity and quality of different forest types, soil health, water availability, insect pest dynamics, crop-weed competition, milk and inland and marine fish production	4
5.	Climate change and loss of biodiversity; spatial and temporal changes in forest and plantation productivity and agricultural production in context of climate change	3
6.	Adaptation and mitigation options to climate change; carbon sequestration; modeling climate change and its impact on forests	4
7.	International summit, conferences, protocols and negotiations on climate change; clean development mechanism; carbon trading, credits, footprints	3
8.	Government strategies and policies on climate change management	3
9.	Recent techniques for assessing the impact of high temperature on tree species and crops, recent techniques for assessing the impact of CO_2 fertilization on productivity, recent techniques for assessing the impact of elevated CO_2 on tree species	5
	Total	32

I. Course Title : Participatory Approaches in Forest Management

II. Course Code : FRM 510

III. Credit Hours : 1+1

IV. Aim of the course

To inculcate knowledge and skills in students to employ participatory tools and techniques for effective planning, implementation, monitoring and evaluation of forestry projects, to efficiently carry out forest resource management and to effectively resolve conflicts by adopting participatory techniques.

V. Theory

Unit I

Participatory approaches- Participatory planning- Participatory data collection, research and project preparation; Participatory implementation- group approaches for implementation of projects and programmes; Participatory monitoring; Participatory evaluation- Concurrent and ex-post evaluation; Peoples' participation- community mobilization.

Unit II

Concept of Social Research, Traditional methods of doing research, Action Research and Participatory Research. Scope and importance of Qualitative Data. Construction and Methods of Data Collection. Different types of Sampling. Interview Techniques. Qualitative methods-Sociometry, Case Studies, observation, coding and content analysis.

Unit III

Participatory Methods of Data Collection-Concept and Need of Data, Information, Appraisal; Various methods of Data Collection, Interpretation of Qualitative and Quantitative Data. Origin of Participatory Methods, FSA, Rapid Rural Appraisal. Key informants, selection of key informants.Semi-structured interviews, Question guide/ checklist and other relevant methods and their applications in forestry and natural resource management.

Unit IV

Objectives of PRA.The Logic and merits of the PRA.Challenges/ constraints of PRA. Major methods of PRA. The fundamental concepts of PRA. Principles of PRA. Operational guidelines for organizing PRA at village level. PRA and PLA – Concept, Methods, Tools, Interpretation and Techniques. Other relevant participatory approaches like RRA, PANR, etc. Emerging tools used for PRA (ICT, GIS, GPS, etc.).

VI. Practical

- Visit to selected forest areas to undertake and understand various participatory research methods including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.

VII. Suggested Reading

Kothari CR. 1992. *Research Methodology- Methods and Techniques*. Wiley Eastern Limited New Delhi.

Narayanasamy N. 2008. *Participatory Rural Appraisal: Principles, Methods and Application*.

Robert C. 1981. *Rapid Rural Appraisal Rationale and Repertoire*. IDS Discussion Paper, No. 155, IDS, Sussex.

Sabarathnam VE. 2002. *R/ R/ PRA for Agriculture*.Vamsaravath Publishers, Hyderabad.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Participatory approaches- Participatory planning- Participatory data collection, research and project preparation	2
2.	Participatory implementation- group approaches for implementation of projects and programmes; Participatory monitoring; Participatory evaluation- Concurrent and ex-post evaluation; Peoples' participation- community mobilization	2
3.	Concept of Social Research, Traditional methods of doing research, Action Research and Participatory Research	2
4.	Impact assessment of rise in atmospheric temperature and CO2 on growth, physiological processes, productivity and quality of different forest types, soil health, water availability, insect pest dynamics, crop-weed competition, milk and inland and marine fish production	2
5.	Scope and importance of qualitative data. Construction and Methods of Data Collection. Different types of Sampling	2
6.	Interview Techniques. Qualitative methods-Sociometry, Case Studies, observation, coding and content analysis	2
7.	Participatory Methods of Data Collection-Concept and Need of Data, Information, Appraisal; Various methods of Data Collection, Interpretation of Qualitative and Quantitative Data	2
8.	Origin of Participatory Methods, FSA, Rapid Rural Appraisal. Key informants, selection of key informants. Semi-structured interviews, Question guide/ checklist and other relevant methods and their applications in forestry and natural resource management	2
9.	Objectives of PRA. The Logic and merits of the PRA. Challenges/ constraints of PRA. Major methods of PRA. The fundamental concepts of PRA. Principles of PRA	2
10.	Operational guidelines for organizing PRA at village level. PRA and PLA – Concept, Methods, Tools, Interpretation and Techniques.	1
11.	Other relevant participatory approaches like RRA, PANR, etc. Emerging tools used for PRA (ICT, GIS, GPS, etc.)	1
	Total	18
	Practical	
1.	Visit to selected forest areas to undertake and understand various participatory research methods	8
2.	Including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.	8
	Total	**16**

I. Course Title : Management of Tree Insect Pests and Diseases

II. Course Code : FRM 511

III. Credit Hours : 2+1

IV. Aim of the course

To provide and understanding to the students on management of insect pests and diseases and aspects related to INM.

V. Theory

Unit I

Principles and methods of integrated pests management; Insect attractants and repellents; male sterility techniques.

Unit II

Important insect pests of nurseries, plantations, avenue trees and their management. Insect pests of seeds of forest trees and their management.

Unit III

Principles of tree disease. management; Integrated forest protection; development of disease management system.

Unit IV

Important diseases of nurseries, plantations and avenue trees and their management, Mycoflora of seeds and their management.

VI. Practical

- Collection and identification of insect pests and non-insect pests;
- Inspection and collection of insect damaged plant specimens;
- Preparations of different pesticides;
- Application of pesticides;
- Collection, preservation and identification of tree diseases, forest nursery and plantation;
- Isolation and characterization of tree pathogens;
- Preparation of fungicidal solutions; *In-vitro* efficacy and *In vivo* efficacy assessments.

VII. Suggested Reading

Agrios GN. 2005. *Plant Pathology*. Elsevier Acad. Press. Singapore.

Butin H. 1995. *Tree Diseases and Disorders*. Oxford Univ. Press, New York.

Evane JW. 1989. *Insect Pest and their Control*. Samir BooK Center, New Delhi (India).

Gonthia P and Nicolotti G. 2013. *Infectious Forest Diseases*. CABI, UK. Guy Watson., 2013, Tree Pests and Diseases.

Pathak H, Maru S, Satya HN and Silawat SC. 2015. *Fungal Diseases of Trees in Forest Nurseries of Indore, India.* J Plant Pathol Microb.

Sinclair W and Howard HL. 2005. *Diseases of Trees and Shrubs*.

Speight MR. 2000. *Insect Pest in Tropical Forestry*. Rose Willey Publications.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concepts and terminologies in forest entomology	1
2.	Insect pest induced loss assessments in different forest nursery seedlings	2
3.	Insect pest induced loss assessments in different forest plantations	2
4.	Principles of integrated pest management	2
5.	Insect attractants and repellents, male sterility techniques	2
6.	Important insect pests of nurseries	1

Sr. No.	Topic	No. of Lecture(s)
7.	Important insect pests of plantation trees, avenue trees and their management	3
8.	Insect pests of seeds of forest trees and their management.	1
9.	Concepts and terminologies forest pathology	2
10.	Disease induced loss assessments in different forest nursery seedlings and plantations	2
11.	Principle methods of tree disease management	2
12.	Integrated forest protection	2
13.	Development of disease management system	2
14.	Important diseases of forest nurseries and their management	3
15.	Important diseases of forest plantations and avenue trees and their management	3
16.	Mycoflora of seeds and their management	2
	Total	32

Practical

1.	Collection and identification of insect pests and non-insect pests	2
2.	Inspection and collection of insect damaged plant specimens	3
3.	Preparations of different pesticides. Application of pesticides	3
4.	Collection, preservation and identification of tree diseases, forest nursery and plantation	3
5.	Isolation and characterization of tree pathogens	2
6.	Preparation of fungicidal solutions; *In-vitro* efficacy and *In vivo* efficacy assessments	3
	Total	**16**

I. Course Title : Forest Ecology, Biodiversity and Management

II. Course Code : FRM 512

III. Credit Hours : 2+1

IV. Aim of the course

This course would enable the students to understand the aspects related to forest ecosystem and its dynamics. As well it provides the knowledge on biodiversity conservation in natural forests and agro-ecosystems, policy issues, IPR, etc.

V. Theory

Unit I

Introduction to forest ecology, forest population, forest community dynamics, forest community structure and analysis, forest productivity on a global scale, ecology of forest landscapes spatial heterogeneity; Hierarchy issues in ecology.

Unit II

Biodiversity-an overview; genetic, species and ecosystem diversity; determinants of biodiversity. Higher plant diversity, species richness and endemism. Managing plant genetic resources: Basic science issues – genetic vulnerability and crop diversity, crop diversity-institutional responses, *in situ* conservation of genetic resources, the science of collecting genetic resources, the science of managing genetic resources, using genetic resources, biotechnology and germplasm conservation, etc.

Unit III

Complementary strategies for plant biodiversity conservation. *In situ* conservation of wild species in nature reserves, in situ conservation components, factors influencing conservation value, national plan for *in situ* conservation. In situ conservation of Forest and agro-biodiversity on-farm: importance of on-farm conservation initiatives, overview of the types of information necessary in the design of an on-farm conservation programme.

Unit IV

Managing plant genetic resources: policy issues (exchange of genetic resources: quarantine, IPR; genetic resources: assessing economic value; conflicts over ownership, management and use; national and international treaties/ legislations: CBD, IT-PGRFA, GPA, PVP and FR Act, Biodiversity Act, etc.). International instruments concerning agro-biodiversity, Agenda 21, convention on biological diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms.

VI. Practical

- Study of forest community structure and its successional status;
- Estimation of productivity of forest ecosystem;
- Trip to different regions of the state to study forest vegetation, Collection and preservation of specimen;
- Methods of vegetation analysis, Measurement of biomass and productivity;
- Quantification of litter production and decomposition;
- Visit to national parks, wildlife sanctuaries, botanical gardens and arboreta.

VII. Suggested Reading

Bonneuil, Christophe and Jean-Baptiste F. *The Shock of the Anthropocene: The Earth, History and Us. London*; Brooklyn, NY: Verso, 2016. (Chapter 1: Welcome to the Anthropocene).

Brush SB. 1999. *Genes in the Field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

Chandna RC. 2002: *Environmental Geography*, Kalyani, Ludhiana.

Cunninghum WP and Cunninghum MA. 2004: *Principles of Environmental Science: Inquiry and Applications*, Tata Macgraw Hill, New Delhi.

Engels JMM. 1995. *In Situ Conservation and Sustainable Use of Plant Genetic Resources For Food and Agriculture in Developing Countries*. IPGRI/ DSE.

Jarvis D, Staphit B and Sears L. 2000. *Conserving Agricultural Biodiversity in Situ: A Scientific Basis for Sustainable Agriculture*. IPGRI, Rome, Italy.

Maxted N, Ford-Lloyd BV and Hawkes JG. 1997. *Plant Genetic Conservation: The In Situ Approach*. Chapman & Hall, London.

Wood D and Lenne J. 1999. *Agrobiodiversity: Characterisation, Utilization and Management*. CAB International, Wallingford.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction to forest ecology, forest population, forest community dynamics, forest community structure and analysis	2

Sr. No	Topic	No. of Practical(s)
2.	Forest productivity on a global scale, ecology of forest landscapes spatial heterogeneity; Hierarchy issues in ecology	2
3.	Biodiversity-an overview; genetic, species and ecosystem diversity; determinants of biodiversity. Higher plant diversity, species richness and endemism	2
4.	Managing plant genetic resources: Basic science issues – genetic vulnerability and crop diversity, crop diversity-institutional responses, in situ conservation of genetic resources	3
5.	The science of collecting genetic resources, the science of managing genetic resources, using genetic resources	2
6.	Biotechnology and germplasm conservation	1
7.	Complementary strategies for plant biodiversity conservation. In situ conservation of wild species in nature reserves, in situ conservation components, factors influencing conservation value, national plan for in situ conservation	4
8.	In situ conservation of Forest and agro-biodiversity on-farm: importance of on-farm conservation initiatives, overview of the types of information necessary in the design of an on-farm conservation programme	4
9.	Managing plant genetic resources: policy issues (exchange of genetic resources: quarantine, IPR; genetic resources: assessing economic value; conflicts over ownership, management and use	4
10.	National and international treaties/ legislations: CBD, IT-PGRFA, GPA, PVP and FR Act, Biodiversity Act, etc.)	4
11.	International instruments concerning agro-biodiversity, Agenda 21, convention on biological diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms	4
	Total	32

Practical

1.	Study of forest community structure and its successional status	2
2.	Estimation of productivity of forest ecosystem	2
3.	Trip to different regions of the state to study forest vegetation, Collection and preservation of specimen	4
4.	Methods of vegetation analysis, Measurement of biomass and productivity	3
5.	Quantification of litter production and decomposition	2
6.	Visit to national parks, wildlife sanctuaries, botanical gardens and arboreta	3
	Total	**16**

Course Title with Credit Load
Ph.D. (Forestry) in Forest Resource Management

Course Code		Course Title	Credit Hours
		Major Courses	
FRM 601*	I	Forest Management	2+1
FRM 602	II	Forest Economic Analysis	2+1
FRM 603	I	Climate Change and Forestry	1+1
FRM 604	II	Geo-informatics in Natural Resource Management	2+1
FRM 605*	I	Environmental Impact Analysis and Assessment	2+1
FRM 606	II	Forest Soil Management	2+1
FRM 607	I	Environmental Modelling and Biostatistics	2+0
FRM 608	II	Approaches in Forest Resource Management	1+1
FRM 609	I	Forest Hydrology and Watershed Management	2+1
FRM 610	II	Operational Research in Forest Management	1+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Biology and Tree Improvement or Forest Products and Utilization	06
		Supporting Courses	
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
FRM 691*	I/ II	Doctoral Seminar	1+0
FRM 692*	I/ II	Doctoral Seminar	1+0
		ii) Thesis Research	
FRM 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Forest Resource Management

I. Course Title : Forest Management

II. Course Code : FRM 601

III. Credit Hours : 2+1

IV. Aim of the course

To provide the recent knowledge on management of Indian forests, different methods of yield regulation in regular and irregular forests and forest evaluation and appraisal in regulated forests.

V. Theory

Unit I

Evolution of Indian forest management system and current approaches of forest management. Goal-Dimension matrix in forest management and its application to natural forest and plantations. Case studies in relation of even and uneven aged stands. Project planning, classical approaches to yield regulation in forest management,salient feature and strategies.

Unit II

Operational research methods in forest management and application; use of operational research methods in forest planning models; emphasis on algorithms, problem formulation and interpretation of results.

Unit III

Simulation modeling of forest operations processing facilities; principles and methodology for performing simulation experiments; emphasis on building, running and analyzing simulation based models applicable to forest operations and wood products processing. Application of programming-linear and dynamic, network analysis, PERT (program evaluation and review technique) and CPM (Critical path method), inventory models.

Unit IV

Working plans and working schemes, their role in nature conservation, biodiversity and other dimensions and control.

VI. Practical

- Application of above techniques through a case analysis using forest inventories;
- Application and use of operational research methods in forest planning models;
- Simulation modeling of forest operations and processing facilities.

VII. Suggested Reading

Arunachdam A and Kha ML 2001. *Sustainable Management of Forest in India*, IBD, Dehradun.

Bentley J and Recknagel AB. 1995. *Forest Management*. International book distributors, Dehra Dun.

Davis *et al*. 2005. *Forest Management*, IV Edition. Waveland Press Inc, USA.

Innes JL. 1993. *Forest Health-Its Assessment and Status*, CAB international, U.K.
Pulparambil J. 2002. *Forest Management – An HRD Approach*. Uppal Publishing House, New Delhi.
Raison RJ, Brown AJ and Flimn PW. 2003. *Criteria and Indicators for Sustainable Forest Management*. CAB Publications, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Principles of forest management; scope and objectives of forest management, ecosystem management, development of forest management in India	3
2.	Case studies in relation of even and uneven aged stands. Project planning	3
3.	Site quality evaluation and importance. Stand density	2
4.	Classical approaches to yield regulation in forest management, salient feature and strategies, Basis of yield regulation. Methods of yield regulation. Examples in relation to Indian forests	5
5.	Forest evaluation and appraisal in regulated forests. Operational research methods in forest management and application	3
6.	Application of operational research methods in forest planning models; emphasis on algorithms, problem formulation and interpretation of results	3
7.	Simulation modeling of forest operations processing facilities; principles and methodology for performing simulation experiments; emphasis on building, running and analyzing simulation based models applicable to forest operations and wood products processing	4
8.	Application of programming-linear and dynamic, network analysis, PERT (program evaluation and review technique) and CPM (Critical path method), inventory models	3
9.	Working plans and working schemes, their role in nature conservation, biodiversity and other dimensions and control	3
10.	Preparation of working plan, different types of map, steps in working plan preparation. Difference between management plan, working plan, microplan	3
	Total	30
	Practical	
1.	Application of above techniques through a case analysis using forest inventories	5
2.	Application and use of operational research methods in forest planning models.	5
3.	Simulation modeling of forest operations and processing facilities.	6
	Total	16

I. Course Title : Forest Economic Analysis

II. Course Code : FRM 602

III. Credit Hours : 2+1

IV. Aim of the course

Is to provide different aspects forest economics, Issues and dynamics of domestic and international demand and supply of forestry products.

V. Theory

Unit I

Use of theoretical frameworks of consumer behavior, market equilibrium, efficiency of perfect and imperfect competition, game theory, and social welfare functions in decision making about optimization of forest resources; Issues and dynamics of domestic and international demand and supply of forestry products.

Unit II

Models of optimal resource use – Applications of dynamic programming and optimal control – Optimal management of forestry resources – Logistic growth – Maximum sustainable yield – Optimal harvest rule – Regulated and unregulated common property. Economics of Forest Resource – optimal harvesting of single rotation and multiple rotation forests.

Unit III

National income accounting – estimation and methods – Issues and methodologies in green accounting.

Unit IV

Valuation of forestry goods and services – Direct valuation methods – Indirect valuation methods. Environmental pollution as a case of common property management- Policy initiatives for improving the management of common property resources and environmental conservation. Environmental regulation and policies – market based instruments – economic instruments – pollution charges, taxes, tradable permits.

VI. Practical

- Efficiency of perfect and imperfect competition – consumer surplus analysis. Game theory – social welfare function;
- Derivation of the fundamental equation of renewable resources – Estimation of growth curves and stock dynamics for forestry resources. Simple two period problem of optimal resource use – optimal rotation;
- National income accounting – methods Environmental Resource Accounting – Green GDP;
- Direct valuation methods – Indirect valuation methods. Criteria for evaluating the environment related projects and review of Environmental impact Assessment (EIA) techniques;
- Practical considerations and comparison of instruments of environmental policy – pollution control methodologies.

VII. Suggested Reading

Tom Totenberg and Lynne Lewis. 2009. *Environmental and Natural Resource Economics* Pearson – Addision Wesley publication, 9th edition.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Use of theoretical frameworks of consumer behavior, market equilibrium, efficiency of perfect and imperfect competition	3
2.	Game theory, and social welfare functions in decision making about optimization of forest resources	3
3.	Issues and dynamics of domestic and international demand and supply of forestry products	3
4.	Models of optimal resource use – Applications of dynamic programming and optimal control – Optimal management of forestry resources – Logistic growth – Maximum sustainable yield – Optimal harvest rule	4
5.	Regulated and unregulated common property	2
6.	Economics of Forest Resource – optimal harvesting of single rotation and multiple rotation forests	3
7.	National income accounting – estimation and methods – Issues and methodologies in green accounting	3
8.	Valuation of forestry goods and services – Direct valuation methods – Indirect valuation methods	4
9.	Environmental pollution as a case of common property management-Policy initiatives for improving the management of common property resources and environmental conservation	3
10.	Environmental regulation and policies – market based instruments – economic instruments – pollution charges, taxes, tradable permits	4
	Total	32
	Practical	
1.	Efficiency of perfect and imperfect competition – consumer surplus analysis. Game theory – social welfare function	3
2.	Derivation of the fundamental equation of renewable resources – Estimation of growth curves and stock dynamics for forestry resources. Simple two period problem of optimal resource use – optimal rotation.	4
3.	National income accounting – methods Environmental Resource Accounting – Green GDP	2
4.	Direct valuation methods – Indirect valuation methods. Criteria for evaluating the environment related projects and review of Environmental impact Assessment (EIA) techniques	4
5.	Practical considerations and comparison of instruments of environmental policy – pollution control methodologies	3
	Total	16

I. Course Title : Climate Change and Forestry

II. Course Code : FRM 603

III. Credit Hours : 1+1

IV. Aim of the course

To develop an understanding among the students on the recent aspects of climate change, mitigation and adaptation options and the current national and international initiatives to tackle climate change.

V. Theory

Unit I

History of climate change, Institutional developments towards climate change. Recent developments in global climate changes: Changes in source and sinks of carbon in the last few decades. Global warming potentials of major GHG's.

Unit II

Effect of climate change on: Ocean, Soil, Forest, Biodiversity, Agriculture and Livelihood and relevant mitigation measures to address these issues. Climate change, Economic development and energy conservation dilemma. Role of alternate energy sources and its current status towards offsetting fossil fuel use. Carbon Footprint: concepts, methods of assessment, applications and its uses in different fields with special reference to Agriculture. Role of agroforestry strategies to increase terrestrial carbon sinks. Global dimming; role of aerosols in global dimming and implications to solar energy constant.

Unit III

Policy issues: Kyoto protocol, carbon trading mechanisms, Montreal agreement, Marrakesh Accord, REDD, REDD+ and other recent international agreements and negotiations to address the climate change issues. Other Climatic aberrations and its relationship to climate change: Ozone depletion, ENSO, etc. India's stand on climate change: Recent developments in the strategies; Green India Mission, CAMPA, Millennium goal and other policy initiatives to mitigate climate change.

VI. Practical

- Atmospheric CO_2 measurement methods;
- Soil Carbon assessment, Soil carbon dynamics;
- Atmospheric CO_2 flux measurements. Exposing plants to elevated CO_2 concentration.

  FACE and FATE experiments, Open top chambers and its importance in understanding the effect of increased CO_2 concentration and plant growth;
- Differential responses of species to elevated CO_2 concentrations. Diurnal plant response t light, temperature and CO_2 concentration.

VII. Suggested Reading

Houghton John. 2009. *Global Warming* (Fourth edition). Cambridge Press.

J Jager and HL Ferguson. 2007. IPCC Assessment Report. *Climate Change Journal Climate Change: Source, Impact and Policy*, Proceeding of 2nd World Climate Conference. Cambridge University Press, 1993.

Parry, Martin L, Canziani, Osvaldo F, Palutikof, Jean P, Van der Linden, Paul J and Hanson, Clair E. 2007. IPCC. Cambridge University Press, Cambridge, United Kingdom.

Reddy KR and Hodges HF. 2000. *Climate Change and Global Crop Productivity*. CABI Publishing.

Robert M, Clausen and Henry L Gholz. *Carbon and Forest Management*. School of Forest Resources and Conservation. University of Florida, Gainesville, FL 32611, USA.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	History of climate change, Institutional developments towards climate change	1
2.	Recent developments in global climate changes: Changes in source and sinks of carbon in the last few decades	1
3.	Global warming potentials of major GHG's	1
4.	Effect of climate change on: Ocean, Soil, Forest, Biodiversity, Agriculture and Livelihood and relevant mitigation measures to address these issues	2
5.	Climate change, Economic development and energy conservation dilemma. Role of alternate energy sources and its current status towards offsetting fossil fuel use	2
6.	Carbon Footprint: concepts, methods of assessment, applications and its uses in different fields with special reference to Agriculture. Role of agroforestry strategies to increase terrestrial carbon sinks	2
7.	Global dimming: role of aerosols in global dimming and implications to solar energy constant	2
8.	Policy issues: Kyoto protocol, carbon trading mechanisms, Montreal agreement, Marrakesh Accord, REDD, REDD+ and other recent international agreements and negotiations to address the climate change issues	2
9.	Other Climatic aberrations and its relationship to climate change: Ozone depletion, ENSO, etc.	2
10.	India's stand on climate change: Recent developments in the strategies; Green India Mission, CAMPA, Millennium goal and other policy initiatives to mitigate climate change	2
	Total	16
	Practical	
1.	Atmospheric CO_2 measurement methods	2
2.	Soil Carbon assessment, Soil carbon dynamics	3
3.	Atmospheric CO_2 flux measurements. Exposing plants to elevated CO_2 concentration	3
4.	FACE and FATE experiments, Open top chambers and its importance in understanding the effect of increased CO_2 concentration and plant growth	3
5.	Differential responses of species to elevated CO_2 concentrations. Diurnal plant response to light, temperature and CO_2 concentration	4
	Total	16

I. Course Title : Geo-informatics in Forest Resource Management

II. Course Code : FRM 604

III. Credit Hours : 2+1

IV. Aim of the course

Is to develop and understanding among the students on basics of geomatics and its application for sustainable management of natural resources.

V. Theory

Unit I

Brief introduction to Remote sensing and GIS, types of remote sensing, aerial photography, scale, process of aerial photography. Platforms, orbit and sensors, types of sensors: ground based, air borne and space borne; geostationary satellite and polar orbiting satellite.

Unit II

Data structure, type and model: Raster and Vector data structure, vector data type, point, line and polygon. Data hierarchical models and overlays. Spatial analysis of vector based and raster based data in the software. Digital elevation models, Global positioning system and differential GPS.

Unit III

Optical, thermal and microwave remote sensing, LiDAR remote sensing. Satellite image interpretation and recognisation elements: tone, color, texture, pattern, shape, size and associated features.Introduction of ERDAS, Arc GIS and PolSar-Pro, ENVI softwares, Digital image processing, image rectification, geometric corrections, Image enhancement techniques, Digital image classification, supervised and unsupervised classification.

Unit IV

Applications of Multispectral, Hyperspectral, thermal and microwave remote sensing. Case studies on application of remote sensing and GIS in natural resource management.

VI. Practical

- Spectral characteristics of vegetation, water and soil;
- Study of Topo-sheets, Forest watershed delineation using GPS, Satellite remote sensing;
- Study of satellite imageries; Digital image interpretation, Digital image processing in ERDAS software, image classification in ERDAS, preparation of thematic maps in Arc GIS, Watershed delineation and clipping using ERDAS and Arc GIS. Mapping of forest with PolSarPro software, Biomass estimation using RS techniques.

VII. Suggested Reading

Campbell JB. 2002. *Introduction to Remote Sensing*-Third edition. Taylor and Francis, London.

Environment System Research Institute.1999. *GIS for Everyone*. Redlands, CA:ESRI.

Jackson MJ. 1992. *Integrated Geographical Information Systems*. International Journal of Remote Sensing, 13(6-7): 1343-1351.

Joseph G. 2005. *Fundamentals of Remote Sensing*-Second edition. Universities Press.

Lillesand TM and Kiefer WR. 1994. *Remote Sensing and Image Interpretation*, Fourth edition. John Wiley & Sons, Inc., USA.

Obi Reddy, GP and Sarkar D. 2012. *RS and GIS in Digital Terrain Analysis and Soil Landscape Modelling*. NBSS & LUP, Nagpur.

Prithvish Nag. 1995. *Digital Remote Sensing*. IBD, Dehradun.

Surender Singh and Patel. 1999. *Principles of Remote Sensing*. Scientific Publishers, Jodhpur, India.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Brief introduction to Remote sensing and GIS, types of remote sensing, aerial photography, scale, process of aerial photography	3
2.	Platforms, orbit and sensors, types of sensors: ground based, air borne and space borne; geostationary satellite and polar orbiting satellite	3
3.	Data structure, type and model: Raster and Vector data structure, vector data type, point, line and polygon. Data hierarchical models and overlays	4
4.	Spatial analysis of vector based and raster based data in the software. Digital elevation models, Global positioning system and differential GPS	4
5.	Optical, thermal and microwave remote sensing, LiDAR remote sensing. Satellite image interpretation and recognisation elements: tone, color, texture, pattern, shape, size and associated features	4
6.	Introduction of ERDAS, Arc GIS and PolSar-Pro, ENVI softwares, Digital image processing, image rectification, geometric corrections, Image enhancement techniques, Digital image classification, supervised and unsupervised classification	6
7.	Applications of Multispectral, Hyperspectral, thermal and microwave remote sensing	4
8.	Case studies on application of remote sensing and GIS in natural resource management	4
	Total	32
	Practical	
1.	Spectral characteristics of vegetation, water and soil;	3
2.	Study of Topo-sheets, Forest watershed delineation using GPS, Satellite remote sensing	3
3.	Study of satellite imageries; Digital image interpretation, Digital image processing in ERDAS software, image classification in ERDAS	4
4.	Preparation of thematic maps in Arc GIS, Watershed delineation and clipping using ERDAS and Arc GIS	3
5.	Mapping of forest with PolSarPro software, Biomass estimation using RS techniques	3
	Total	16

I. Course Title : Environmental Impact Analysis and Assessment

II. Course Code : FRM 605

III. Credit Hours : 2+1

IV. Aim of the course

To impart the knowledge on nature and principles of EA; Procedure and monitoring of EA results; Developing, conducting and evaluating an EA. Report Writing; EIA/ EA Project Report; EIA/ EA Review and Decision Making Process; Environmental Management Plan.

V. Theory

Unit I

EIA Functions, development and environmental degradation. International and National Laws. EIA steps. Social Impact Analysis. The Convention on Environmental Impact Assessment in a local context – Objective and scope, Obligation to notify and consult, Public participation, Content of EIA documentation, Implementation and Compliance. Protocol on Strategic Environmental Assessment- Objective, Key provisions.

Unit II

Nature and principles of EA; Procedure and monitoring of EA results; Developing, conducting and evaluating an EA. Report Writing; EIA/ EA Project Report; EIA/ EA Review and Decision Making Process; Environmental Management Plan.

Unit III

Methods of EIA – Check Lists – Matrices – Networks – Cost-Benefit Analysis. Assessment of Impact on Land, Water, Air, Social and Cultural Activities and on Flora and Fauna- Mathematical Models- Public Participation.

Unit IV

Plan For Mitigation Of Adverse Impact On Environment – Options For Mitigation of Impact on Water, Air, Land And on Flora and Fauna – Addressing The Issues Related To The Project Affected People. Post Project Monitoring.

VI. Practical

- Environmental auditing – History of environmental auditing. Introduction to the types of environmental audit;
- Analyze proposed development project plans for possible environmental effects and prepare appropriate initial studies;
- Utilize EIA documents for policy development, project planning or for legal or political action planning.

VII. Suggested Reading

Anjanayulu Y. 2002. *EIA Methdlogies*. BSP BS publication.

Brady J. 2011. *The response of organizations*. In: Brady J, Ebbage A, Lunn R (eds.) *Environmental Management in Organizations: The IEMA Handbook*, 2nd edn. Earthscan, London, pp. 251–260.

Humphrey N and Hadley M. 2000. *Environmental Auditing*. Palladian Law Publishing Ltd,

Lawrence and Dravid P. 2003. *EIA Practical Solutions to Recrurrent Problems*.

Morgan RK. 1988. EIA- *A Methodological Perspective* Kluwer Academic Publishers.

Smith LG. 1993. *Impact Assessment and Sustainable Resource Management*. John Wiley & Sons. New York.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	EIA Functions, development and environmental degradation. International and National Laws. EIA steps. Social Impact Analysis	3
2.	The Convention on Environmental Impact Assessment in a local context – Objective and scope, Obligation to notify and consult,	

Sr. No	Topic	No. of Lecture(s)
	Public participation	3
3.	Content of EIA documentation, Implementation and Compliance. Protocol on Strategic Environmental Assessment- Objective, Key provisions	4
4.	Nature and principles of EA; Procedure and monitoring of EA results; Developing, conducting and evaluating an EA	4
5.	Report Writing; EIA/ EA Project Report; EIA/ EA Review and Decision Making Process; Environmental Management Plan	4
6.	Methods of EIA – Check Lists – Matrices – Networks – Cost-Benefit Analysis. Assessment of Impact on Land, Water, Air, Social and Cultural	4
7.	Activities and on Flora and Fauna- Mathematical Models- Public Participation	3
8.	Plan For Mitigation Of Adverse Impact On Environment	1
9.	Options For Mitigation of Impact on Water, Air, Land And on Flora and Fauna	3
10.	Addressing The Issues Related To The Project Affected People. Post Project Monitoring	3
	Total	32

Practical

1.	Environmental auditing – History of environmental auditing	4
2.	Introduction to the types of environmental audit	4
3.	Analyze proposed development project plans for possible environmental effects and prepare appropriate initial studies	4
4.	Utilize EIA documents for policy development, project planning or for legal or political action planning	4
	Total	16

I. Course Title : Forest Soil Management

II. Course Code : FRM 606

III. Credit Hours : 2+1

IV. Aim of the course

To acquire knowledge on advances in forest soil management. Hydrology of forest plantation. Stand development and soil productivity. Harvest removal and nutrient budgeting.

V. Theory

Unit I

Soils and their management for plantation forestry: Soils of the tropics, Soil requirements for plantation forestry, physical properties of major soils of India, soil erosion and erodibility, Erosion control.

Unit II

Dynamics of nutrient supply in plantation soils: variability of nutrient stores in forest soils, changes in nutrient content, nutrient losses and their assessment, nutrient gains, Nutrient transformation in soils. Nitrogen fixation in Tropical forest Plantations: N fixation process, species, rates of N fixation, factors influencing N fixation; Nutrient cycling – comparison of plantation productivity – case studies.

Unit III

Organic matter: Decomposition and mineralization; Litter accumulation, litter decomposition, effect of litter on soil, Interpretation of accumulation, decay and mineralisation processes, management of litter and soil organic matter in forest plantations. Soil and stand management for short rotation plantations; Water availability, Nutrient supply, uptake and tree growth, constraints on production, nutrient amendments and correction of nutrient deficiency.

Unit IV

Nutritional factors controlling stand growth. Reforestation of salt affected, acid soils and coastal soils. Effects of fire on soils: Types of fires, effects of fire on soil properties, effects of fire on air and water quality.

Unit V

Management and long term soil productivity – soil compaction and erosion – Harvest removal and nutrient Budgeting – Harvest effect on water quality – strategies for future management.

VI. Practical

- Nutrient budgeting for different plantation systems;
- Quantification of physical and chemical soil constraints in plantation and Agroforestry systems;
- Evolving new strategies for development.

VII. Suggested Reading

Binkley D and R Fisher 2012. *Ecology and Management of Forest Soils* (4th Edition), John Wiley & Sons Singapore Pte. Ltd., Singapore.

Brady NC and Weil RR. 2010. *Elements of the Nature and Properties of Soils* (3rd Edition.), Pearson Education, New Delhi.

Das DK. 2011. *Introductory Soil Science* (3rd Edition), Kalyani publisher, Ludhiana (India).

Gupta PK. 2009. *Soil, Plant, Water and Fertilizer Analysis* (2nd Edition), AGROBIOS, Jodhpur (India).

ISSS. 2002. *Fundamentals of Soil Science*. Indian Society of Soil Science, IARI, New Delhi.

J Benton and Jones Jr. 2012. *Plant Nutrition and Soil Fertility Manual* (2nd Edition), CRC Press, USA.

Jackson ML. 2012. *Soil Chemical Analysis: Advanced Course*, Scientific Publisher.

Jaiswal PC. 2006. *Soil, Plant and Water Analysis* (2nd Edition), Kalyani Publishers, Ludhiana.

Khan TO. 2013. *Forest Soils: Properties and Management,* Springer International Publishing, Switzerland.

Mengel *et al*. 2001 *Principles of Plant Nutrition* (5th Edition), Springer.

Pritchett and Fisher RF 1987. *Properties and Management of Forest Soils*. John Wiley, New York.

Reddy MV. 2001. *Management of Tropical Plantation Forests and Their Soil Litter System-Litter, Biota and Soil Nutrient Dynamics*, Science Publishers, U. S.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Soils and their management for plantation forestry: Soils of India	2
2.	Soil requirements for plantation forestry, physical properties of major soils of India, soil erosion and erodibility, erosion control	3
3.	Dynamics of nutrient supply in plantation soils: variability of nutrient stores in forest soils, changes in nutrient content	1
4.	Nutrient losses and their assessment, nutrient gains, nutrient transformation in soils	2
5.	Nitrogen fixation in tropical forest plantations: N fixation process, species, rates of N fixation, factors influencing N fixation	2
6.	Nutrient cycling – comparison of plantation productivity – case studies	2
7.	Hydrology of forest plantations: Forest hydrological cycle; The role of hydrological modelling in plantation management	2
8.	Organic matter: decomposition and mineralization; Litter accumulation and decomposition, effect of litter on soil, Interpretation of accumulation, decay and mineralisation processes	3
9.	Management of litter and soil organic matter in forest plantations	2
10.	Soil and stand management for short rotation plantations	1
11.	Water availability, Nutrient supply, uptake and tree growth, constraints on production, nutrient amendments and correction of nutrient deficiency	3
12.	Nutritional factors controlling stand growth	1
13.	Reforestation of salt affected and acid soils, coastal soils	2
14.	Effects of fire on soils: types of fires, effects of fire on soil properties, effects of fire on air and water quality	2
15.	Management and long term soil productivity – soil compaction and erosion	2
16.	Harvest removal and nutrient budgeting – harvest effect on water quality – strategies for future management	2
	Total	32
	Practical	
1.	Nutrient budgeting for different plantation systems	4
2.	Quantification of physical and chemical soil constraints in plantation and Agroforestry systems	6
3.	Evolving new strategies for development	6
	Total	16

I. Course Title : Environmental Modeling and Biostatistics

II. Course Code : FRM 607

III. Credit Hours : 2+0

IV. Aim of the course

To acquire knowledge on different environmental modeling approaches, sensitivity analysis and various statistical tools.

V. Theory

Unit I

Modeling for environmental sciences and management. Types of models. Causal diagrams, System Dynamics, Introduction to modelling software package, Population modelling, Modeling of material flows through the systems (pollutants transfer, etc). Modeling of cycles in nature (carbon cycle, etc.).

Unit II

Environmental modelling: scope and problem definition, goals and objectives, definition; modelling approaches – deterministic, stochastic and the physical approach; applications of environmental models; the model building process. Types of Model – Physical models, Conceptual models, Mathematical Models.

Unit III

Sensitivity analysis. Extinction risk. Multi-species population dynamics – Decision trees and Spatial models. Population Dynamics Predator-Prey (Lotka-Volterra methods) Model Builder in ArcGIS GIS Data for environmental models. GIS functions in environmental models. Model validation. Physical environmental models. Human (cultural, social, economic, etc.) environmental models.

Unit IV

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack Knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling. Statistical fundamentals are reviewed and expanded upon with multi variable regression analysis of Variance (ANOVA).

VI. Suggested Reading

Clarke K *et al*. 2001. Geographic Information Systems and Environmental Modeling. Prentice Hall.

DeMers M. 2002. *GIS Modeling in Raster*. Wiley.

Goodchild *et al.* 1996. *GIS and Environmental Modeling: Progress and Research Issues*. GIS world, Inc.

Hooman R and Lukas KB. 2005. *Bioinformatics Basics: Applications in Biological Science And Medicine*. John Wiley.

Hooman Rashidi, Lukas K and Buehler. 2005. *Bioinformatics Basics: Applications in Biological Science and Medicine*. Taylor & Francis.

Maguire Batty and Goodchild. 2005. *GIS, Spatial Analysis, and Modeling*. ESRI Press.

Nirmal Khandan N. 2001. *Modelling Tools for Environmental Engineers and Scientists*, CRC Press, Boca Raton, Florida.

Rosner B. 2006. *Fundamentals of Biostatistics,* ed. 6,. Duxbury Press. USA.

Smith J and Smith P. 2007. *Introduction to Environmental Modelling*. Oxford: Oxford University Press.

Whitlock MC and Schluter D. 2009. *The Analysis of Biological Data*. Roberts and Company Publishers.

Zar JH. 2010. *Biostatistical Analysis*. 5th Edition. Pearson Education International.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Modeling for environmental sciences and management. Types of models. Causal diagrams, System Dynamics	3
2.	Introduction to modelling software package, Population modelling, Modeling of material flows through the systems (pollutants transfer, etc.). Modeling of cycles in nature (carbon cycle, etc.)	3
3.	Environmental modelling: scope and problem definition, goals and objectives, definition; modelling approaches– deterministic, stochastic and the physical approach	4
4.	Applications of environmental models; the model building process. Types of Model – Physical models, Conceptual models, Mathematical Models	3
5.	Sensitivity analysis. Extinction risk. Multi-species population dynamics- Decision trees and Spatial models	2
6.	Population Dynamics Predator-Prey (Lotka-Volterra methods) Model Builder in Arc GIS	2
7.	GIS Data for environmental models. GIS functions in environmental models	2
8.	Model validation. Physical environmental models. Human (cultural, social, economic, etc.) environmental models	2
9.	Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing	4
10.	Re-sampling techniques – Boot strapping and Jack Knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling. Statistical fundamentals are reviewed and expanded upon with multi variable regression analysis of Variance (ANOVA)	4
	Total	29

I. Course Title : Approaches in Forest Resource Assessment

II. Course Code : FRM 608

III. Credit Hours : 1+1

IV. Aim of the course

To inculcate knowledge and skills in students to employ participatory tools and techniques for effective planning, implementation, monitoring and evaluation of forestry projects, to efficiently carry out forest resource management and to effectively resolve conflicts by adopting participatory techniques.

V. Theory

Unit I

Participatory extension – Importance, key features, principles and process of participatory approaches; Different participatory approaches (RRA, PRA, PLA, AEA, PALM, PAR,PAME, ESRE, FPR) and successful models.

Unit II

Participatory tools and techniques. Space Related Methods: village map and village forest map (social and resource),mobility services and opportunities map and transect; Time related methods: time line, trend analysis, seasonal diagram. Daily activity schedule, dream map; Relation oriented methods:cause and effect diagram (problem tree), impact – diagram, well being ranking method, Venn diagram, matrix ranking, livelihood analysis after and before implementation of Watershed Programmes.

Unit III

Preparation of action plans, concept and action plan preparation; Participatory technology development and dissemination; Participatory planning and management, phases and steps in planning and implementation aspects; Process monitoring, participatory evaluation.

VI. Practical

- Visit to selected forest areas to undertake and understand various participatory research methods including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.

VII. Suggested Reading

Kothari CR. 1992. *Research Methodology- Methods and Techniques* Wiley Eastern Limited New Delhi.

Narayanasamy N. 2008. *Participatory Rural Appraisal: Principles, Methods and Application*.

Robert Chambers. 1981. "*Rapid Rural Appraisal" "Rationale and Repertoire*", IDS Discussion Paper, No. 155, IDS, Sussex.

Sabarathnam VE. 2002. *R/ R/ PRA for Agriculture.*Vamsaravath Publishers, Hyderabad.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Participatory extension – Importance, key features, principles and process of participatory approaches	2
2.	Different participatory approaches (RRA, PRA, PLA, AEA, PALM, PAR, PAME, ESRE, FPR) and successful models	2
3.	Participatory tools and techniques. Space Related Methods: village map and village forest map (social and resource), mobility services and opportunities map and transect	2
4.	Time related methods: time line, trend analysis, seasonal diagram. Daily activity schedule, dream map	2
5.	Relation oriented methods: cause and effect diagram (problem tree), impact – diagram, well being ranking method, Venn diagram, matrix ranking	2
6.	Livelihood analysis after and before implementation of Watershed Programmes	1
7.	Preparation of action plans, concept and action plan preparation	1
8.	Participatory technology development and dissemination	2
9.	Participatory planning and management, phases and steps in planning and implementation aspects; Process monitoring, participatory evaluation	2
	Total	16

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Visit to selected forest areas to undertake and understand various participatory research methods	8
2.	Including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.	8
	Total	16

I. Course Title : Forest Hydrology and Watershed Management

II. Course Code : FRM 609

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and understanding among the students on various aspects of hydrology and watershed management and different government schemes on watershed management.

V. Theory

Unit I

Introduction to watershed hydrology, its management and agricultural sustainability issues; need of integrated watershed management in India; delineation of watersheds. Hydrology of watershed systems; estimation of surface runoff and sediment yields; effect of precipitation and hydro-climatic conditions on watershed systems; watershed erosion processes and their prevention; instrumentation and measurement of watershed management indicators.

Unit II

Use of GPS, GIS, RS and Decision Support Systems (DSS) in watershed management; technologies for rain-fed farming; socio-economic evaluation of the watershed management projects. Peoples' participation and livelihood analysis; cropping system and resource conservation techniques in watersheds.

Unit III

Heuristics and indigenous technical knowledge (ITKs) in watershed management; watershedassociations and groups in villages of India; Government policies, acts and schemes on watershed management

Unit IV

Mathematical modelling of hydrologic processes-precipitation, infiltration, evapo-transpiration, run-off, soil water balance. Watershed modeling. Frequency analysis for design of hydrologic systems; time series analysis for hydrologic design and forecasting.

VI. Practical

- Rain water budgeting – run off and soil loss, infiltration, soil moisture, deep percolation and ground water recharge, rainfall measurement hydrographs.
- Techniques for measuring subsurface flow on hill slopes. Field study of hill slope

flow processes.

- Survey of watershed, Preparation of micro-plan and planning of watershed for effective implementation.
- Preparation of contour maps, Estimation of earth work, Design of check dams, Acquaintance with water lifting devices, Use of measurement, Conveyance and control structures. Watershed delineation using GIS techniques.

VII. Suggested Reading

Chow VT, David M and Mays LW. 1988. *Applied Hydrology*. McGraw Hill.
Ghanshyan Das. 2000. *Hydrology and Soil Conservation Engineering*. Prentice Hall.
Isobel W Heathcote. 1998. *Integrated Watershed Management: Principles and Practice*. Wiley Publ.
Kenneth N Brooks, Peter FF folliott, Hans M Gregersen, Leonard F DeBano. 1991. *Hydrology and the Management of Watersheds*. Wiley-Blackwell.
Tideman EM. 1996. *Watershed Management*. Omega Scientific Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction to watershed hydrology, its management and agricultural sustainability issues; need of integrated watershed management in India; delineation of watersheds	4
2.	Hydrology of watershed systems; estimation of surface runoff and sediment yields	3
3.	Effect of precipitation and hydro-climatic conditions on watershed systems; watershed erosion processes and its prevention	3
4.	Instrumentation and measurement of watershed management indicators.	1
5.	Use of GPS, GIS, RS and Decision Support Systems (DSS) in watershed management; technologies for rain-fed farming; socio-economic evaluation of the watershed management projects	4
6.	Peoples' participation and livelihood analysis; cropping system and resource conservation techniques in watersheds	3
7.	Heuristics and indigenous technical knowledge (ITKs) in watershed management; watershedassociations and groups in villages of India	3
8.	Government policies, acts and schemes on watershed management	2
9.	Mathematical modelling of hydrologic processes-precipitation, infiltration, evapo-transpiration, run-off, soil water balance	3
10.	Watershed modeling	3
11.	Frequency analysis for design of hydrologic systems; time series analysis for hydrologic design and forecasting	3
	Total	32
	Practical	
1.	Rain water budgeting – run off and soil loss, infiltration, soil moisture, deep percolation and ground water recharge, rainfall measurements hydrograph	4
2.	Techniques for measuring subsurface flow on hill slopes. Field study of hill slope flow processes	3
3.	Survey of watershed, Preparation of micro-plan and planning of watershed for effective implementation	3

Sr. No	Topic	No. of Practical(s)
4.	Preparation of contour maps, Estimation of earth work, Design of check dams, Acquaintance with water lifting devices, Use of measurement, Conveyance and control structures	4
5.	Watershed delineation using GIS techniques	2
	Total	**16**

I. Course Title : Operational Research and Forest Modeling

II. Course Code : FRM 610

III. Credit Hours : 1+1

IV. Aim of the course

To provide different techniques and skills used in forest research, yield response models and their applications in forestry.

V. Theory

Unit I

Introduction to Operations Research-definitions- applications in forest science and management- Project Planning- Project Cycle-Project Evaluation tools-Log Frame Approach-Participatory Rural Appraisal – PERT -CPM- Advantages and Limitations, Application in Forestry Sector.

Unit II

Systems – Definitions – Components of a system – Modeling approach – Different kinds of models – their classification and properties – Simulation – Elements and basic concepts – Deterministic simulation – state variables, rate variables and drying variables – Feedback models and their solutions.

Unit III

Growth of biological populations – measurement of growth rate – population growth models – Discrete one species models – Exponential – Logistic – Gempertz and Mitcherlich– Richards Function Properties of models and estimation to biological data. Two species models – Predator and Prey models. 1569

Unit IV

Yield response models in single and multiple inputs – Quadratic – Square root – Estimating physical and Economic optimum Optimization of resources under constraints – Linear and non-linear programming – Formulation and their applications in Forestry.

VI. Practical

- Practicing Log Frame Approach(LFA-Participatory Rural Appraisal- PERT -CPM- Problems in Mathematical model – their classification and properties;
- Simulation – Examples – Growth Models – Linear – Exponential – Logistic – Richards – Gempertz and Mitcherlich – Predator and Prey models;
- Problems in Yield response models in single and multiple inputs – Quadratic – Square root –– Quadratic and square response models for several inputs – Estimating physical and Economic optimum;
- Formulation of L.P.P – Graphical method – Simplex method – Duality in L.P.P.

VII. Suggested Reading

Ranganathan CR. 2006. *A First Course in Mathematical Models of population Growth with MATLAB Programs*, Associated Publishing Company, New Delhi.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction to Operations Research-definitions- applications i n forest science and management	1
2.	Project Planning- Project Cycle-Project Evaluation tools-Log Frame Approach-Participatory Rural Appraisal – PERT -CPM- Advantages and Limitations, Application in Forestry Sector	2
3.	Systems – Definitions – Components of a system – Modeling approach	1
4.	Different kinds of models – their classification and properties – Simulation – Elements and basic concepts – Deterministic simulation – state variables, rate variables and drying variables – Feedback models and their solutions	3
5.	Growth of biological populations – measurement of growth rate – population growth models	2
6.	Discrete one species models – Exponential – Logistic – Gempertz and Mitcherlich– Richards Function Properties of models and estimation to biological data	2
7.	Two species models – Predator and Prey models	1
8.	Yield response models in single and multiple inputs	1
9.	Quadratic – Square root –Estimating physical and Economic optimum Optimization of resources under constraints	2
10.	Linear and non-linear programming – Formulation and their applications in Forestry	1
	Total	16
	Practical	
1.	Practicing Log Frame Approach(LFA-Participatory Rural Appraisal- PERT -CPM- Problems in Mathematical model – their classification and properties	6
2.	Simulation – Examples – Growth Models – Linear – Exponential – Logistic – Richards – Gempertz and Mitcherlich – Predator and Prey models	4
3.	Problems in Yield response models in single and multiple inputs – Quadratic – Square root — Quadratic and square response models for several inputs – Estimating physical and Economic optimum	4
4.	Formulation of L.P.P – Graphical method – Simplex method – Duality in L.P.P.	3
	Total	16

Supporting Courses
(Compulsory at M.Sc. level)

I. Course Title : General Statistical Methods and Computer Applications

II. Course Code : FOR 511

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students who do not have sufficient background of statistical methods. The students would be exposed to concepts of general statistical methods and statistical inference that would help them in understanding the importance of statistical methodology. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation of results.

V. Theory

Unit I

Review of probability. Random variable and mathematical expectation. Discrete and continuous probability distributions, viz., Binomial, Poisson and Normal distributions.

Unit II

Correlation and regression, Rank correlation, Non-linear regression, Partial and multiple correlation coefficient, Intra class correlation,Multiple linear regression.

Unit III

Introduction to theory of estimation, Testing of statistical hypothesis: chi-square, t and F distributions. Tests of significance based on chi-square, t and F tests. Large sample tests, Fisher Z transformation.

Unit IV

Analysis of variance: One way and two way classification. Design of Experiments: Basic Principles of design of experiments, Completely Randomised Design, Randomised Block Design, Latin Square Design. Elementary idea of factorial experiments. Estimation of genetic parameters from ANOVA table.

Unit V

Non-parametric tests: Sign test, Wilcoxon test, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test. MS Excel, Introduction to computer softwares.

VI. Practical

- Random variable and mathematical expectation;
- Fitting of distributions, viz., Binomial, Poisson, Normal;
- Correlation and regression;
- Non-linear regression;

- Multiple linear regression;
- Testing of hypothesis based on chi square, t and F tests. Large sample tests. Completely Randomised Design, Randomised Block Design, Latin Square Design and Factorial experiments. Non-parametric tests. Exercises based on computer software.

VII. Suggested Reading

Aggarwal BL. 1996. *Basic Statistics*. Wiley Eastern Limited, New Age International Ltd.

Bansal ML, Singh S, Singh TP and Kumar R. 2004. *Statistical Methods for Research Workers*. Kalyani Publishers.

Chandel SRS. 2014. *A Handbook of Agricultural Statistics*. Achal Prakashan.

Goon AM, Gupta MK and Dasgupta B. 1968. *Fundamentals of Statistics*, vol I, II. The World Press, Calcutta.

Snedecor GW and Cochran WG. 1980. *Statistical Methods*. East West Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Review of probability. Addition and multiplication law of probability	2
2.	Random variable and mathematical expectation	1
3.	Discrete and continuous probability distributions: Binomial, Poisson and Normal distributions	4
4.	Correlation and regression. Rank correlation	2
5.	Non-linear regression	1
6.	Partial correlation coefficient, multiple correlation coefficient, Multiple linear regression. Intra class correlation	4
7.	Introduction to theory of estimation	1
8.	Testing of statistical hypothesis: chi-square, t and F distributions. Tests of significance based on chi-square, t and F tests. Large sample test. Fisher z transformation	5
9.	Analysis of variance: One way and two way classification	2
10.	Design of Experiments: Basic Principles of design of experiments, Completely randomised design, Randomised block design, Latin square design	4
11.	Elementary idea of Factorial experiments. Estimation of genetic parameters from ANOVA table	3
12.	Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test	2
13.	MS Excel, Introduction to computer software	2
	Total	**33**
	Practical	
1.	Random variable and mathematical expectation	1
2.	Discrete and continuous probability distributions: Binomial, Poisson and Normal distributions	2
3.	Correlation and regression. Rank correlation	1
4.	Non-linear regression	1
5.	Multiple linear regression. Intra class correlation	2
6.	Tests based on chi-square, t and F tests. Large sample test	2
7.	Analysis of variance: One way and two way classification	1

Sr. No	Topic	No. of Practical(s)
8.	Design of Experiments: Basic Principles of design of experiments, Completely randomised design, Randomised block design, Latin square design	2
9.	Elementary idea of Factorial experiments. Estimation of genetic parameters from ANOVA table	1
10.	Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test.	1
11.	MS Excel, Applications of computer software to statistical analysis	2
	Total	**16**

Supporting Courses (Compulsory at Ph.D. level)

I. Course Title : Research Methodology in Forestry

II. Course Code : FOR 610

III. Credit Hours : 2+1

IV. Aim of the course

The students would exposed to concepts of design of experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental/ field data. The students would also be exposed to elementary sampling techniques. It would help them in understanding the concepts involved in planning and designing their surveys, presentation of survey data, analysis of survey data and presemntation of results.

V. Theory

Unit I

Experimental Design: Research problem. Types of Research. Need for designing of experiments, Basic principles of design of experiment. Uniformity trials, size and shape of plots and blocks; Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design. Factorial experiments, (symmetrical as well as asymmetrical). Confounding in symmetrical factorial experiments, Factorial experiments with control treatment. Split plot and strip plot designs; Analysis of covariance and missing plot techniques. Balanced incomplete block design, Fitting of response surfaces. Transformations of data. Groups of experiments.

Unit II

Sampling Theory: Basic terms used in sampling. Simple random sampling, Stratified random sampling, Systematic random sampling. Elementary idea of probability proportional to size, multistage, cluster and inverse sampling.

Unit III

Elementary idea to multivariate analytical tools- Classification and Discriminant function. Factor analysis, Principal component and cluster analysis.

VI Practical

- Analysis of data obtained from CRD, RBD, LSD;
- Analysis of factorial experiments without and with confounding;
- Analysis with missing data;
- Split plot and strip plot designs;
- Transformation of data; Fitting of response surfaces. Balanced incomplete block design;
- Groups of experiments. Simple random sampling, Stratified random sampling, Systematic random sampling.

VII Suggested Reading

Aggarwal BL. 2011. *Theory and Analysis of Experimental Designs*. CBS Publisher, New Delhi.

Gomez KA and Gomez AA. 1984. *Statistical Procedure for Agricultural Research*. John Wiley and Sons.

Johnson Richard A and Dean W Wichern. 2015. *Applied Multivariate Statistical Analysis*. Prentice Hall of India.

Mukopadhyay Parimal. 2008. *Theory and Methods of Survey Sampling*. Prentice Hall of India.

Sahu PK and Das AK.2014. *Agriculture and Applied Statistics* 2. Kalyani Publisher.

Singh D and Chaudhary FS. 2018. *Theory and Analysis of Sample Survey Design*. New Age International Ltd.

Zar Jerrold H. 2010. *Biostatistical Analysis*. Prentice Hall.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Need for designing of experiments, Basic principles of design of experiment. Uniformity trials, size and shape of plots and blocks	3
2.	Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design	4
3.	Factorial experiments, Confounding in symmetrical factorial experiments	4
4.	Factorial experiments with control treatment	1
5.	Split plot and strip plot designs	3
6.	Analysis of covariance and missing plot techniques	2
7.	Balanced incomplete block design, Fitting of response surfaces. Transformations of dat	3
8.	Groups of experiments	2
9.	Basic terms used in sampling. Simple random sampling	3
10.	Stratified random sampling, Systematic random sampling	3
11.	Elementary idea of multistage, cluster and inverse sampling	2
12.	Elementary idea to multivariate analytical tools- Classification and Discriminant function. Factor analysis, Principal component and cluster analysis	2
	Total	**32**
	Practical	
1.	Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design	3
2.	Factorial experiments, Confounding in symmetrical factorial experiments	3
3.	Factorial experiments with control treatment	1
4.	Split plot and strip plot designs	2
5.	Analysis of covariance and missing plot techniques	2
6.	Balanced incomplete block design, Fitting of response surfaces. Transformations of data	2
7.	Groups of experiments	1
8.	Simple random sampling, Stratified random sampling, Systematic random sampling	2
	Total	**16**

ANNEXURE I

List of BSMA Committee Members for Forestry

S.No.	Name and Address	Specialization
1.	**Dr L K Dashora** **Former Dean and ICAR Professor Emeritus** Agriculture University, Borkhera, Baran Road, Kota, Rajasthan/ R 5/51 Jaishri Colony, Dhulkot Road Udaipur-313 001 E-Mail: dashoralk_3303yahoo.com Mob: 09414285066	**Chairman**
2.	**Dr P K Mahajan** **Dean** College of Forestry, Dr YS Parmar Univ. of Horticulture and Forestry, Solan E-Mail: dean_cof@yahoo.co.in, deancof@yspuniversity.ac.in pawan_cof@yahoo.com Mob: 09418323933	**Convener**
3.	**Dr Dinesh Kumar** **Scientist G** Silviculture and Forest Management Division, Forest Research Institute Dehradun E-Mail: kumard@icfre.org Mob: 09411173576	**Member**
4.	**Dr Sushil Kumar Gupta** **Dean** College of Forestry, Ranichauri P.O. Ranichauri, Distt. Tehri Garhwal-249 199, Uttarakhand, India Phone: +91-1376-252080 (O), Fax: +91-1376-252128 E-mail: deanranichauri2013@gmail.com, sushilgupta67@rediffmail.com, Mobile: 09419109864	**Member**
5.	**Dr R.S Dhillon** **Professor and Head** Department of Forestry, College of Agriculture, Chaudhary Charan Singh Haryana Agriculture University, Hisar E-Mail: rsdhillon67@gmail.com, Mob: 09416343281	**Member**

S.No.	Name and Address	Specialization
6.	**Dr Sanjeev Thakur** **Professor and Head** Department of Tree Improvement and Genetic Resources, College of Forestry, Dr YS Parmar University of Horticulture and Forestry Nauni-Solan-173230 E-Mail: sanjeevtigr@yspuniversity.ac.in Mob: 09418150975	**Member**
7.	**Dr S S Narkhede** **Dean (Agri.) and Director of Instruction,** College of Forestry, Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, District Ratnagiri-415712 E-Mail: ssn_forest@rediffmail.com Mob: 09422863027	**Member**
8.	**Dr P O Nameer** **Professor and Head** Department of Wildlife Sciences, College of Forestry, Kerala Agricultural University-680656, Thrissur E-Mail: nameer.po@kau.in Mob: 09446573106	**Member**
9.	**Dr Kulwant Rai Sharma** **Professor and Head** Department of Forest Products, College of Forestry, Dr YS Parmar University of Horticulture and Forestry, Solan-173230 E-Mail krai1960@yahoo.com, Mob: 09418230268	**Member**
10.	**Dr Bhupender Dutt** **Professor** Department of Forest Products, College of Forestry, Dr YS Parmar University of Horticulture and Forestry, Solan-173230 E-Mail: bdbfp@yahoo.co.in Mob.: 0821913706	**Member**

Sericulture

Contents

Acknowledgements

Dr P. Venkataramana, Dean (Seri), College of Sericulture, Chintamani and Chairman of the BSMA committee on Sericulture and Dr V. Shankaranarayana, Former Dean (Seri), College of Sericulture, Chintamani and Convenor of the BSMA committee on Sericulture immensely acknowledges the Indian Council of Agricultureal Research, New Delhi for providing an opportunity to revise the post graduate programme syllabi in Sericulture offered in different State Agricultural universities of the country. The revision was done keeping in mind the recent advances in the field of sericulture in the country, abroad, farmers and industry. We hope, the revised syllabi will be of great help in catering the requirements of the above clients.

Dr P.Venkataramana
Dr V. Shankaranarayana

Preamble

Salient feature of revised syllabi and major changes made including new courses/ topics/ aspects added

- M.Sc. (Agri.) in sericulture courses for majority of the courses the title has been modified and syllabi is upgraded based on the recent advances in that particular course/ field.
- In the Genetics and Breeding of Mulberry course the recent technologies such as nano technology is included.
- The pests and diseases of both silkworms and host plant have been split into two courses separately for silkworms and mulberry.
- The silkworm seed and cocoon production the course have also separated into two courses, viz., silkworm egg production technology and silkworm rearing technology including the seed act 2010 by increasing one more credit hour.
- In the course silk technology it has been split into two courses *i.e*, Silk Technology-I for (M.Sc.) and silk technology-II for (Ph.D.) which covers the advanced technologies.
- In the course Non-mulberry sericulture the contents and syllabus is upgraded with more practical orientation including proteomics, transcriptomics and genomics organism.
- In the minor courses, viz., nutrition of host plant of silkworms recent topics on fertilizer use efficiency, enumeration of soil micro flora, trenching and mulching techniques in mulberry have been included.
- The biotechnological aspects of silkworms a mulberry dealt separately with more emphasis on practical aspects.
- In the sericulture by product utilization and value addition more emphasis has been laid on recycling of flimsy/ waste cocoons, use of seri proteins, etc.

Ph.D. (Agri.) in Sericulture

- The course title and syllabi of most of the courses modified keeping the recent advances in the courses in mind.
- The conventional, non-conventional methods of breeding, evaluation of germplasm for different stresses and recent breeding techniques applicable to mulberry have been included.
- The new topics an aeroponics and hydroponics are included.
- In the integrated pest management in sericulture course, the new topics such as taxonomy of protozoan and fungal species and different dis-infectetants used have also been covered.
- In the minor courses the silk technology-II is added to deal with new topics such as species and type concepts and recent preservation techniques.
- In the seri business management course the credit hours increased with more practical components and visit to seri business units/ centre/ institution/ NGO's, tasar and muga reeling technology, silk testing and grading, SERM and ARM, non-mulberry silk reeling technology, etc.

Aspects included in line with the national initiatives:

- Detailed study of silkworm and mulberry pests and diseases
- Seed act 2010
- Advanced silk technological aspects
- Fertilizer use efficiency.
- Trenching and mulching technique in mulberry
- Seri by product utilization, value addition
- Poly cross breeding in mulberry
- Histopathology of viruses, protozoans
- Entrepreneurship development in sericulture
- Silk preservation techniques
- Non mulberry silk reeling technology.

Topics covered related to global development:

- Nano technology
- Soil microflora
- Hydroponic and aeroponics
- Genomics, proteomics and transcriptomics
- Seri protein usage

The following nomenclature and Credit Hrs has been followed while providing the syllabus.

	Masters' Programme	Doctoral Programme
(i) Course work		
Major courses	20	12
Minor courses	08	06
Supporting courses	06	05
Common courses	05	–
Seminar	01	02
(ii) Thesis Research	30	75
Total	70	100

Course Title with Credit Load
M.Sc. (Agri.) in Sericulture

Course Code	Course Title	Credit Hours
	Major courses	
SER 501	Mulberry Production Technology	1+1
SER 502	Genetics and Breeding of Mulberry	1+1
SER 506	Systematics and Morphology of Sericigenous insects	1+1
SER 509	Silkworm Egg Production Technology	1+1
SER 510	Silkworm Rearing Technology	1+1
SER 511	Genetics and Breeding of Silkworms	1+1
SER 512	Diseases and Pests of Silkworms	1+1
SER 514	Silk Technology-I	1+1
SER 515	Non-mulberry Sericulture	1+1
	Principles of Biochemistry	1+1
	Design and Analysis of Experiments	1+1
	Scientific/ Technical writing Skills	1+1
	Research Methodology	1+1
		13+13=26
	Minor courses*	
SER 503	Nutrition of Host Plants of Silkworms	1+1
SER 504	Mulberry Pests and Diseases	2+1
SER 505	Biotechnology of Mulberry	1+1
SER 507	Anatomy and Physiology of Sericigenous insects	1+1
SER 508	Silkworm Biochemistry and Nutrition	1+1
SER 513	Biotechnology of Silkworm	1+1
SER 516	Sericulture By-product utilization and Value addition	1+1
		8+7=15

*Note: The students may opt the optional courses from any disciplines/ departments as recommended by the advisory committee of the student based on the research topic.

Major Courses Contents
M.Sc. (Agri.) in Sericulture

I. Course Title : Mulberry Production Technology

II. Course Code : SER 501

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is a perennial deep-rooted high biomass producing foliage crop, cultivated as a sole food for silkworm (*Bombyx mori* L). Mulberry cultivation is the very foundation of commercial sericulture to raise a successful cocoon crop. The quantity of leaf produced and its quality has a direct bearing on silkworm health and the quantity of cocoons produced. Thus, the profitability of sericulture and quality of cocoons depends on nutritive quality of mulberry leaves, as nearly as 70% of the silk proteins produced by the silkworm are directly derived from the mulberry leaves in addition to other nutrients. Hence, cultivation and best yield of the mulberry plants occupy important place in sericulture.

V. Aim of the course

The course is designed to provide both theory and practical knowledge on scope of mulberry sericulture, global distribution and factors influencing mulberry leaf yield and quality. Mulberry varieties, selection of site for garden, propagation techniques, soil and climatic requirements will be taught. Package of practices for raising mulberry saplings, rainfed and irrigated mulberry cultivation, separate chawki garden, tree mulberry, mulberry cultivation in hilly areas, intercropping, organic farming and IFS component will be part of the course. Use of growth hormones and growth regulators on mulberry leaf yield and quality will be studied in addition to pests and diseases of mulberry. Mulberry farm management and economics of mulberry production will e added.

The course is organized as follows:

No	Blocks	Units
1	Introduction, scope and varieties	I. Overview and scope of mulberry sericulture II. Varieties of mulberry
2	Mulberry production	I. Raising of mulberry saplings and planting. II. Establishment of mulberry garden
3	Mulberry protection	I. Mulberry pests and their management II. Mulberry diseases and their management
4	Economics	I. Economic of mulberry production

VI. Theory

BLOCK 1: Introduction, scope and varieties

Unit I: Overview and Scope of mulberry sericulture

Scope of mulberry sericulture, an overview of sericulture industry in the world and India. Leaf quality requirements, factors influencing mulberry leaf yield and quality. Scope for mechanization in mulberry cultivation.

Unit II: Varieties of mulberry

Mulberry varieties, Traditional mulberry varieties, popular mulberry varieties in different climatic zones, high yielding varieties, varieties for rainfed condition, varieties for specific conditions.

BLOCK 2: Mulberry production

Unit I: Raising of mulberry saplings and planting

Technology for raising of saplings for bush and tree type mulberry cultivation. Preparation of bed, planting material, transportation, storage, planting, weeding, fertilizer application and disease and pest management, uprooting, transportation and planting in main field.

Unit II: **Establishment of mulberry garden**

Package of practices for rainfed and irrigated mulberry cultivation, separate chawki garden, tree mulberry, mulberry cultivation in hilly areas. Selection of land, land preparation, planting, initial care and maintenance for different methods of mulberry cultivation and pruning practices. Mechanization in mulberry cultivation, intercropping, organic farming and IFS component. Manure and fertilizer schedule, irrigation schedule, use of biofertilizers for enhanced yield, use of growth hormones and growth regulators.

BLOCK 3: Mulberry protection

Unit I: Mulberry pests and their management

Mulberry pest status, occurrence, type of damage, symptoms, crop loss, life-cycle, different methods of management techniques, Integrated Pest Management (IPM) in mulberry.

Unit II: Mulberry diseases and their management

Mulberry diseases, occurrence, damage, symptoms, crop loss and different methods of management techniques and Integrated Disease Management (IDM) in mulberry.

BLOCK 4: Economics

Unit I: Economic of mulberry production

Farm records, role of non-monetary inputs in mulberry production, effective farm management, economics of mulberry production.

VII. Practicals

- Analysis of area, production and productivity of mulberry and sericulture in Karnataka, India and world;
- Study of Agronomic features of different mulberry varieties;
- Practising of different mulberry planting systems;
- Study of rooting and sprouting behaviour of mulberry varieties;
- Raising saplings through soft, semi soft and apical tender shoots;

- Mulberry nursery establishment and management;
- Study of mulberry as an intercrop in plantations;
- Selection of fruits and preparation of mulberry seeds for raising mulberry seedlings;
- Study of different planting systems of tree mulberry;
- Study of Intercropping in mulberry garden;
- Study of organic mulberry farming;
- Study of Mulberry as IFS component;
- Effect of different pruning systems on mulberry yield;
- Estimation of leaf area by non-destructive and destructive methods;
- Study of different leaf preservation techniques and different methods of leaf harvest with special reference to chawki and grown up silkworms;
- Study of different schedules of operation in mulberry garden and fertilizer application, methods of application and irrigation schedules;
- Study of weed flora in mulberry garden;
- Study of Farm records and Economics of mulberry cultivation;
- Institutional/ Farmers field visits.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of mulberry cultivation and relate the key learning to both research and extension
- Utilise methods and tools for mulberry nursery and mulberry production
- Utilise material in scientific publications relevant to mulberry production technology and adoption that critically reflect on their benefits.

X. Suggested Reading

Anonymous. 1975. *Textbook of Tropical Sericulture.* Japan Overseas Co-operation volunteers, Japan, p.594.

Aruga H. 1994. *Principles of Sericulture*. Oxford & IBH, New Delhi, p. 376.

Dandin SB, Jaiswal and Giridhar. 2003. *Handbook of Sericulture Technologies.* CSB, Bangalore, p.287.

Ganga G and Sulochana Chetty J. 1991. *An Introduction to Sericulture*. Oxford & IBH, New Delhi, p.176.

Ganga G 2003. *Comprehensive Sericulture.* Volume 2. *Silkworm Rearing and Silk Reeling.* Oxford & IBH, New Delhi, p.429.

Govindaiah, Gupta VP, Sharma DD, Rajadurai S and Nishitha Naik V. 2005. *Textbook on Mulberry Crop Protection,* p 247.

Jolly MS. 1987. *Appropriate Sericulture Techniques.* Central Sericultural Research and Training Institute, CSB, Mysore, p.215.

Kamal Jaiswal, Sunil P Trivedi, Pandey, BN and Khatri RK. 2009. *Moriculture,* pp. 130-147.

Kichisaburo Minamizawa. 1984. *Moriculture: Science of Mulberry Cultivation,* pp. 372-402.

Rangaswamy G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly M. 1976. *Manual on Sericulture-I.Mulberry Cultivation*, FAO, Rome, P.150.
Savithri G, Sujathamma P and Neeraja P. 2016. *Sericulture industry: an overview,* pp. 28-35.
Ullal, S.R. and Narasimhanna, M.N. 1981. *Handbook of Practical Sericulture,* CSB, P.209.

Journals

- *Bulletin of Indian Academy of Sericulture*, CSTRI, Berhampore
- *Indian silk,* CSB, Bangalore
- *Journal of Sericultural Science of Japan,* Japan
- *Seridoc*, CSRTI (CSB), Mysore
- *Sericologia*, ISC, Bangalore
- *Korean Journal of Sericulture*, Korea
- *Indian Journal of Sericulture*, CSRTI (CSB), Mysore
- And other Periodicals, Journals, Reports, Brochures, etc.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Genetics and Breeding of Mulberry

II. Course code : SER 502

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is perennial and highly heterozygous crop. In order to develop high yielding mulberry varieties for different situations, genetic principles and different breeding methods are prerequisite. In order to improve mulberry genetically, knowledge on different aspects of origin and diversity, floral structure, biology and pollination, genetic basis and concept of breeding, use of germplasm and conventional methods and non-conventional methods of breeding is essential. Hence this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of mulberry origin and diversity, floral structure, biology and pollination, genetic basis and general concept of breeding. Establishment of germplasm and genetic improvement of mulberry by conventional and non-conventional methods of breeding are dealt.

The course is organised as follows:

No.	Blocks	Units
1.	Taxonomy and botanical description and classification of mulberry	I Origin and diversity studies of mulberry
		II Study of floral structure, biology and pollination
		III Genetic basis and general concept of mulberry breeding
2.	Mulberry germplasm and breeding methods	I Mulberry germplasm
		II Conventional methods of breeding
		III Non-conventional methods of breeding

VI. Theory

BLOCK 1: Taxonomy and botanical description and classification of mulberry

Unit 1: Origin and diversity studies of mulberry

Centre of origin and diversity studies of mulberry, Mulberry species and their distribution in India and other countries. Taxonomy of the genus *Morus*. Botanical description of the *Morus* spp.

Unit 2: Study of floral structure, biology and pollination

Reproduction and genetic constitutions in mulberry –asexual reproduction- characteristics of mulberry florets- sexual behaviour-anthesis-reproductive variability. Pollination in mulberry. Cytology of mulberry, cell division- mitosis and meiosis and their significance. Karyomorphological studies. Microsporogenesis and Megasporogenesis in mulberry. Embryological studies of mulberry.

Unit 3: Genetic basis and general concept of mulberry breeding

Expression of gene: Segregation of genes, linkage, homozygosis, quantitative inheritance, features of polygenic inheritance, population structure, Selection of Parents for Hybridization. Procedure of Hybridization:Pruning and Synchronization of Flowering, Bagging, Tagging, Pollination. Harvesting and storing of F_1 seeds, Raising F_1 generation. Seedling Selection criteria. Difficulties in hybridization, Consequences of hybridization. Combining ability: general combining ability and specific combining ability, Heritability, genetic advance and genetic divergence.

BLOCK 2: Mulberry germplasm andbreeding methods

Unit 1: Mulberry germplasm

Establishment of mulberry,objectives and need, exploration, collection and introduction of mulberry germplasm, acclimatization and utilization. Introductions, world collection of mulberry germplasm, plant quarantine, conservation and maintenance of mulberry germplasm, characterization and evaluation of mulberry germplasm, role of mulberry germplasm study in mulberry improvement.

Unit 2: Conventional methods of breeding

Objectives and pre-requisites of mulberry breeding. Genetics of important traits. Early works of mulberry breeding, problems associated with mulberry breeding, conditions favouring mulberry breeding. Reproductive systems and plant breeding methods, Pollination in mulberry and crossing techniques. Mulberry varieties developed through direct selection, selection without controlled pollination, controlled pollination methods, handling of segregating progenies, Conventional methods of breeding- introduction, clonal selection, backcross method. Intervarietal and distant hybridization. Heterosis breeding. Population improvement. Polycross hybrids – Principles involved, advantages and disadvantages, steps in development of polycross hybrids. Multilocational trial and mulberry authorization programme, testing of feed quality. Advanced generation breeding. Improved varietal evaluation distribution and maintenance. Challenges for future.

Unit 3: Non-conventional methods of breeding

Polyploidy breeding in mulberry: Introduction, origin of polyploids, general features of polyploidy, induction of polyploidy and optimal level, special features of triploids, process of triploid mulberry development, varieties developed by polyploidy breeding in mulberry.

Mutation breeding in mulberry: Induction of mutation, bud mutation and chimeras, mutation breeding achievements in mulberry, usefulness of induced mutation, cutting back treatment, limitations and achievements of mutation breeding in mulberry.Breeding for leaf quality, resistance against diseases and pests, tolerance for drought, alkalinity and salinity. Evaluation of mulberry genotypes for different growth and yield parameters. Centres involved in mulberry improvement. Statistical approaches for yield test: Field plot techniques in mulberry breeding experiments. Different experimental designs-RCBD, ARCBD and LSD. Recent approaches in mulberry improvement: *In-vitro* techniques- achievements and prospects.

VII. Practicals

- Floral structure of mulberry;
- Floral biology of mulberry;
- Practising of staggered pruning in mulberry for inducing flowering;
- Sporogenesis: Micro and Megasporogenesis in mulberry;
- Preparation of mitosis slides in mulberry;
- Preparation of meiosis slides in mulberry;
- Study of pollen morphology, pollen fertility and viability;
- Study of stigma receptivity;
- Pollination and crossing techniques in mulberry;
- Characterization of available mulberry germplasm;
- Collection of mulberry fruits, extraction of seeds and raising of seedlings;
- Practising of selection in segregating population/ progenies;
- Study of varietal characteristics of released mulberry varieties;
- Layout of field experiments in mulberry for yield evaluation;
- Techniques of induction of mutants and polyploidy in mulberry;
- Testing for resistance to biotic and abiotic stresses in mulberry;
- Breeding for quality improvement in mulberry;
- Visit to Germplasm research station, CSGRC, Hosur.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text book/ Publication reviews
- Student presentations
- Group work
- Students interview of key policy makers
- Case analysis and case studies, guest lectures
- Review of policy documents

IX. Learning outcome

After successful completion of this course the students are expected to be able to get equipped with the different breeding methods for improvement of mulberry.

X. Suggested Reading

Amitabh Sarkar. *Mulberry breeding*. Kalyani publication, New Delhi.

Chakraborti SP, Roy Chowdhuri S and Bindroo BB. 2013. *A text book on mulberry breeding and genetics*. Kalyani publications, New Delhi.

Dandin SB. 1986. *Mulberry breeding for tropics*. In "*Lectures on Sericulture*" Edt. (G. Boraiah), Suriamya Publishers, Bangalore, pp. 25-28.

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Giridhar K. 1996. *Studies on some improved varieties of mulberry and their influence on the silkworm*, *Bombyx mori* L. Ph. D. Thesis, Mysore University, Mysore, India.

Jalaja KS and Ram Rao DM. 2008. *Characterization of seven mulberry genotypes for their leaf quality and bioassay with silkworm*, *Bombyx mori* L. *Sericologia*, **48**(1):85-93.

Machii H, Koyama A, Yamanuchi H and Katagiri K. 1997. *Manual for the characterization and evaluation of genetic resources. Misc. Natl. Inst. Seri. Entomol. Sci.,* **22**: 105-124.

Machii M. 1990. *Leaf disc transformation of mulberry plant* (*Morus alba* L.) by *Agrobacterium* Ti plasmid. *J. Seric. Sci. Japan*, **59**: 105-110.

Masilamani S, Reddy AR, Sarkar A, Sreenivas BT and Kamble CK. 2000. *Heritability and genetic advance of quantitative traits in mulberry* (*Morus* spp.). *Indian J. Seric*., **13**(1): 16-20.

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Rangaswami G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly MS. 1978. *Manual of Sericulture. Vol. 1 Mulberry Cultivation*, FAO, Rome, p.150.

Sarkar A and Fujita H. 1993b. *Japanese system of mulberry breeding: First selection*. *Indian Silk*, September, 9-14.

Sarkar A, Jalaja Kumar S and Datta RK. 2000. *Gradual improvement of mulberry varieties under irrigated condition in South India and the optimal programme for varietal selection in the tropics*. *Sericologia*, **12**: 142-148.

Sastry CR. 1984. *Mulberry varieties, exploitation and pathology*. *Sericologia,***24**(3): 333-359.

Singh BD. *Plant breeding Principles and methods*. Kalyani publication, New Delhi.

Susheelamma BN, Jolly MS, Sharma Giridhar K, Dwivedi NK and Suryanarayana N. 1988. *Correlation and path analysis in mulberry under stress and non-stress conditions*. *Sericologia,* **28**(2): 239-243.

Journals

- *Bulletin of Indian Academy of Sericulture*, CSTRI, Berhampore
- *Indian silk,* CSB, Bangalore
- *Journal of Sericultural Science of Japan,* Japan
- *Seridoc*, CSRTI (CSB), Mysore
- *Sericologia*, ISC, Bangalore
- *Korean Journal of Sericulture*, Korea
- *Indian Journal of Sericulture*, CSRTI (CSB), Mysore
- And other Periodicals, Journals, Reports, Brochures, etc.

Websites

- www.csb.gov.in/
- https://www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Systematics and Morphology of Sericigenous insects

II. Course Code : SER 506

III. Credit Hours : 1+1

IV. Why this course ?

This course gives an impetus to study the morphological differences among sericigenous insects and to define new eco-races adopting morpho taxonomy, chemo taxonomy; to establish and explore new sericigenous fauna in different agro climatic zones.

V. Aim of the course

To inculcate basic systematics study among the students and to explore new fauna among sericigenous group of insects. Defining new genara, species and tribes in sericigenous insects in various habitats of different Agro-climatic zones of Karnataka/ India

The course is organized as follows:

No	Blocks	Units
1.	Morphological studies	I Introduction to Morphology II Morphology of integument III Morphology of body segments and appendages
2.	Systematics of sericigenous insects	I Introduction, scope and methods II Type concept III Preparation of keys IV Zoological nomenclature

VI. Theory

BLOCK 1: Morphological studies

Unit 1: Introduction to morphology

Introduction, general morphology with special reference to the morphology of sericigenous insects.

Unit 2: Morphology of integument

Structure, segmentation and out growths, body regions, appendages and other structures, their modifications in general.

Unit 3: Morphology of body segments and appendages

Morphology of head, thorax, abdomen and their appendages, antennae, mouthparts, setae, legs, cerci, styli and others. Morphology of reproductive organs – modifications.

BLOCK 2: Systematics of sericigenous insects

Unit 1: Introduction, scope and methods

Introduction to systematics: Concept, scope and applications, methods involved in systematics.

Unit 2: Type concept

Holotype, syntype, erection of type and preservation of type.

Unit 3: Preparation of keys

Key formation for sericigenous insects to identify orders, families, genera, species and tribes/ eco-races.

Unit 4: Zoological nomenclature

Binomial nomenclature; concept, scope and application.

VII. Practicals

- Study of head of sericigenous insects;
- Study of thorax and abdomen of sericigenous insects;
- Study of integument, their processes, out growths and setal maps;
- Preparation of temporary/ permanent slides to study the processes;
- Drawing of sketches using grid and camera lucida;
- Collection and preservation of specimens – whole specimen, dry/ wet preservation, labelling of the specimens;
- Study of type concept – Hollotype, Syntype and allotype;
- Preparation of keys to orders, families, genera, species and tribes;
- Study of different sericigenous insects by making diagrams;
- Study of Chaetotaxy in sericigenous insects;
- Study of immature stages of silkworm *Bombyx mori* L.;
- Study of immature stages of Tropical Tasar silkworm;
- Study of immature stages of Eri silkworm;
- Study of Polymorphism in silkworm *Bombyx mori* L., Tropical Tasar and Eri silkworm;
- Field visits for collection of Non-mulberry silkworms;
- Collection and preservation of sericigenous insects (Dry preservation);
- Collection and preservation of immature stages of sericigenous insects (Wet preservation);
- Visit to Taxonomic section of department of entomology to understand preservation of specimens and their management.

VIII. Teaching Methods/ Activities

- Lectures
- Collections, preservation of specimens and submission of different species of sericigenous insects
- Drawing of specimens – habitat sketches using camera lucida and grids
- Photography of specimens using scientifically advanced camera
- Micro photography/ photo microscopy of specimens
- Preparation of permanent slides
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected

- To identify the sericigenous fauna
- To understand the basic principles of morphology
- To understand the basic principles of systematics
- Understanding the Type concept, erection of types
- To establish confidence in systematics of sericigenous insects

X. Resources

Dilip De Sarkar. 1998. *The Silkworm – Biology, Genetics and Breeding*. Vikas Publishing House Pvt. Ltd., New Delhi.

Imms AD. 1961. *General Text Book of Entomology*. 9th Edn., Rev. by O.W. Richards & R.G. Davies, Bombay.

Saxena AB. 1996. *Development of Behaviour in Insects*. Anmol Publications Pvt. Ltd., New Delhi.

Saxena AB. 1996. *Principles of Insect Morphology*. Anmol Publications Pvt. Ltd., New Delhi.

Saxena AB. 1996. *Ecology of Insects*. Anmol Publications Pvt. Ltd., New Delhi.

Journals

- *Bulletins of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - Published by NASSI, Bangalore.
- *Indian Silk* - Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silkworm Egg Production Technology

II. Course Code : SER 509

III. Credit Hours : 1+1

IV. Why this course ?

The silk cocoon yield and productivity directly depend on quality of silkworm eggs produced and distributed to the farmers. The silkworm egg production should be organized and handled scientifically for good quality disease free egg production at both seed and at commercial egg production. The present course is designed to make the student understand the organization of egg production and Acts associated with silkworm seed production, establishment of grainage, grainage equipments, activities, mother moth examination for disease free layings, egg incubation and preservation schedules, production of hybrid seeds and economics of egg production.

V. Aim of the course

The course is formulated with the aim of equipping the PG students with best scientific and practical knowledge on all the activities of egg production starting from organizational setup of seed production, grainage equipment, grainage activities, mother moth examination for producing student community of scientific and high technology expertise.

The course is organised as follows:

No.	Blocks	Units
1.	Organization of egg production	I Three tier multiplication of silkworm seeds II Seed Act
2.	Grainage	I Establishment of grainage II Grainage activities
3.	Artificial Hatching of eggs	I Production of hybrid eggs II Artificial methods of hatching

VI. Theory

BLOCK 1: Organization of egg production

Unit 1: Three tier multiplication of silkworm seeds

Organization of egg production. Breeder stock, foundation stock and commercial egg production (egg cards and loose egg preparation).

Unit 2: Seed Act

Seed legislative act, 1959. Seed Act 2010.

BLOCK 2: Grainage

Unit 1: Establishment of grainage

Location of grainage, plan of grainage, grainage equipments and capacity of grainage.

Unit 2: Grainage activities

Seed areas, seed cocoon market, procurement and transportation of seed cocoons, selection, storage, handling and processing of seed cocoons. Sex separation in pupal stage, moth emergence, synchronization of moth emergence, pairing, depairing, moth examination, laying preparation on egg cards/ loose egg production, rejection of defective eggs, disinfection and washing and incubation of eggs.

BLOCK 3: Artificial Hatching of eggs

Unit 1: Production of hybrid eggs

Production of hybrid seeds (Multivoltine × Bivoltine), (Bivoltine × Bivoltine), (Bivoltine × Bivoltine) × (Bivoltine × Bivoltine) (Double Cross Hybrid). Grainage pests. Economics of egg production and special determinants.

Unit 2: Artificial methods of hatching

Artificial methods of hatching of bivoltine eggs, cold and hot acid treatments, physical and chemical methods, hibernation schedules.

VII. Practicals

- Silkworm breeds and their classification;

- Study of ground plan of model grainage building;
- Study of grainage equipments;
- Preliminary examination of seed cocoons for production of dfls, study of handling and processing of seed cocoons;
- Study of sex separation at pupal and adult stages;
- Study of Silkworm egg incubation;
- Study of silkworm egg hibernation schedules;
- Study of grainage pests and their management;
- Preservation of male moths for reuse;
- Preservation of male and female pupae for synchronization;
- Effect of mating duration on egg production and fertility status of eggs;
- Disinfection of grainage equipments;
- Designation of multivoltine and bivoltine seed areas in Karnataka;
- Estimation of cocoon requirement for production of unit number of DFLs;
- Production of non-hibernating eggs of silkworm;
- Production of hibernating eggs of silkworm (on egg cards and loose egg preparation);
- Artificial hatching of silkworm eggs through acid treatment;
- Economics of silkworm egg production.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussion
– Group work
– Laboratory exercises
– Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the organization of silkworm seed production structure, Grainage, silkworm egg production, seed act, artificial methods of hatching, egg incubation and hibernation schedules
– Utilize this knowledge in producing healthy and quality seed production, serve the farming community with scientific grainage techniques for quality egg production.

X. Suggested Reading

Anonymous. 1997. *Silkworm Egg Production*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Dandin SB and Gupta VP. 2002. *Advances in Indian Sericulture Research*. CSR&TI, Mysore.

Datta RK. 1996. *Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994,* Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Narasimhanna MN. 1998. *Manual on Silkworm Egg Production*. CSB, Bangalore.

Journals

- *Bulletin of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.

- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.
- *Current Science* – Indian Institute of Science, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silkworm Rearing Technology

II. Course Code : SER 510

III. Credit Hours : 1+1

IV. Why this course ?

Silkworm rearing is the main contributing factor and plays a major role in quality cocoon production. It is important to know the different silkworm rearing methods for rearing young and late-age silkworms. The knowledge on scientific methods starting from egg incubation, black boxing, brushing, young age rearing, late age rearing, mounting of ripe silkworms, maintenance of environmental conditions during silkworm rearing, care during mounting, etc., is very important for sericulture experts to lead the sericulture community with a scientific and technical expertise.

V. Aim of the course

The course is designed with the aim of equipping the PG students with the best scientific knowledge and technical expertise in the field of silkworm rearing technology, different methods/ techniques involved in silkworm rearing, maintenance of environmental condition during rearing, etc., for quality silkworm production inturn contributing to the economy of individual farmer.

The course is organised as follows:

No.	Block	Units
1.	Planning for silkworm rearing	I Planning for chawki rearing and late age silkworm rearing II Disinfection and disinfectants III Mulberry leaf preservation IV Incubation of silkworm eggs
2.	Silkworm rearing	I Early instar silkworm rearing II Late age silkworm rearing
3.	Mounting, harvesting and marketing of silk cocoons	I Mounting of ripe worms and cocoon marketing III Comparison of different rearing methods

VI. Theory

BLOCK 1: Planning for silkworm rearing

Unit 1: Planning for chawki rearing and late age silkworm rearing

Planning for rearing, criteria to be considered for rearing, plan of rearing house for chawki and late age silkworm rearing, rearing equipment, measurement and regulation of environmental factors.

Unit 2: Disinfection and disinfectants

Disinfection of rearing room and equipment.

Unit 3: Mulberry leaf preservation

Planning for silkworm rearing; harvesting, transportation and preservation of mulberry leaves.

Unit 4: Incubation of silkworm eggs

Different methods of incubation of silk moth eggs, black-boxing, hatching and brushing.

BLOCK 2: Silkworm rearing

Unit 1: Early instar silkworm rearing

Early instar silkworm (Chawki) rearing, different methods, environmental conditions, quality of leaf, feeding, bed cleaning, spacing. Chawki rearing centres.

Unit 2: Late age silkworm rearing

Different methods of late age silkworm rearing, environmental conditions, feeding and bed spacing. Management of silkworm during moulting.

BLOCK 3: Mounting,harvesting and marketing of silk cocoon

Unit 1: Mounting of ripe worms and cocoon marketing

Mounting of ripe worms, different kinds of mountages. Rearing house and equipment for shoot method of rearing.

Unit 2: Comparison of different rearing methods

Comparing shoot feeding and shelf method of rearing.

VII. Practicals

- Ground plan for model rearing house for shelf method of rearing;
- Chemical and physical agents used in silkworm rearing and disinfection;
- Rearing equipments for shelf method of rearing;
- Incubation of silk moth eggs and black- boxing;
- Hatching and brushing;
- Early instar silkworm rearing;
- Late age silkworm rearing;
- Regulation of environmental conditions for silkworm rearing;
- Harvesting and preservation of mulberry leaf;
- Management of silkworms during moulting;
- Mounting of ripe silkworms;
- Cocoon harvesting, grading, transportation and marketing;
- Rearing house and equipment for shoot method of rearing;
- Shoot feeding for late age silkworm rearing;
- Harvesting and preservation of mulberry shoots;
- Spacing and bed cleaning in shoot feeding method of silkworm rearing;
- Economics of silkworm rearing;

- Rearing from brushing to mounting for seed and silk production.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand thoroughly the scientific silkworm rearing techniques, scientific management of silkworms during special conditions like during mounting, mulberry care, spinning stage, etc., inturn contributing to build a technically competent Sericultural expertise.

X. Suggested Reading

Anonymous. 1998. *Illustrated Textbook on Sericulture*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Boraiah G. 1994. *Lectures on Sericulture*. SBS Publishers, Bangalore.

Dandin SB and Gupta VP. 2002. *Advances in Indian Sericulture Research*. CSR&TI, Mysore.

Dandin SB, Jayant Jayaswal and Giridhar K. (Eds.) 2003. *Handbook of Sericulture Technologies*. CSB, Bangalore.

Datta RK. 1996. *Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994.* Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Govindan R, Chinnaswamy KP, Krishnaprasad NK and Reddy DNR. 2000. *Advances in Tropical Sericulture. Vol. 4– Proceedings of NSTS – 1999,* UAS, Bangalore.

Govindan R, Devaiah MV and Rangaswamy HR. 1978. *Reshme Vyavasaya (Kannada)*. UAS, Bangalore.

Hiroo and Sibuya-ku. 1975. *Textbook of Tropical Sericulture*. Japan Overseas Corporation Volunteers, Tokyo, Japan.

Krishnaswami S, Narasimhanna MN, Suryanarayan SK and Kumararaj S. 1973. *Sericulture Manual-2 - Silkworm Rearing*. Agriculture Service Bulletin, FAO, Rome.

Rajan RK and Himantharaj HT. 2005. *Silkworm Rearing Technology*. Central Silk Board, Bangalore.

Ramakrishna Naika, Govindan R and Sannappa B. 2002. *Organic Sericulture*. Seri Scientific Publishers, Bangalore.

Tanaka Y. 1964. *Sericology*. Central Silk Board, Bangalore.

Tazima Y. 1972. *Handbook of Silkworm Rearing*. Fuji Pub.Co. Ltd., Tokyo, Japan.

Ullal SR and Narasimhanna MN. 1981, *Handbook of Practical Sericulture*. CSB, Bangalore.

Yasuji Hamamura. 2001. *Silkworm Rearing on Artificial Diet*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Yonemura M and Rama Rao N. 1925. *Handook of Sericulture*. Mysore Government Branch Press.

Journals

- *Bulletin of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.

- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Genetics and Breeding of Silkworms

II. Course Code : SER 511

III. Credit Hours : 1+1

IV. Why this course ?

Silkworm crop improvement needs sustainable efforts in order to achieve higher silk productivity of superior quality. Understanding of genetic basis of expression of characters and application of this understanding for breeding silkworms that meet the present day scenario is essential. Hence, this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of silkworm genetics and principles of silkworm breeding. The subject is addressed to understand reproductive biology, hereditary traits and principles of silkworm breeding

The course is organized as follows:

No	Blocks	Units
1	Genetics of silkworm	I Cytology II Reproductive biology III Inheritance of characters
2	Breeding of silkworm	I Silkworm breeding resources II Methods of silkworm breeding

VI. Theory

BLOCK 1: Genetics of silkworm

Unit 1: Cytology

Ancestor and cytological basis of origin of silkworms. Cytological aspects of silkgland and achievements in deciphering molecular biology of silk gene. Hormonal control mechanisms.

Unit 2: Reproductive biology

Phenomena of spermatogenesis and oogenesis with relevance to crossing over, cell division types in silkworms, synaptonemal complex, fertilization, chromosomes in silkworms. Sex determination, parthenogenesis, polyploidy, mosaics.

Unit 3: Inheritance of characters

Hereditary traits of importance in egg, larva, pupa-cocoon and adult.

E- Group as a tool in genetics and significance. Linkage groups in silkworms. Sex linked inheritance, Quantitative and Qualitative Characters in silkworm breeding. Genetics of cocoon colours. *Bombyx mori* L. genome and latest genome sequence, Translocation of characters in metamorphic stages.

BLOCK 2: Breeding of silkworm

Unit 1: Silkworm breeding resources

Multivoltine and bivoltine races and hybrids. Silkworm germplasm and resource potential.

Unit 2: Methods of silkworm breeding

Methods of silkworm breeding and their importance with relevance to Indian scenario. Breeding for thermotolerance, disease resistance, special characters required for the nation and also for silk export. Sex linked and sexlimited races- their importance and need of the hour, Authorization and release of silkworm races.

VII. Practicals

- Study of mitosis and meiosis in silkworm;
- Study of oogenesis in silkworm;
- Study of spermatogenesis and fertilization in silkworms;
- Study of important hereditary traits in egg and larva of silkworm *Bombyx mori* L.;
- Study of important hereditary traits of pupa and cocoons of silkworm *Bombyx mori* L.;
- Study of important hereditary traits of adult *Bombyx mori* L.;
- Study of Marker genes and linkage groups in silkworm;
- Study of heterosis - working out heterosis, heterobeltiosis and standard heterosis for economic characters;
- Study of silkworm germplasam;
- Study of biometrical methods in silkworm breeding;
- Study of modern methods of silkworm breeding;
- Study of induction of parthenogenesis in silkworm breeds;
- Study of induction of polyploidy in silkworm breeds;
- Study of conventional methods of silkworm breeding;
- Study of breeding of newly evolved silkworm breeds;
- Study of breeding of non-mulberry silkworms;
- Study of breeding plans;
- Visit to CSGRC,CSB, Hosur.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Visits to Germplasam centers
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the reproductive biology, inheritance of traits and breeding methods
- Utilise this knowledge to plan for silkworm breeding activities.

X. Suggested Reading

Anonymous. 1993. *Principles and Techniques of Silkworm Breeding*. ESCAP, UN, New York. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. p.111.

Gardner EJ, Simmons MJ and Snustad DP. 1991. *Principles of Genetics,* John Willey& Sons Inc., New York. p. 649.

Hiratsuka E. 1999. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. p. 500.

Jolly MS, Sen SK, Sonwalker TN and Prasad GK. 1979. *Non-mulberry Silks*. FAO - Agricultural Service Bulletin, Rome. p. 178.

Kovalev PA. 1970. *Silkworm Breeding Stocks*. Central Silk Board, Bombay. p. 233.

Sarker DD. 1998. *The Silkworm Biology, Genetics and Breeding.* Vikas Publishing House Pvt. Ltd., New Delhi. p. 338.

Sarin C. 1990. *Genetics*. Tata McGraw – Hill Publishing Co. Ltd., New Delhi. p. 528.

Singh BD. 1997. *Plant Breeding: Principles and Methods.*Kalyani Publishers, New Delhi. p. 702.

Singh RK and Chaudhary BD. 1996. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi. p. 318.

Sreeramareddy G. 1998. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

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- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada*) - Department of Sericulture, Government of Karnataka, Bangalore.
- *Current Science* – Indian Institute of Science, Bangalore.

Websites

- www.csb.gov.in/
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- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Diseases and Pests of Silkworm

II. Course Code : SER 512

III. Credit Hours : 1+1

IV. Why this course ?

Silkworms are affected by a number of diseases caused by Microsporidia, fungi, viruses, bacteria and mixed infections and also attacked by insect pests. The exposure to these pathogens and pests results in mortality of silkworms and economic loss to the silkworm rearers. A better understanding of causative agents, symptoms, sources of infection, predisposing factors, transmission and management of silkworm diseases and pests is very important to improve cocoon productivity and maximize economic benefit to silkworm rearers by better avoidance/ management of silkworm diseases and pests.

V. Aim of the course

The course is designed to provide both theory and practical knowledge regarding the subjects of Classification of disease-causing organisms of mulberry and non-mulberry silkworms including viral, fungal, bacterial, protozoan and mixed infections. Knowledge on their occurrence, causative agent, etiology, symptoms and infection, sources of infection, predisposing factors, transmission and management, symptoms, seasonal incidence of diseases associated with mulberry and non-mulberry silkworms is important. Diagnosis of different pathogens based on symptoms (external and internal), regulation of environmental factors contributing to diseases, prevention and control of diseases also attain importance. Know how on pests of mulberry and non-mulberry silkworms, uzi fly occurrence, nature and extent of damage, life-cycle and management, other pests and predators effecting silkworm crop and their management and pesticide toxicity/ residual toxicity, use of eco-friendly pesticides and biological control will also be dealt.

The course is organized as follows:

No	Blocks	Units
1.	Silkworm diseases and their management	I Importance and Classification II Silkworm pathogens, disease development and diagnosis III Management of silkworm diseases
2	Silkworm pests and their	I Ujifly, *Exorista bombycis* Louis—a major pest of silkworms. II Other pests and predators affecting silkworm crop and their management. III Pesticide toxicity

VI. Theory

BLOCK 1: Silkworm diseases and their management

Unit 1: Importance and classification

Taxonomic position of silkworm disease causing organisms including viruses, bacteria, fungi, protozoans, classification of various pests causing economic loss to silkworms, and their importance.

Unit 2: Silkworm pathogens, disease development and diagnosis

Occurrence, causative agent, symptoms and infection, source of infection, predisposing factors, seasonal incidence, transmission and management of the pathogens individually including viral, fungal, bacterial, protozoan and mixed infections. Diagnosis of different pathogens based on symptoms (external and internal), patho-physiology and histopathology.

Unit 3: Management of silkworm diseases

Comparative etiology of silkworm pathogens. Management, prevention and control of diseases of silkworms, regulation of predisposing and environmental factors contributing to diseases, rearing disease resistant breeds of silkworm. Management of alternative hosts of silkworm disease causing pathogens (lepidopteran crop pests and pests of mulberry). Intergrated disease management.

BLOCK 2: Silkworm pests and their management

Unit 1: Ujifly, *Exorista bombycis* Louis - a major pest of silkworms

History and taxonomy, Bio-ecology, Life cycle-egg, maggot, pupa, adult, oviposition, damage and extent of damage caused, prevention and control, biological control and IPM.

Unit 2: Other pests and predators affecting silkworm crop and their management

Pests and predators causing loss to silkworms and cocoons including Ants, type of damage, management. Straw itch mite, life cycle, kind of damage, management.

Dermestid beetles, classification, life cycle, nature of damage, management. Rats, squirrels, lizards, earwigs, etc.,

Unit 3: Pesticide toxicity

Poisoning by agricultural chemicals to silkworms, acute and chronic symptoms of poisoning by different agricultural chemicals. Residual toxicity of chemicals on mulberry and damage caused, prevention and control.

VII. Practicals

- Sterilization techniques for isolation of silkworm pathogens;
- Isolation and purification of *Bm*NPV;
- Isolation and purification of *Bm*CPV;
- Isolation and purification of *Bm*IFV and *Bm*DNV;
- Isolation and purification of white muscardine fungus *Beauveria bassiana* from silkworm *Bombyx mori;*
- Isolation and purification of brown muscardine fungus *Aspergillus tamarii* from silkworm *Bombyx mori;*
- Isolation and purification of bacteria from the gut and haemolymph of silkworm *Bombyx mori;*
- Study of life cycle, symptoms and diagnosis of *Bm*NPV;
- Study of life cycle, symptoms and diagnosis of *Bm*CPV;
- Study of life cycle, symptoms and diagnosis of *Bm*IFV and *Bm*DNV;
- Study of life cycle, symptoms and diagnosis of silkworm microsporidiosis;
- Study of life cycle, symptoms and diagnosis of white and green muscardines;
- Study of bacteria invading the digestive system and haemolymph;
- Study of bacterial toxicosis in mulberry silkworm;
- Intergrated management for prevention of silkworm diseases;
- Study of life-cycle of silkworm ujifly and its management;
- Study of life cycle and management of dermestid beetles;
- Visit to sericulture farmers fields.

VIII. Teaching Methods/ Activities

– Lectures

- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of silkworm protection and relate the key learning for further scientific research in the area of silkworm protection.
- Utilise methods and tools for prevention and management of diseases and pests of silkworms.
- Utilise material in scientific publications relevant for silkworm protection for enhancing cocoon crop productivity through effective management of silkworm diseases and pests.

X. Suggested Reading

Dandin SB and Giridhar K. 2014. *Handbook of Sericulture Technologies*; Central Silk Board, Ed., Dr., pp 247.

Govindan R, Narayanaswamy TK and Devaiah MC. 1998. *Principles of Silkworm Pathology,* p.420.

Nataraju B, Sathyaprasad K, Manjunath D and Aswani Kumar C. 2005. *Silkworm Crop Protection*. Central Silk Board, Bangalore, pp. 1-285.

Pringle Jameson A. 1984. *Report On The Diseases of Silkworms In India*, IBS, New Delhi, pp. 1-64.

Journals

- *Bulletins of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silk Technology-I

II. Credit Hours : 1+1

III. Course code : SER 514

IV. Why this course ?

Sericulture is an agro based industry, which concentrates on production of quality leaf, cocoon and raw silk. The raw silk production by reelers from different machineries plays an important role in fabric production. Therefore, cocoon is considered as raw material for silk reeling industry which has to be processed by adopting recent techniques in all aspects of reeling that aim at quality raw silk production. The knowledge on recent techniques serves as an effective tool in reeling cocoons which throws light to produce competitive technical man power in processing of raw material. Hence is this course.

V. Aim of the course

The course is designed to make the students to get acquainted with activities in different reeling units operated both in private and government sectors. These activities will help in learning all techniques of silk reeling for quality raw silk production. In addition, they get knowledge on responsibilities of reeling units on management of labour and exploitation of reeling waste generated for by-product utilization.

Organisation of course:

No.	Blocks	Units
1	Cocoon as raw material	I Physical characteristics
		II Commercial characteristics
2	Transaction of cocoons	I Defective cocoons
		II Cocoon marketing
3	Steps in silk reeling	I Cocoon stifling
		II Cocoon cooking and brushing
		III Cocoon reeling
		IV Re-reeling
		V Reeling water
4	Silk testing and examination	I Different methods of silk examination
		II Silk testing and grading
5	Post reeling technology	I Doubling, twisting and weaving
		II Marketing of raw silk.

VI. Theory

BLOCK 1: Cocoon as raw material

Unit 1: Physical characteristics

Introduction; Importance and use of silk, cocoon quality. Physical characteristics- cocoon colour, shape, size, wrinkles, uniformity and compactness.

Unit 2: Commercial characteristics

Cocoon weight, shell weight, shell percentage, filament length, denier, non-breakable filament length, reelability and raw silk percentage.

BLOCK 2: Transaction of cocoons

Unit 1: Defective cocoons

Types of defective cocoons, reasons for defective cocoons, cocoon sorting, methods of sorting, estimation of defective cocoons per kg. Technological aspects. Selection of raw material for silk reeling – scientific method of testing and classification of cocoons.

Unit 2: Cocoon marketing

Marketing based on visual observation and based on quantitative parameters, open auction system (Quality based pricing) and E-transaction. Limitations of open auction system and estimation of renditta.

BLOCK 3: Steps in silk reeling

Unit 1: Cocoon stifling

Definition, different methods of stifling of cocoons - sun drying, steam stifling, hot air drying (shelf carrier type, Tunnel type, Band type- hot air circulating, air heating type and one step band type) and other methods. Effect of storage on stifling. Moisture percentage, Phenomenon of cocoon drying, drying percentage, equilibrium moisture percentage (Phenomenon of moisture evaporation). Effect of cocoon thickness and compactness on cocoon stifling, advanced system of cocoon stifling and machineries.

Unit 2: Cocoon cooking and brushing

Cocoon cooking- objectives of cocoon cooking, effect of pressure and temperature on infiltration of water into cocoon cavity, swelling of sericin layer, different methods of cooking (Open pan, two pan and three pan cooking system). Brushing of cocoons, different methods of brushing. Effect of temperature on solubility of sericin and fibroin layers, dipping period and brushing.

Unit 3: Cocoon reeling

Cocoon reeling- definition, different methods of reeling (Open/ Floating/ Sunken), Importance of croissure, length of the croissure and croissure angle and silk reeling, reeling machineries – Silk reeling on charaka, cottage basin, multiend, semi automatic and automatic reeling machines.

Unit 4: Re-reeling

Re-reeling, reel permeation, different methods of permeation, re-reeling methods, advantages and disadvantages of open re-reeling and closed type of re-reeling.

Unit 5: Reeling water

Reeling water: Different sources of water used in reeling, characteristics/ Properties of water (Impurities of water), Physical and chemical properties of water, Importance of reeling water, water qualities suggested by Kim and amelioration of water, different methods of amelioration (aeration, filtration, sedimentation and ion exchange method), amelioration of reeled water and reuse of water after treatment.

BLOCK 4: Silk testing and examination

Unit 1: Different methods of silk examination

Different silk examination methods and lacing, book and bale making.

Unit 2: Silk testing and grading

Silk testing and grading-grading of raw silk based on I.S.A., silk testing tools for physical (visual inspection) and mechanical properties of silk. Procedure adopted for conducting physical and mechanical properties of silk and equipments used for testing of raw silk.

BLOCK 5: Post reeling technology

Unit 1: Doubling, twisting and weaving

Silk throwing, weaving, warping and wefting, silk doubling and twisting, by-products of reeling units, types of reeling waste (brushing waste, reeling waste, cooking waste, re-reeling waste, throwing waste and pelade layer) as raw material for spun silk industry.

Unit 2: Marketing of raw silk

Factors influencing the assessment of rawsilk quality. Role of silk exchange, auctioning of raw silk based on physical and mechanical properties and economics of silk reeling.

VII. Practicals

- Classification of cocoons of silkworm breeds;
- Study of Physical and Commercial characters of cocoons;
- Study of mode and time of cocoon transportation and marketing;
- Cocoon sorting, methods and estimation of defective cocoons;
- Cocoon stifling methods and estimation of drying and moisture percentage;
- Practising of cocoon cooking and brushing methods;
- Estimation of reeling and cooking waste percentage;
- Reeling appliances and practising reeling on Charaka and improved Charaka;
- Study of reeling appliances and practising reeling on Cottage basin and Domestic basin;
- Visit to government filature to acquaint with large scale reeling on Multiend reeling machine;
- Visit to Automatic reeling machine unit at Ramanagara;
- Silk examination, skein making and book making;
- Study of Reeling water and its quality;
- Amelioration of silk reeling water and its importance;
- Study of physical properties of mulberry raw silk;
- Study of microscopic examination of silk bave;
- Study of quality tests of raw silk and By-products in silk reeling;
- Visit to Central silk technological research institute, Bengaluru.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After undergoing this course the students are able to assess the quality of cocoon as raw material for reeling industry and acquaint with different techniques of reeling in quality silk production.

X. Suggested Reading

Bhaskar RN and Govindan R. 2005. *Techniques in Silk Reeling*, Department of Sericulture, UAS,GKVK, p.50.

Ganga G. 2003. *Comprehensive Sericulture.* Volume 2. *Silkworm Rearing and Silk Reeling.* Oxford & IBH, New Delhi, p.429.

Kamal Jaiswal, Sunil P Trivedi, Pandey BN and Tripathi AK. *Mulberry sericulture problems and prospects*, A P H publishing corporation, New Delhi.

Kim BH. 1978. *Raw Silk Reeling*, Korean edition Seoul Publishing Company, P 275.

Krishnaswami S, Madhava Rao NR, Suryanarayan SK and Sundaramurthy TS. 1972. *Manual on Sericulture-III.Silk Reeling,* FAO, Rome, p.112.

Mahadevappa D, Halliyal VG, Shankar AG and Bhandiwad R. *Mulberry silk reeling technology*, Oxford & IBH publishing Co. Pvt. Ltd.

Manual on Bivoltine silk Reeling Technology. 2003. Published by JICA, PPP BST Project, p.122

Savithri, Sujathamma and Neeraja, *Sericulture industry: An overview*.

Tripurari S. *Sericulture and silk industry, Consortium on rural technology*, Madhuvan, Delhi.

Journals

- *Bulletins of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

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- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Non-mulberry Sericulture

II. Course Code : SER 515

III. Credit Hours : 1+1

IV. Why this course ?

This course enlightens various types of silk producing insects, viz., Tasar, Eri and Muga and their production techniques. Thishighlights wild rearing in-situ in forest area and also semi domestication of wild non-mulberry silks. This also helps to explore possibilities of new sericigenous insects and other minor silk producers.

V. Aim of the course

This course is designed to provide basic and applied aspects of non-mulberry sericulture. This course will approach multi-disciplinary perspective, it aims to equip students to identify, evaluate and explore new species of sericigenous insects to address the tribals self employment programme.

The course is organized as follows:

No	Blocks	Units
1.	Underexploited non-mulberry silks	I Scope, importance, distribution in the World II Introduction to Anaphe, Coan and Fagara silks
2.	Commercially exploited non-mulberry silks	I Scope, importance and their distribution in the World II Rearing of Eri silkworms III Rearing of Tasar (tropical/ temperate) IV Rearing of Muga silkworms V Economics of non-mulberry silkworm rearing

VI. Theory

BLOCK 1: Underexploited less known non-mulberry silks

Unit 1: Scope, importance and distribution in the World

Uses of less known sericigenous species for commercial exploitation, distribution pattern on different host plants and their statistics.

Unit 2: Introduction to Anaphe, Coan and Fagara silks

Systematics, morphology and cocoon characteristics of Anaphe, Fagara, Coan silks and possibilities of their exploitation.

BLOCK 2: Commercially exploited non-mulberry silks

Unit 1: Scope, importance and their distribution in the world

Scope, importance, distribution in the country and World of Eri, Tropical Tasar, Temperate Tasar and Muga silks and their primary and secondary host plants.

Unit 2: Rearing of Eri silkworm

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of eri using improved techniques and crop protection.

Unit 3: Rearing of Tasar (tropical/ temperate)

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of tropical/ temperate tasar using improved techniques and crop protection.

Unit 4: Rearing of Muga silkworms

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of muga silkworms using improved techniques and crop protection.

Unit 5: Economics of non-mulberry silkworm rearing

Economics of non-mulberry silkworm rearing, viz., eri, tasar and muga silkworm rearing and their cost benefit ratio.

VII. Practicals

- Study of primary and secondary host plants of eri silkworm;
- Study of primary and secondary host plants of tasar silkworm;
- Study of primary and secondary host plants of muga silkworm;
- Cultivation of popular castor genotypes for eri silkworm rearing;
- Preparation of rearing house for eri silkworm rearing;
- Rearing of eri silkworm on different castor genotypes;
- Calculation of consumption indices in eri silkworm using leaves of different castor genotypes;
- Collection and dry preservation of different primary and secondary host plants of non-mulberry silkworms;
- Preparation of disease free layings of eri silkworm;
- Morphology of eggs and larvae of eri silkworm;
- Morphology of pupa and moth of eri silkworm;
- Morphology of eggs and larvae of tasar and muga silkworms;
- Morphology of pupa and moth of tasar and muga silkworms;
- Effect of different mating durations on fecundity and fertility of eri silk moths;
- Study of different natural enemies of eri silkworm;
- Study of different diseases of eri silkworm;
- Practising of tasar egg production;
- Economics of eri silkworm rearing;
- Visit to Eri Silkworm Seed Production Centre, CSGRC Hosur, CSB.

VIII. Teaching Methods/ Activities

- Lectures
- Collections of various non-mulberry silkworms
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to

- acquire skills on rearing of vanya silks, their host plants and rearing technologies. In addition, it enables to explore less known silkworm species and exploit them.

X. Suggested Reading

Jolly MS, Sen SK and Ahsan MM. 1974. *Tasar culture*. Ambika Publishers, Bombay.

Jolly MS, Sen SK Sonwalkar TN and Prasad GK. 1979, *Sericulture Manual - 4 – Non-Mulberry Silks*. Agriculture Service Bulletin, FAO, Rome.

Sannappa B, Jayaramaiah M., Govindan R and Chinnaswamy KP. 2002, *Advances in Ericulture*. Seri Scientific Publishers, Bangalore.

Sarkar DC. 1980. *Ericulture in India*. Central Silk Board, Bangalore.

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- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.

- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

Minor Courses
M.Sc. (Agri.) in Sericulture

I. Course Title : Nutrition of Host Plants of Silkworms

II. Course code : SER 503

III. Credit Hours : 1+1

IV. Why this course ?

Silkworm is monophagous insect mainly feeding on mulberry and drawing its nourishment for growth and development. It is mainly dependent on the quality of leaf used for silkworm rearing. Production of quality leaf by adopting standard package of practices to increase biochemical parameters of mulberry which are directly involved not only to improve the quality parameters but also enhance productivity per unit area. Therefore, the technical knowledge on nutritional management of mulberry definitely helps in improving quality parameters of silk. Hence this course.

V. Aim of the course

The main aim of this course is to provide both basic and applied knowledge on nutritional management through different methods and means of application. Further, it also provides nutritional requirement for different growth stages which is required for silkworm growth and development. In addition, the complementary use of chemicals, fertilizers, organic manure and bio-fertilizer is important to maintain and sustain higher level of soil fertility and productivity. The principles of manure and fertilizer application and their toxicity affect on quality parameters of mulberry is the need of the hour. The beneficial effect of optimum nutrition and toxicity due to excess nutrients application and deficiency symptoms due to lack of nutrient availability affect the growth of mulberry. The academic knowledge on the above helps in strengthening the skills of students to serve the farming community effectively who are involved in quality leaf production and success of sericulture.

Organisation of course

No.	Block	Units
1,	Organic manure application	I Principles of manure application
2	Nutrition of non-mulberry silkworm host plants	I Nutrition of non-mulberry silkworm host plants
3	Physico-chemical properties of soil and Nutrient uptake	I Influence of physical and chemical properties of soil
4	Application of major nutrients	I Principles of fertilizer application. II Role of nitrogen III Role of Phosphorus IV Role of Potash V Role of secondary nutrients
5	Nutrient deficiency	VI Nutrient deficiencies and toxicity of nutrients

VI. Theory

BLOCK 1: Organic manure application

Unit 1: Principles of manure application

Role of mineral nutrition on growth and development of mulberry, Classification of minerals i.e. organic and inorganic, Types of organic nutrition –FYM, Compost, Pressmud, Animalmanure-Poultry manure, piggery manure, Horse manure, methods of green manuring and composting.

BLOCK 2: Nutrition of non-mulberry silkworm host plants

Unit 1: Nutrition of non-mulberry silkworm host plants

Nutritional aspects of Castor, Tapioca, Terminalia, Soalu and Som.

BLOCK 3: Physico-chemical properties of soil and Nutrient uptake

Unit 1: Influence of physical and chemical properties of soil

Types of mulberry soils, soil structure, texture, CEC, clay and mineral composition, soil pH, micro and macro fauna, organic matter and their influence on growth and development.

Role of physical and chemical properties on nutrient uptake and growth. Absorption pattern of major and micro nutrients in different soils. Response of mulberry varieties on absorption pattern of N, P, K and micronutrients.

BLOCK 4: Application of major nutrients

Unit 1: Principles of fertilizer application

Role of bio-fertilizers –Nitrogen fixing bacteria, phosphate solubilizing fungi, exploitation of K solubilizing organism, VAM, application methods, split application based on soil test for both rainfed and irrigated conditions.

Unit 2: Role of nitrogen

Sources of nitrogen, types and method of application on growth and development and biochemical constituents of mulberry and their effect on rearing parameters.

Unit 3: Role of Phosphorus

Sources of Phosphorus, types and methods of application on growth and development and biochemical constituents of mulberry and effect on rearing parameters.

Unit 4: Role of Potash

Sources of Potash, types and methods of application on growth and development and biochemical constituents of mulberry and effect on rearing parameters.

Unit 5: Role of secondary nutrients

Sources of secondary nutrients, types and methods of application on growth and development and biochemical constituents of mulberry and effect on rearing parameters.

BLOCK 5: Nutrient deficiency

Unit 1: Deficiencies of Major nutrients and their toxicity

Deficiency symptoms of N, P and K toxicity in mulberry plants and their effect on quality of mulberry, correction of the soil by soil application, foliar application and fertigation methods.

Unit 2: Deficiencies of Secondary nutrients and their toxicity

Deficiency symptoms of S, Mn, Fe, Mo, Mg, Ca, Zn and other micronutrients and their toxicity in mulberry plants and their effect on quality of mulberry, correction of the through soil and foliar application and fertigation.

VII. Practical

- Collection of soil samples in mulberry garden and interpretation of soil test results;
- Development of recommended fertilizer schedule for both rainfed and irrigated mulberry;
- Modern methods of vermin-composting techniques by using sericulture wastes;
- Different methods of green manuring and conservation practices;
- Growth and root parameters of mulberry under different moisture regimes;
- Estimation of mulberry yield per unit area in both rainfed and irrigated condition;
- Use of soil amendments on sprouting and rooting pattern in mulberry;
- Pot culture studies on the effect of nutrient solution and bacterial inoculants on the growth of mulberry cuttings;
- Enumeration of beneficial microflora (Bacteria, Fungi and Actinomycetes) in mulberry rhizosphere;
- Induction of deficiency symptoms of major nutrients using sand culture techniques;
- Practising of foliar nutrient application in mulberry;
- Application of conventional methods of fertilizer application in mulberry;
- Practising supply of nutrients to mulberry through fertigation;
- Study of different methods of fertilizer application in mulberry;
- Study on effect of fertilizer use pattern on physico-chemical properties of mulberry soil;
- Supplementation of deficit nutrients for both rainfed and irrigated mulberry schedule as per soil test;
- Enumeration of micro fauna of soils under mulberry cultivation;
- Study of fertilizer use efficiency in mulberry;
- Practising Seri Suvarna Technology (Trenching and Mulching) in mulberry garden.

VIII. Teaching Methods/ Activities

– Lectures
– Providing study material/ lecture material
– Practical manuals
– Assignments (Reading/ Writing)
– Text Books/ Publications/ reviews/ technical bulletins/ manuals/ proceedings of scientific seminars
– Student presentations
– Experimentation
– Group discussions
– Group work

– Laboratory exercises
– Scientific journals and periodicals
– Layout of experiments
– Study visits

IX. Learning outcome

After the successful completion of this course the students are expected to:

- Assess the quantity of manures and fertilizers requirement for rainfed and irrigated mulberry
- Identify the deficiency symptoms of major and micro nutrients
- Adopt IPNM model for productivity enhancement

X. Suggested Reading

Bongale UD. 2003. "Nutritional Management and quality improvement in sericulture", *Proceedings of the national seminar on mulberry sericulture research in India* 26th to 28th November 2001,P-1037.

Dandin SB and Giridhar K. 2014. *Handbook of Sericuilture Technologies*,CSB, Bengaluru,P-427.

Ganga G. 2003. *Comprehensive Sericulture*. Volume 2. *Silkworm Rearing and Silk Reeling*. Oxford & IBH, New Delhi, P.429.

Nutritional Management and Quality improvement in Sericulture. 2003. KSSRDI. Banglore.

Rajanna L, Das PK, Ravindran S, Bhogesha K, Mishra RK, Singhvi NR, Katiyar RS and Jayaram H. 2005. *Mulberry cultivation and physiology*, Central Silk Board, Bangalore, p. 367.

Rangaswamy G, Narasimhanna MN, Kasiviswanathan K and Sastry CR. 1976. *Manual on Sericulture-I. Mulberry cultivation,* FAO, Rome, p.150.

Journals

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- *Journal of Sericultural Science of Japan* – Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* – Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* – CSR & TI, Mysore.
- *Journal of Sericulture and Technology* – Published by NASSI, Bangalore.
- *Indian Silk* – Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* – Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* – Department of Sericulture, Government of Karnataka, Bangalore.
- *Current Science* – Indian Institute of Science, Bangalore.

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I. Course Title : Mulberry Pests and Diseases

II. Course Code : SER 504

III. Course Credit : 2+1

IV. Why this course ?

Mulberry is key a factor in the production of quality silk cocoon by the silkworm rearers. As nutrient rich silkworm food crop the mulberry also attracting various pests and suffers from diseases. The knowledge on various important pests and diseases affecting mulberry in different seasons, symptoms, their life cycle and different management practices are necessary for quality mulberry leaf production economically. Hence, is this course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge in managing diseases and pests in mulberry eco-system. It helps to equip students to understand different pests infesting mulberry crop at different stages and seasons, diseases affecting mulberry crop and their management so that producing technically competent sericulture manpower for leading sericulture formats towards scientific quality mulberry production.

This course is organized as follows:

No.	Blocks	Units
1	Mulberry diseases and their management	I Fungal diseases II Bacterial diseases III Viral diseases IV Nematode diseases
2	Mulberry pests and their management	I Leaf eating pests (Defoliating pests) II Sucking pests (Sap feeders) III Other Minor pests of mulberry

VI. Theory

BLOCK 1: Mulberry diseases and their management

Unit 1: Fungal diseases

Root rot diseases, powdery mildew, leaf spot and leaf rust diseases. Classification, occurrence, symptoms and damage, extent of crop loss and management.

Unit 2: Bacterial diseases

Leaf blight and Rot diseases-Classification, occurrence, symptoms of damage extent of crop loss and management.

Unit 3: Viral diseases

Leaf mosaic and mulberry dwarf diseases classification, occurrence, symptoms extent of crop loss and management.

Unit 4: Nematode disease

Root knot diseases- Classification, occurrence, symptoms, identification of root knots extent of crop loss and management.

BLOCK 2: Mulberry Pests and their Management

Unit 1: Leaf eating pests (Defoliators)

Mulberry leaf roller, Bihar hairy caterpillar, wingless grasshopper, cutworm, rootgrubs -Classification, status, seasonal incidence, damaged caused symptoms, loss, lifecycle and management.

Unit 2: Sap feeders (Sucking pests)

Thrips, jassids, spiraling whitefly, scale insects, mealy bugs, spider mites -Classification, status, seasonal incidence, damaged caused symptoms, loss, lifecycle and management.

Unit 3: Minor pests of mulberry

Stem borer, termites, May–June beetles, stem girdler beetle - RotsClassification, status, seasonal incidence, damaged caused symptoms, loss, lifecycle and management.

VII. Practicals

- Collection of insect and non-insect pests from mulberry garden and their preservation;
- Classification of mulberry pests based on taxonomy and nature of feeding;
- Classification of mulberry diseases;
- Collection of diseased specimen from mulberry garden and their preservation;
- Classification of mulberry diseases based on taxonomy and parts of the plants damaged;
- Incidence and estimation of damage to mulberry caused by mulberry leaf webber;
- Incidence and estimation of damage to mulberry caused Bihar Hairy Caterpillar;
- Study of life cycle of mulberry leaf webber;
- Study of life cycle of Black Headed Hairy Caterpillar;
- Study of life cycle of mulberry leaf spot;
- Study of life cycle of mulberry leaf rust;
- Study of life cycle of powdery mildew of mulberry;
- Isolation of leaf spot fungus and bacterial blight pathogen in the laboratory and characterization;
- Varietal response of mulberry to root knot nematode disease;
- Incidence, symptoms and damage of Tukra disease on different varieties of mulberry;
- Life cycle of wingless grasshopper and cutworm on mulberry;
- Incidence of thrips on the available varieties of mulberry;
- Collection of specific predators and parasites in mulberry garden, preservation and their classification;
- Diseases and pests associated with mulberry nursery and tree mulberry;
- Commonly used insecticides and fungicides in mulberry garden-classification, forms, formulations and their applications.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals/ Publication reviews
- Study visits

IX. Learning outcome

After successful completion of this course, the students are expected be able to:

– Understand the nature of pest and diseases of mulberry, their occurrence, symptoms, damage caused at different stages of the mulberry plant.
– Learn different management practices for pest and diseases in mulberry and use this knowledge for successful mulberry leaf production.

X. Suggested Reading

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Gautam RD. 1994. *Biological Pest Suppression*. Westvill Publishing House, New Delhi.

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• *Sericologia* – Jacques Rousseau, 69350, La Mulatiere, France.
• *Indian Journal of Sericulture* – CSR & TI, Mysore.
• *Journal of Sericulture and Technology* – Published by NASSI, Bangalore.
• *Indian Silk* – Central Silk Board, Bangalore.
• *Bulletin of Indian Academy of Sericulture* – Bhubaneshwar, Orissa.
• *Reshme Krishi (Kannada)* – Department of Sericulture, Government of Karnataka, Bangalore.

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• www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
• www.tnau.ac.in/
• www.csrtimys.res.in/

I. Course Title : Biotechnology of Mulberry

II. Course code : SER 505

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is perennial and highly heterozygous crop. Hence, selection in segregating progenies is very difficult. In order to aid the selection in mulberry, the biotechnological tools, viz., Tissue culture techniques, molecular markers and recombinant DNA technology are more useful to aid in selection. Application of these techniques will shorten the breeding procedure. Hence this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of Tissue culture techniques, molecular markers and recombinant DNA technologies to PG students.

The course is organised as follows:

No.	Blocks	Units
1	Mulberry biotechnology, scope and prospects	I Mulberry biotechnology, scope and prospects II Mulberry germplasm characterization III Genotyping and phenotyping
2	Recombinant DNA technology	I Genes transfer systems II QTL mapping III Seri bioinformatics

VI. Theory

BLOCK 1: Mulberry biotechnology, scope and prospects

Unit 1: Mulberry biotechnology, scope and prospects

Scope of breeding for hardier and productive mulberry genotypes. Preservation of genetic material. Development of transgenic mulberry. Molecular linkage map of mulberry. Micropropagation: *In-vitro* propagation in mulberry-production of haploids- induction of haploids, advantages and disadvantages of haploids. Double haploids-induction, advantages and disadvantages of double haploids. Practical achievements of DH method, polyploids- Somaclonal variations, Procedures, advantages, disadvantages and their applications. Secondary metabolites. Gametoclonal variations – their scope and applications. Cryopreservation: Definition and meaning, Steps in cryopreservation, Advantages and disadvantages, Cryopreservation Requirements, applications of cryopreservation in mulberry for germplasm preservation.

Unit 2: Mulberry germplasm characterization

Mulberry germplasm characterization by using molecular markers. Introduction, features of ideal DNA markers, types of DNA markers, uses in crop improvement. Application of biotechnological tools in screening for biotic and abiotic stress tolerance in mulberry.

Unit 3: Genotyping and phenotyping

Introduction, definition of genotype and phenotype. Phenotyping- advantages and disadvantages. Methods of genotyping, advantages and disadvantages of genotyping and applications of genotyping. Marker Aided Selection (MAS) for economically important traits in mulberry. Steps involved in MAS. Application of MAS, advantages of MAS, limitations of MAS.

BLOCK 2: Recombinant DNA technology

Unit 1: Genes transfer systems

Vector mediated gene transfer, microinjection, electroporation, direct DNA uptake, gene gun technique, selectable markers and reporter system; comparison of transgenic technology and traditional breeding methods, detection of transgenic mulberry. Prospects of transgenic mulberry. Procedure of development of transgenic mulberry. Advantages and disadvantages of transgenic mulberry. Risks in transgenic technology. Biosafety and regulatory issues, Achievements.

Unit 2: QTL mapping

Development of maps, Advantages and limitations of QTL mapping. Methods of mapping. Requirements and steps involved in QTL mapping. Mapping populations (F2S and back crosses RILs, NILs, DHs). Tagging of economically important traits in mulberry.

Unit 3: Seri bioinformatics

Bioinformatics in crop improvement-introduction, branches of bioinformatics, computer programmes used in biology, applications in crop improvement, varietal information system, PGR data base. Studies on Genomics- genomics in crop improvement, types of genomics: structural, functional and applications, achievements and limitations. Studies on proteomics. Studies on metabolomics, advantages of bioinformatics, limitations. Intellectual Property Rights. Plant variety protection act (PVPA): introduction, types of protection, basic requirements, organizations involved, procedure of PVP, material to be protected, types of varieties, exemptions under PVPA, advantages and disadvantages of PVPA. Nano- technology: introduction, main features, Application of nano-technology, application in mulberry improvement.

VII. Practicals

- Laboratory safety rules;
- Seri biotechnology lab and its facilities;
- Preparation of MS medium for tissue culture in mulberry;
- Selection, collection and preparation of plant material for mulberry tissue culture;
- Culturing of plant material/explant in culture media;
- Tissue culture techniques for mulberry propagation;
- Hardening of tissue cultured mulberry plants;
- Isolation of genomic DNA- mulberry leaf;
- Isolation of genomic DNA- mulberry leaf;
- Amplification of DNA in mulberry by using PCR;
- Study of diversity of mulberry germplasm by using molecular markers;
- Study of diversity of mulberry germplasm by using molecular markers;
- Comparative study of diversity of mulberry germplasm through morphological traits and molecular markers;
- Techniques for gene transformation in mulberry;
- Techniques for gene transformation in mulberry;
- Molecular databases in mulberry;

- Visit to MAS lab in Department of Biotechnolgy, UAS, GKVK, Bengaluru;
- Visit to Seri-Biotechnology Research Laboratory, CSB, Kodathi, Bengaluru.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text books/ Publication reviews
- Student presentations
- Group work
- Student's interview of key policy makers
- Case analysis and case studies and guest lectures
- Review of policy documents
- Visits

IX. References

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Kendrew J. 1994. *The Encyclopedia of Molecular Biology*. Blackwell Scientific Publications, Oxford.

Old RW and Primrose SB. 1994. *Principles of gene manipulation: An Introduction to genetic engineering*, 5th Ed. *Blackwell Scientific Publications*, U. S. A.

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- www.tnau.ac.in/
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I. Course Title : Anatomy and Physiology of Sericigenous insects

II. Course Code : SER 507

III. Credit Hours : 1+1

IV. Why this course ?

To understand the basic principles of anatomy, different organs/ systems such as respiratory, circulatory, digestive, nervous and reproductive systems and their functional aspects (physiology) to strengthen the knowledge of students to take up meaningful research studies among sericigenous insects.

V. Aim of the course

This course is designed to provide basic information/ knowledge on anatomy; internal organs/systems, functions and their (physiology) thorough understanding of the sericigenous insects. Silk production among various sericigenous insects, their evolution and differences will also be studied.

The course is organized as follows:

No	Blocks	Units
1.	Anatomy of sericigenous insects	I Introduction, scope and importance II Anatomical studies of different systems III Comparison of anatomical structures among various sericigenous
2.	Physiology of different systems	I Introduction, scope and importance II Physiology of different systems III Silkworm nutrition and synthetic/artificial diets

VI. Theory

BLOCK 1: Anatomy of sericigenous insects

Unit 1: Introduction, scope and importance

Different structures of the various internal systems. The scope of the study for their application aspects and its importance for future research work.

Unit 2: Anatomical studies of various systems

Digestive, circulatory, respiratory, excretory, muscular, reproductive and nervous systems (including central, visceral and peripheral) and sense organs of larva, pupa and adult. Endocrine and exocrine glands (including silkglands).

Unit 3: Comparison of anatomical structures among various sericigenous insects

Variation of anatomical structures in different life stages, viz., larva, pupa and adult among different sericigenous insects mulberry, tasar, eri and muga.

BLOCK 2: Physiology of different systems

Unit 1: Introduction, scope and importance

Relation of structure to function and its application aspects.

Unit 2: Physiology of different systems

Physiology of digestive, circulatory, respiratory, excretory, muscular, reproductive, nervous system and endocrine and exocrine glandular systems, Hormonal mechanism, enzymes, pheromones, nutritional role of vitamins and other growth factors. Properties of haemolymph, histology, nerve impulses, sensory physiology. Silkglands and silk sysnthesis.

Unit 3: Silkworm nutrition and synthetic/artificial diets

Qualitative and quantitative nutritional requirement of silkworms, vitamins, carbohydrates, proteins and role of microbes in nutrition. Preparation of artificial/synthetic diets for silkworms. Endocrinal aspects of silk production.

VII. Practicals

- Study of digestive system of mulberry silkworm and silk moth;
- Study of excretory system of mulberry silkworm and silk moth;
- Study of digestive system of larva of Eri silkworm;
- Study of nervous system and endocrine glandular system mulberry silkworm larvae and Eri silkworm larvae;
- Study of circulatory and reproductive system in mulberry silkworm;
- Study of circulatory and reproductive system in Eri silkworm;
- Study of silk glands in mulberry silkworm, tasar, Eri and muga silkworms;
- Study of properties of haemolymph of mulberry, Eri and tasar silkworms;
- Study of physiology of digestion and excretion of mulberry silkworm;
- Study of physiology of circulatory and nervous system of mulberry silkworm;
- Study of physiology of reproductive system of mulberry silkworm;
- Study of physiology of silk protein synthesis;
- Study of endocrine systems, diapauses and hibernation;
- Preparation of artificial diets/synthetic diets;
- Study of comparative anatomy of digestive system of pupa and adult of mulberry silkworm;
- Study of comparative anatomy of digestive system of pupa and adult of Eri silkworm;
- Detection of frequency of variation in vaorioles in eri moths resulting from larvae fed with different hosts;
- Visit to sericulture institutes.

VIII. Teaching Methods/ Activities

- Lectures
- Dissections, drawing of sketches using camera lucida; grid/ photograph of the system
- Text Books
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals
- Student presentations
- Assignments, practical record maintenance
- Preparation of artificial diets and their application.

IX. Learning outcome

After successful completion of this course the students are expected to be able to – acquire basic knowledge about various systems in sericigenous insects, their structure and function. This will enable the students to thoroughly understand the nutritional requirements and silk production aspects. This will help the students to take up further research work meaningfully.

X. Suggested Reading

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- www.csrtimys.res.in/

I. Course Title : Silkworm Biochemistry and Nutrition

II. Course Code : SER 508

III. Credit Hours : 1+1

IV. Why this course ?

The silkworm growth directly depends on the food it consumes, digestion of consumed food to nutrients and assimilation of the digested nutrients into its body and then produce silk cocoons. The present course is designed to make the students understand the nutrients required for normal growth of silkworm and produce quality cocoons.

V. Aim of the course

The post graduate students should have a clear understanding of importance of feeding leaf with suitable nutrients in order to obtain reliable results of experiments conducted with silkworms. The course on silkworm biochemistry and nutrition will aim at enlightening the students on importance of raising silkworm on suitable mulberry leaves that nourish silkworm so as to undoubtedly infer the impact of treatments imposed during the experimentation. Further, they will be competent enough to emphasise on the balanced nutrition to mulberry among the farmers, since it's the sole food for silkworm.

The course is organized as follows:

No.	Blocks	Units
1	Nutrients for silkworm growth	1. Requirement of nutrients to silkworm 2. Metabolism and Utilization of nutrients
2	Biochemistry of nutrient utilization	1. Biochemical pathway for survival and cocoon production

VI. Theory

BLOCK 1: Nutrients for silkworm growth

Unit 1: Requirement of nutrients to silkworm

Carbohydrate, protein and fat metabolism, chemical nature of vitamins and hormones. Nutritional requirements of amino acids, lipids, vitamins, minerals. qualitative and quantitative requirements of nutrients.

Unit 2: Metabolism and Utilization of nutrients

Metabolism of amino acids, lipids, vitamins, minerals, Leaf composition as affecting silkworm growth, feed efficiency, supplementation of nutrients.

BLOCK 2: Biochemistry of nutrient utilization

Unit 1: Biochemical pathway for survival and cocoon production

Physiology of moulting, egg and pupal diapause in silkworm, biochemical pathways of silk synthesis and biochemistry of haemolymph.

VII. Practicals

- Qualitative tests for carbohydrates in silkworm heamolymph;
- Quantitative estimations of total soluble sugars in silkworm heamolymph;
- Qualitative tests for proteins and free amino acids in silkworm heamolymph;
- Quantitative estimations of proteins in silkworm heamolymph;
- Qualitative tests for lipids in silkworm heamolymph;
- Quantitative estimations of lipids in silkworm heamolymph;
- Determination of ascorbic acid level in the mulberry leaves;
- Determination of ascorbic acid level in silkworm heamolymph;
- Study of amylase activity in silkworm haemolymph;
- Study of phosphatase activity in silkworm haemolymph and digestive juice;
- Study of esterase activity in silkworm egg, larval haemolymph and silk glands;
- Qualitative tests for phospholipids and cholesterol in silkworm tissues;
- Quantitative estimation of phospholipids and cholesterol in silkworm tissues;
- Study of food consumption indices in silkworm;
- Estimation of lipid biomass in different silkworm breeds;
- Estimation of silk gland biomass in different silkworm breeds;
- Study of isozymes of different enzymes associated with silk productivity;
- Visit to Seri Bio-technology research laboratory/CSGRC.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the role and requirement of various nutrients in silkworm
- Learn the important biochemical pathways in silkworm that ultimately influence cocoon production.

X. Suggested Reading

Hamamura Y. 2001. *Silkworm rearing on Artificial Diet*. Oxford & IBH Publishing Co. Pvt., New Delhi. p. 287.

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I. Course Title : Biotechnology of Silkworm

II. Course Code : SER 513

III. Credit Hours : 1+1

IV. Why this course ?

Silkworm breeding by conventional methods takes relatively longer time. Combining different desirable traits in to one individual requires breaking linkage between desirable and undesirable traits. Application of biotechnology is essential to achieve early results in silkworm crop improvement.

V. Aim of the course

The course is aimed to provide knowledge on biotechnological methods and their application in silkworm crop improvement. The course will address the available methods and approaches that can be applied in the field of sericulture.

The course is organized as follows:

No	Blocks	Units
1	Biotechnological tools	1. Tissue culture techniques 2. Biotechnological methods
2	Application of biotechnology in silkworm	1. Molecular characterization and mapping 2. Transgenics, Bioinformatics and biosafety

VI. Theory

BLOCK 1: Biotechnological tools

Unit 1: Tissue culture techniques

Development ofpolyploids, gametoclonal variations - their scope and applications. Cryopreservation.

Unit 2: Biotechnological methods

Biotechnology and its scope in silkworm, recombinant DNA technology, genes transfer systems-vector mediated gene transfer, microinjection, electroporation, direct DNA uptake, gene gun technique, selectable markers and reporter system. Molecular markers.

BLOCK 2: Application of biotechnology in silkworm

Unit 1: Molecular characterization and mapping

Mulberry silkworm germplasm characterization by using molecular markers, Development of maps, QTL mapping, MAS for economically important traits in silkworm, Mapping populations (F2S and back crosses RILs, NILs, DHs), Molecular mapping and tagging of economically important traits.

Unit 2: Transgenics, Bioinformatics and biosafety

Transgenic silkworm-prospects, achievements in silkworm. Silkworm as a bioreactor for foreign gene expression, Molecular aspects of silk synthesis. Application of biotechnological tools in screening for biotic and abiotic stress resistance. Biosafety and regulatory issues, Intellectual Property Rights. Seri bioinformatics. Genomics-structural, functional and applications.

VII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work

– Laboratory exercises
– Scientific journals and periodicals

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the different biotechnological methods available in silkworm crop improvement
– Utilise methods and tools for evolving new silkworm breeds with desirable trait combinations

IX. Suggested Reading

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Gopinathan KP. 1992. "Biotechnology in sericulture", *Current Science*, 62(3): 283-287.

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I. Course Title : Sericulture By-product utilization and Value addition

II. Course Code : SER 516

III. Credit Hours : 1+1

IV. Why this course ?

Sericulture generates a huge quantity of by-products at each stage of sericulture activity such as rearing bed waste, left over mulberry leaves, mulberry twigs, the discarded silk moth, waste egg sheets, pierced cocoons and damaged cocoons, etc. at grainage. And also inturn it possesses a vast entrepreneurship opportunities in silkworm rearing, silk reeling, re-reeling, twisting, winding, weaving, etc. The present course is designed to make the students to understand all these opportunities in seri-by-products utilization and also entrepreneurship development thus making sericulture as one of the most profitable agro-enterprises.

V. Aim of the course

The course is designed with the aim of making the PG students to understand the best utilization of by-products generated at each stage of sericultural activity and their value addition for generating additional income making them good entrepreneurial managers in sericulture by exploring the vast entrepreneurial opportunities to make sericulture as one of the profitable enterprises for sustainable sericulture.

The course is organised as follows:

No.	Blocks	Units
1.	Entrepreneurship in sericulture	1. Entrepreneurship in sericulture and problems. 2. Sericultural entrepreneurship development in different countries.
2.	Entrepreneurship development in different stages 2.	1. Entrepreneurship development during mulberry cultivation Entrepreneurship development during egg production and silkworm rearing. 3. Entrepreneurship development during silk reeling and post reeling activities.
3.	Value addition of by-products in sericulture	1. Value addition during host plant cultivation 2. Value addition during silkworm rearing 3. Value addition during silk reeling and post reeling.

VI. Theory

BLOCK 1: Entrepreneurship in sericulture

Unit 1: Entrepreneurship in sericulture and problems

Concept, need, scope, prospects and problems of entrepreneurship in sericulture.

Unit 2: Sericultural entrepreneurship development in different countries

Sericultural entrepreneurial development in India, China, Japan and other sericultural countries.

BLOCK 2: Entrepreneurship development in different stages

Unit 1: Entrepreneurship development during mulberry cultivation

Entrepreneurship development in mulberry cultivation- kisan nursery, composting, vermicomposting, bio-digester, bio gas production, livestock production, fisheries, mushroom cultivation.

Unit 2: Entrepreneurship development during egg production and silkworm rearing

Entrepreneurial development in silkworm-egg production, Chawki rearing centres and cocoon production.

Unit 3: Entrepreneurship development during silk reeling and post reeling activities

Entrepreneurship development in silk reeling – establishment of reeling units, twisting and dying units, weaving units. Entrepreneurship development in manufacture/ production, marketing/ hiring of sericulture material/equipments and seri-inputs.

BLOCK 3: Value addition of by-products in sericulture

Unit 1: Value addition during host plant cultivation

Value addition during host plant cultivation - mulberry as fuel, green manure, fodder, live fencing material, wind breaks. Mulberry fruits and uses in pickle, jam, jelly, beverage/wine preparation. Mulberry as medicine, mulberry in agriculture and sports industry, mulberry in biogas production, mulberry as shade and avenue tree. Processing of mulberry leaves for tea preparation and food products.Medicinal value of mulberry.

Unit 2: Value addition during silkworm rearing

Value addition during silkworm rearing –silkworm litter as livestock feed; as an organic manure, raw material for biogas production, mushroom raising, poultry feed, fish feed, silkworm excreta in cosmetic industry. Silkworm in human consumption.

Unit 3: Value addition during silk reeling and post reeling

Pupal oil extraction and its uses, pupal powder as animal feed and manure. Flimsy cocoons and waste cocoons used as raw material in spun silk industry and quilting purpose. Silkworm pupa in human consumption-commercialized products and locally prepared dishes. Preparation of handicrafts, toys, wall plates, garlands, greeting cards, etc., from waste cocoons. Sericin for medicine, cosmetics, artificial membranes and plastic industry and other uses of silk.

VII. Practicals

- Visit to grainage for collection of waste cocoons including pierced cocoons;
- Visit to Chawki rearing centres and cocoon production centres for collection of different by-products;
- Visit to Silk reeling units, twisting, dying and weaving units for collection of different by-products;
- Preparation of compost, vermi-compost and biodigester from mulberry waste;
- Value addition during host plant cultivation-mulberry as fuel, green manure, fodder, live fencing material, wind breaks;
- Estimation of calorific value of mulberry wood as fuel;
- Mulberry fruits for table purpose and preparation of pickles, juice, jam, jelly, beverage/wine;
- Raising of mulberry saplings from desired genotypes for social forestry, avenue tree and eco-friendly flora;
- Processing of mulberry leaf for the tea preparation;
- Preparation of different food products with mulberry leaf as ingredient;
- Mushroom cultivation using silkworm litter as substrate;
- Value addition during silkworm rearing – silkworm litter as cattle, sheep and goat feed;
- Preparation of mulberry silage along with popular fodders;
- Quantification of biogas production using silkworm waste;
- Pupal oil extraction and pupal powder preparation and nutrient status estimation;
- Preparation of handicrafts, toys, wall plates, garlands, greeting cards, etc. using waste cocoons;

- Estimation of manurial value of compost and vermi-compost derived from mulberry waste;
- Using of silkworm pupae as animal, fishery and poultry feed.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals/ Publication reviews
- Study visits

IX. Learning outcome

After successful completion of this course, the students are expected be able to:

– Understand the entrepreneurship opportunities in sericulture and their problems during different stages of sericulture entrepreneurship
– Importance of value addition and utilization of sericultural by-products in agriculture and allied sectors.
– Non-textile opportunities for seri by-products and their value added products

X. Suggested Reading

Anonymous. 2002. *Silk Weaving*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Anonymous. 2002. *Colours from Nature – Silk Dyeing Using Natural Dyes*. Vol. I and II, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Bernard P Corbman. 1983. *Textiles: Fiber to Fabric*. 6th Edition, Mc. Graw – Hill International Editions, Home Economic Series, Singapore, p. 594.

Charles J Huber. 1929. *The Raw Silk Industry of Japan*. The Silk Association of America, Inc., New York.

Dandin SB and Gupta VP. 2002. *Advances in Indian Sericulture Research*. CSR&TI, Mysore.

Dandin SB, Jayaswal J and Giridhar K. (Eds.). 2003. *Handbook of Sericulture Technologies*. CSB, Bangalore.

Datta RK. 1996. *Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Govindan R, Chinnaswamy KP, Krishnaprasad NK and Reddy DNR. 2000. *Non-Mulberry Sericulture, Silk Technology and Sericulture Economics and Extension. Vol. 3– Proceedings of NSTS* – 1999, UAS, Bangalore.

Sinha S. 1990, *The Development of Indian Silk*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Tazima Y. 1978, *The Silkworm: An Important Laboratory Tool*. Kodansha Ltd., Tokyo.

Tripurari Sharan. 1984. *Sericulture and Silk Industry*. Published by Y.K. Sharma, Consortium on Rural Technology, Delhi.

Ullal SR and Narasimhanna MN., 1981. *Handbook of Practical Sericulture*. CSB, Bangalore.

Yasuji Hamamura. 2001. *Silkworm Rearing on Artificial Diet*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Yonemura M and Rama Rao N. 1925, *Handbook of Sericulture*. Mysore Government Branch Press.

Journals

- *Bulletins of Sericultural Experimental Station* – Suginami, Tokyo, Japan.

- *Journal of Sericultural Science of Japan* – Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* – Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* – CSR & TI, Mysore.
- *Journal of Sericulture and Technology* – NASSI, Bangalore.
- *Indian Silk* – Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi* (*Kannada*) – Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
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Course Title with Credit Load
Ph.D. (Agri.) in Sericulture

Course Code	Course Title	Credit Hours
	Major courses	
SER 601	Genetics and Breeding of Mulberry - II	1+1
SER 602	Physiology and Nutrition of Mulberry	1+1
SER 604	Physiological and Biochemical Genetics of silkworm	1+1
SER 605	Silkworm Pathology	1+1
SER 606	Integrated Pest Management in Sericulture	1+1
	Research and publications ethics	1+1
		6+6=12
	Minor courses*	
SER 603	Physiology and Nutrition of silkworm	1+1
SER 607	Sericulture Biotechnology	1+1
SER 608	Silk Technology-II	1+1
SER 609	Seri-Business Management	1+1
		4+4=8

*Note: The students may opt the optional courses from any disciplines/ departments as recommended by the advisory committee of the student based on the research topic.

Major Courses Contents
Ph.D. (Agri.) in Sericulture

I. Course Title : **Genetics and Breeding of Mulberry-II**

II. Course Code : **SER 601**

III. Credit Hours : **1+1**

IV. Why this course ?

In order to develop high yielding mulberry varieties for different situations, genetic principles and different advanced breeding methods are highly essential. In order to improve mulberry genetically, use of suitable germplasm and conventional methods and non-conventional methods of breeding are useful to meet the current needs. Hence this course.

V. Aim of the course

To make the students to get acquainted with advances in genetics, Cytogenetics and advanced breeding methods for mulberry improvement.

This course is organised as follows:

No.	Blocks	Units
1	Origin and distribution of mulberry, germplasm and biometrical techniques	1. Origin and exploitation of the genus *Morus* 2. Conservation and maintenance of mulberry germplasm 3. Biometrical Techniques in Breeding
2	Conventional and non-conventional breeding methods for mulberry improvement	1. Conventional methods of mulberry breeding 2. Non- conventional methods of breeding 3. Biotechnological approaches for mulberry improvement

VI. Theory

BLOCK 1: Origin and distribution of mulberry, germplasm and biometrical techniques

Unit 1: Origin and exploitation of the genus *Morus*

Origin and exploitation of the genus *Morus*. Species of mulberry and their distribution. Wild species and local genotypes and their importance. A critical appraisal of taxonomy of genus *Morus*. Mode of reproduction in relation to breeding methods in mulberry and genetic constitution. Recent advances in cytology of mulberry. Karyomorphological studies, mitotic and meiotic studies. Recent advances in embryological studies. Study of different ploidy levels of mulberry.

Unit 2: Conservation and maintenance of mulberry germplasm

Different types mulberry conservation. Role of mulberry germplasm in mulberry improvement. Characterization and evaluation of mulberry germplasm for morphological, anatomical, physiological, reproductive, biochemical and molecular traits. Evaluation of commercially released varieties/ genotypes for different growth and yield parameters. Utilization of mulberry gene bank. National and international institutes involved in mulberry germplasm conservation.

Unit 3: Biometrical Techniques in Breeding

Introduction, Assessment of variability: simple measures of variability, Components of variance -Genetic diversity. Aids of selection: Correlation coefficient analysis, Path analysis-Discriminant function. Choice of Parents and Breeding procedures: Partial diallel analysis, Line x Tester analysis - Biparental cross analysis. Varietal adaptation:Components of adaptability, Assessment of stability.

BLOCK 2: Conventional and non-conventional breeding methods for mulberry improvement

Unit 1: Conventional methods of mulberry breeding

Procedures followed for different methods of conventional breeding-Introduction, mass selection and clonal selection. Handling of segregating progenies-pedigree selection and back cross method of selection. Exploitation of heterosis, different kinds of heterosis, estimation of heterosis in mulberry. Three tier system of evaluation of mulberry. Advances in conventional methods of breeding. Poly cross hybrids – Principles involved, advantages and dis advantages. Steps in development of polycross hybrids. Advanced generation breeding. Preliminary yield evaluation, multilocational trial and mulberry authorization for evaluation. Steps for orderly distribution of improved varieties. Release of new varieties. Multiplication system and distribution- Kisan nursery-important varieties developed in conventional method.

Unit 2. Non-conventional methods of breeding

Present status of mulberry varietal improvement through mutation. Importance of induced mutation, recent achievements in mulberry mutation breeding. Limitations of mutation breeding.

Polyploidy, induction of polyploidy in mulberry, special features of triploids in mulberry, process of triploid mulberry development, varieties developed by polyploidy breeding in mulberry. Breeding methods followed for leaf quality parameters, biotic and abiotic stress. Breeding strategies for climate change. Participatory plant breeding (PPB) – introduction, types, stages of participation, objectives, advantages of PPB, role of farmers in PPB.

Unit 3: Biotechnological approaches for mulberry improvement

Recent advances in application of plant tissue culture. Applications of molecular markers in mulberry improvement. Genome characterization.

Development of transgenic mulberry – procedure. Nanotechnology: introduction, main features and its applications. Plant Variety Protection Act (PVPA) – Introduction, types of protection, basic requirements, organizations, procedure, material to be protected, types of varieties, exemptions under PVPA, advantages and disadvantages of PVPA. Statistical approaches for yield tests in mulberry: Field plot techniques in mulberry breeding experiments. Different experimental designs-RCBD, Augmented Randomized Complete Block Design (ARCBD) and LSD.

VII. Practicals

- Geographic distribution of the genus *Morus,* using maps;
- Evaluation of mulberry germplasm maintained at the Department of Sericulture, UAS, GKVK, Bengaluru;
- Study of diversity of mulberry germplasm maintained at the Department of Sericulture, UAS, GKVK, Bengaluru;
- Collection and categorization of available mulberry germplasm using standard key;
- Studies on conservation and maintenance of mulberry Gene bank;
- Identification of suitable mulberry genotypes for tree mulberry;
- Characterization of suitable mulberry genotypes and quality parameters for chawki silkworm;
- Characterization of suitable mulberry genotypes and quality parameters for late age silkworm;
- Identification of suitable mulberry genotypes for fruit purpose;
- Evaluation of commercially released mulberry varieties for growth and yield parameters;
- Phenotypic evaluation of commercially released mulberry varieties;
- Hands on training in callusing, sub-culturing,root initiation, shoot initiation and hardening of tissue culture plants, Triploids, etc.;
- Active bud treatment for polyploid induction in mulberry;
- Layout of field experiments in mulberry;
- Testing for resistance to biotic stresses;
- Testing for resistance to abiotic stresses;
- Selective breeding using marker assisted selection for identifying WUE mulberry genotypes;
- Visit to CSGRC Hosur/ CSB.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to:

- Know the importance of maintenance of indigenous and exotic lines of mulberry germplasm and their best exploitation in elite mulberry breeding
- Have Knowledge on different methods of breeding technology of mulberry for practical utilization
- Acquire knowledge on breeding of mulberry for various uses, viz., young silkworm rearing, late age silkworm rearing, production of mulberry fruits and raising of tree mulberry.

X. Suggested Reading

Chakraborti SP, Roy Chowddhuri S and Bindroo BB. 2013. *A text book on mulberry breeding and genetics.* Kalyani publications, New Delhi.

Dandin SB. 1986. Mulberry breeding for tropics, In "*Lectures on Sericulture".Suriamya Publishers*, Bangalore, pp. 25-28.

Das BC and Krishnaswami S. 1969. "Estimation of components of variation of leaf yield and its traits in mulberry". *J. Seric.,* **9**(1): 26-30.

Jalaja KS and Ram Rao DM. 2008. "Characterization of seven mulberry genotypes for their leaf quality and bioassay with silkworm", *Bombyx mori* L. *Sericologia*, **48**(1):85-93.

Sarkar A, Chatterjee KK and Das BC. 1988. An easy and dependable method for strain selection in mulberry. *Sericologia*, **28**(2): 233-235.

Journals

- *Indian Journal of Sericulture*, Central Silk Board, Bangalore
- *Indian Silk*, Central Silk Board, Bangalore
- *Seridoc*, Central Silk Board, Bangalore
- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
- *Sericologia*, International Sericultural Commission, India
- *Bulletin of Indian Academy of Sericulture*

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in
- www.csrtimys.res.in/

I. Course Title : Physiology and Nutrition of Mulberry

II. Course code : SER 602

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is a deep-rooted crop, draws its nourishment from different layers of the soil. Soil is the store house of water and nutrients which balances the vegetative and physiological growth. The physiological growth is more influenced by photosynthetic capacity, water transport system, absorption pattern of nutrients and carbohydrate metabolism in mulberry. Thus, having knowledge on the above vegetative and physiological growth will certainly help the students to acquire technical competency on above aspects. Hence this course**.**

V. Aim of the course

The main aim of this course is to provide both physiological and nutritional management through different metabolism. Further, it also helps in understanding different nutritional requirement for different growth stages which is required for silkworm growth and development. In addition, the factors affecting absorption of nutrients and water, pathway of minerals, transpiration, photosynthesis, C4 pathway, cellular respiration, biotic and abiotic stress operating in mulberry will also be learnt. The principles of above and factors influencing them enhance the quality parameters of mulberry which is the need of the hour. The beneficial effect of all the mechanisms help to understand the phenology of mulberry. The academic knowledge on the above help in strengthening the skill of the students to serve the farming community effectively who are involved in quality leaf production and success of sericulture.

This course is organised as follows

No.	Blocks	Units
1	Mulberry Physiology	1. Factors affecting sprouting and establishment of cuttings, role of aeroponics 2. Role of hormones in bud sprouting and rooting of cuttings
2	Growth and development of mulberry	1. Vegetative growth and development of mulberry
3	Plant growth hormones	1. Plant growth hormones and growth regulators
4	Photoperiodism and thermoperiodism	1. Photosynthesis in mulberry 2. Respiration in mulberry
5	Water and nutrient absorption mechanism	1. Soil properties, nutrient uptake and growth of mulberry 2. Soil fertility and INM in mulberry 3. Role of water in mulberry physiology
6	Dormancy, abiotic and biotic stress in mulberry	1. Dormancy in mulberry buds and seeds 2. Biotic and abiotic stress in mulberry
7	Nutrient deficiency symptoms	1. Deficiency symptoms of major nutrients 2. Deficiency symptoms of secondary and micro nutrients

VI. Theory

BLOCK 1: Mulberry Physiology

Unit 1: Factors affecting sprouting and establishment of cuttings, role of aeroponics.

Factors affecting sprouting and establishment of cuttings, Effect of temperature, cold, frost, light and salt. Aeroponics in mulberry. Possibility of deploying aeroponics in rooting and establishment of mulberry.

Unit 2: Role of hormones in bud sprouting and rooting of cuttings

Role of hormones in bud sprouting and rooting of cuttings and other physical agents like temperature, RH, light and water.

BLOCK 2: Growth and development of mulberry

Unit 1: Vegetative growth and development of mulberry

Duration of vegetative period, leaf area development, phases of development in different age groups of plants (Bush and tree type).

BLOCK 3: Plant growth hormones

Unit 1: Plant growth hormones and growth regulators

Plant growth hormones and growth regulators, classification, nature and biosynthesis in different aged plants and their functions.

BLOCK 4: Photoperiodism and thermoperiodism

Unit 1: Photosynthesis in mulberry

Photosynthesis in mulberry. Factors affecting photosynthesis, light and dark reaction, stages of photosynthesis, Calvin cycle, C-4 pathway and productivity.

Unit 2: Respiration in mulberry

Respiration – Cellular respiration, glycolysis, fermentation, citric acid cycle. Transpiration – role of environmental factors affecting transpiration, role of flowering, fruit set and seed development.

BLOCK 5: Water and nutrient absorption mechanism

Unit 1: Soil properties, nutrient uptake and growth of mulberry

Role of physical and chemical properties of soil on nutrient uptake and growth. Absorption pattern of major and micro nutrients in different soils.

Unit 2: Soil fertility and INM in mulberry

Response of mulberry varieties on absorption pattern of N, P, K and micronutrients. Status of various nutrients and soil fertility status and INM principles.

Unit 3: Role of water in mulberry physiology

Functions of water ecophysiology of plant, absorption of water, Passive absorption and Active absorption, pathway of minerals, root pressure.

BLOCK 6: Dormancy, abiotic and biotic stress in mulberry

Unit 1: Dormancy in mulberry buds and seeds

Viability of buds and seeds, concept of plant stress, biotic and abiotic stress, water deficit stress on mulberry,

Unit 2: Biotic and abiotic stress in mulberry

Effect of temperature, cold, frost, light and salt on mulberry growth and development.

BLOCK 7: Nutrient deficiency symptoms

Unit 1: Deficiency symptoms of major nutrients

Deficiency symptoms of N, P and K, toxicity of these nutrients in mulberry plants and their effect on quality of mulberry, reclamation of the soils by soil application, foliar application and fertigation methods.

Unit 2: Deficiency symptoms of secondary and micro nutrients

Key deficiency symptoms of S, Mn, Fe, Mo, Mg, Ca, Zn and other micronutrients and toxicity of these nutrients in mulberry plants and their effect on quality of mulberry, reclamation by soil and foliar application and fertigation methods.

VII. Practicals

- Study of sprouting and rooting in different varieties of mulberry;
- Use of different concentrations of plant growth hormones for establishment of mulberry;
- Study of root parameters in establishment of mulberry;
- Study of transpiration and photosynthesis in mulberry;
- Study of leaf area measurement of different varieties of mulberry;
- Study of different nutrients and their effect on growth and development of mulberry;
- Study of deficiency symptoms of NPK in mulberry;
- Study of mulberry seed viability tests;
- Study of biochemical and mineral composition of leading mulberry varieties;
- Study of absorption patterns of different fertilizers in mulberry;
- Study of different deficiency symptoms in mulberry;
- Study of respiration in mulberry;
- Evaluation of popular mulberry genotypes for biotic and abiotic stresses;
- Effect of various proportions of soil amendments on growth and development of mulberry;
- Study of deficiency symptoms of secondary and micro nutrients in mulberry through pot culture;
- Study of aeroponics in mulberry;
- Visit to aeroponic units at Department of Crop Physiology, UAS, GKVK, Bengaluru;
- Visit to NCBS laboratories, GKVK, Bengaluru.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussions
– Group work
– Laboratory exercises
– Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to:

- Acquire more information on both physiology and agronomic practices to be adopted in rain fed and irrigated mulberry garden.
- The student can utilize better techniques developed for both manure and fertilizer application.
- To gain understanding of different pathways of mulberry which will be helpful for water and nutrient management.

X. Suggested Reading

Bongale UD. 2003. "Nutritional Management and quality improvement in sericulture", *Proceedings of the National seminar on mulberry sericulture research in India* (26 th to 28th November 2001), P-1037.

Dandin SB and Giridhar K. 2014. *Handbook of sericuilture technologies*, CSB, Bengaluru, p.427

Ganga G. 2003. *Comprehensive Sericulture. Volume 2*. Silkworm Rearing and Silk Reeling. Oxford & IBH, New Delhi, p. 429.

Nutritional Management and Quality improvement in sericulture. 2003. KSSRDI. Banglore.

Rajanna L, Das PK, Ravindran S, Bhogesha K, Mishra RK, Singhvi NR, Katiyar RS and Jayaram H. 2005. *Mulberry cultivation and physiology,* Central Silk Board, Bangalore, p. 367.

Rangaswamy G, Narasimhanna MN, Kasiviswanathan K and Sastry CR. 1976. *Manual on Sericulture-I.Mulberry cultivation*, FAO, Rome, p.150.

Journals

- *Indian Journal of Sericulture*, Central Silk Board, Bangalore
- *Indian Silk*, Central Silk Board, Bangalore
- *Seridoc*, Central Silk Board, Bangalore
- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
- *Sericologia*, International Sericultural Commission, India.
- *Bulletin of Indian Academy of Sericulture.*

Websites

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- www.tnau.ac.in
- www.csrtimys.res.in/

I. Course Title : Physiological and Biochemical Genetics of Silkworm

II. Course Code : SER 604

III. Credit Hours : 1+1

IV. Why this course ?

Silk production is affected by both the environment and the genetic background of silkworm. The development of silkworm during its larval stage is crucial in obtaining quality cocoon yield. Understanding the genetic mechanism involved in various physiological and biochemical traits, which inturn influences the cocoon yield is essential in planning silkworm breeding strategies.

V. Aim of the course

The course in designed to make the students realize that silkworm development is influenced by the various physiological processes which are in turn governed by specific genes. Finally the student learns the relationship between these processes, the biochemical pathways and the genes that influence these processes and pathways.

The course is organized as follows:

No	Blocks	Units
1	Developmental Genetics	1. Embryonic development 2. Post-embryonic development
2	Physiological genetics	1. Genetics of Physiology in silkworm 2. Biochemical genetics in silkworm

VI. Theory

BLOCK 1: Developmental Genetics

Unit 1: Embryonic development

Embryonic development of non-hibernating and hibernating eggs; parthenogenesis; development of embryos under special genetic conditions, i.e., controlled by E- group allele, NC gene, NI-gene.

Unit 2: Post-embryonic development

Induction and translocation of quantitative and qualitative traits in silkworm. Quantitative traits affected by maturity genes, influence of environmental conditions on the expression of quantitative characters. Inheritance of moultinism, voltinsim and juvenility.

BLOCK 2: Physiological genetics

Unit 1: Genetics of Physiology in silkworm

Genetic control of hormonal mechanism. Role of voltinism genes on determination of quantitative characters. Maternal inheritance and its biochemical aspects. Genetic analysis of cocoon colours; physiology of pigments, genetic relation in terms of pigment permeability and transmission.

Unit 2: Biochemical genetics in silkworm

Genetic basis of enzymes – amylase – esterase – alkaline phosphatase – acid phosphatase – proteins and blood cells – haemocytes – ultrastructure of silkprotein synthesis – glutinous protein of the mucous gland. Importance of developmental, physiological and biochemical genetics in silkworm management, nutrition and breeding.

VII. Practicals

- Silkworm embryo testing and preparation of slides;
- Embryonic development in non – diapausing eggs;
- Embryonic development in diapausing eggs;
- Linkage maps and regional differentiation of the chromosomes;
- Induction of parthenogenesis in silkworm, *Bombyx mori* L.;
- Maternal inheritance in mulberry silkworm;
- Inheritance of voltinism and moultinism in silkworm;
- Maternal inheritance and biochemical aspects;
- Genetics of cocoon colours in *Bombyx mori* L.;
- Sex determination in mulberry silkworm;
- e-group alleles as a tool of developmental genetics;
- Silkworm nutrition in relation to breeding;
- Preparation of artificial diets for mulberry silkworm, *Bombyx mori* L.;
- Biochemical genetics: genetic basis of enzymes;
- Estimation of amylase activity in different races of silkworm;
- Determination of nad-dependent sorbitol dehydrogenase activity in the diapausing eggs of *Bombyx mori* L.;
- Assessment of environmental influence on expression of quantitative traits;
- Study of induction of polyploidy in silkworm.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the genetic background that influences the development of silkworm by governing the physiological and biochemical processes
- Learn the mode of action of silkworm of decisive genes that are critical in silkworm development

X. Suggested Reading

Anonymous 1993. *Principles and Techniques of Silkworm Breeding*. ESCAP, UN, New York. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. P.111.

Gardner EJ, Simmons MJ and Snustad DP. 1991. *Principles of Genetics,* John Willey& Sons Inc., New York. P. 649.

Hiratsuka E. 1999. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. P. 500.

Jolly MS, Sen SK, Sonwalker TN and Prasad GK. 1979. *Non-mulberry Silks*. FAO - Agricultural Service Bulletin, Rome. P. 178.

Kovalev PA. 1970. *Silkworm Breeding Stocks*. Central Silk Board, Bombay. P. 233.

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Singh RK and Chaudhary BD. 1996. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi. P. 318.

Sreeramareddy G. 1998. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. P.

Tazima Y. 1964. *The Genetics of Silkworm*. Logos Press Ltd., London. P. 253.

Tazima Y. 1978. *The Silkworm: An Important Laboratory Tool*. Kodansha Ltd., Tokyo, Japan. P. 307.

Journals

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- *Seridoc*, Central Silk Board, Bangalore
- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
- *Sericologia*, International Sericultural Commission, India.
- *Bulletin of Indian Academy of Sericulture*

Websites

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- www.tnau.ac.in
- www.csrtimys.res.in/

I. Course Title : Silkworm Pathology

II. Course Code : SER 605

III. Credit Hours : 1 +1

IV. Why this course ?

It is well-known that silkworm diseases are posing a threat in silk cocoon production thereby causing severe losses to the silkworm rearers. Silkworm diseases are estimated to cause a loss of 20 to 40% cocoon production. In addition, the quality of the cocoons produced also gets deteriorated affecting the economy of the cocoon rearers. Thus having detailed knowledge on the silkworm diseases with regard to various aspects will certainly help to produce competent technical man power. Hence is this course.

V. Aim of the course

The course is structured to provide both basic and applied knowledge on the viral, bacterial, protozoan and fungal diseases of silkworm as well as their prevention and control procedures. The course aims to provide the students the knowledge to diagnose and identify the different infections, knowledge on the etiological agents, their interactions, etc. This certainly helps the students to equip them with basic and applied information with respect to various pathogens and their prevention so that it helps them in strengthening their academic knowledge and also to serve the farming community effectively.

The course is organised as follows:

No	Blocks	Units
1.	Viral diseases of silkworm	1. Viral diseases of silkworm 2. Prevention and control of viral diseases of silkworm
2.	Bacterial diseases of silkworm	1. Importance of bacterial diseases of silkworm 2. Bacterial diseases- symptomatology, prevention and control
3.	Protozoan and fungal diseases of silkworm	1. Protozoan diseases, pathogens, symptomatology, prevention and control 2. Fungal diseases, pathogens, symptomatology, prevention and control

VI. Theory

BLOCK 1: Viral diseases of silkworm

Unit 1: Virus diseases of silkworm

Introduction to silkworm virus diseases. Symptomatology and basic knowledge on them. Economic importance, classification of silkworm viruses. Symptomatology and diagnosis of viral infections of silkworm. Purification of viruses and serological techniques. Nature, size and morphology of nuclear polyhedrosis virus, cytoplasmic polyhedrosis virus, infectious flacherie virus, densonucleosis virus.

Unit 2: Prevention and control of viral diseases of silkworms

Predisposing factors, disease cycle including replications, other hosts and spread of virus diseases. Interaction among silkworm viruses. Histopathology and pathophysiology of viral infections. Prevention and control.

BLOCK 2: Bacterial diseases of silkworm

Unit 1: Importance of bacterial diseases of silkworm

Introduction, history and importance ofBacterial diseases of the silkworm. Mixed infections. Etiology of bacterial flacherie, morphology and chemistry, pathogenicity, route of infection, silkworm immunity and serological detection.

Unit 2: Bacterial diseases- symptomatology, prevention and control

Introduction, bacterial septicemia, bacterial diseases of digestive organs. History and importance ofBacterial toxicosis of the silkworm. Structure and chemistry, biosynthesis of protein and chemistry of crystal toxin, histopathology, pathophysiology, Prevention and control.

BLOCK 3: Protozoan and fungal diseases of silkworm

Unit 1: Protozoan diseases, pathogens, symptomatology, prevention and control

Introduction, history and importance of the pathogenic protozoans of silkworms. Biodiversity, isolation, purification, morphology and chemistry of pathogenic protozoans. Strains of Microsporidians infecting silkworm and their life-cycle. Symptoms at the various stages of the life cycle of silkworm, pathologies, routes of infection, alternative hosts, cross infectivity, survival and spread, detection, prevention and control.

Unit 2: Fungal diseases, pathogens, symptomatology, prevention and control.

Introduction to fungal diseases, economic importance and classification of fungal diseases of silkworms, general morphology of Deuteromycetes. Life cycle of the different fungi pathogenic to silkworms-white, green, yellow, black and red muscardines and *Aspergillus* diseases. Pre-disposing factors, symptomatology, pathology (histopathology and pathophysiology), host range, host susceptibility, prevention and control.

VII. Practicals

- Survey for viral and bacterial diseases of silkworm based on external symptoms;
- Survey for protozoan and fungal diseases of silkworm based on external symptoms;
- Isolation and purification of silkworm viral pathogens;
- Isolation and purification of silkworm bacterial pathogens;
- Staining techniques for silkworm viruses and bacteria;
- Identification of silkworm pathogens based on morphology;
- Infectivity techniques for silkworm diseases;
- Cross infectivity of mulberry lepidopteran pests to silkworm;
- Cross infectivity of pathogens of silkworm pathogens to mulberry lepidopteran pests;
- Purification of pebrine pathogens and hatching of spores;

- *In-vitro* evaluation of chemicals against protozoan and fungal pathogens of silkworm;
- *In vivo* evaluation of effective chemicals against protozoan and fungal pathogens;
- Life cycle studies of important bacterial and fungal pathogens of silkworm;
- Interactions among different silkworm pathogens in silkworm;
- Practising hygienic measures in silkworm rearing for prevention of silkworm diseases;
- Practising shoot rearing method with net method of bed cleaning for prevention of silkworm diseases;
- Application of bed disinfectants against different diseases of silkworm;
- Application of room disinfectants to eliminate silkworm pathogens;
- Visit to Silkworm Pathology laboratory of CSB and State Sericulture Institute.

VIII. Teaching Methods/Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Students' presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to.

- Conduct survey for the diseases of silkworm, their diagnosis and identification
- Utilize the culturing and staining techniques for silkworm pathogens
- Prevention and control successfully the silkworm diseases so as to enable the farmers to successfully produce cocoon crops.

X. Suggested Reading

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- *Seridoc*, Central Silk Board, Bangalore
- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
- *Sericologia*, International Sericultural Commission, India.
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I. Course Title : Integrated Pest Management in Sericulture

II. Course Code : SER 606

III. Credit Hours : 1+1

IV. Why this course ?

Suppression of Pests of mulberry and non-mulberry silkworm food plants as well as pests of silkworms by deploying the chemical pesticides is known to be non-environmental friendly and induces resistance among pests causing pest outbreaks. The same is deleterious for silkworms, thus resulting in cocoon crop losses. Hence, it is always advisable to make use of the available methods of prevention and suppression methods in suitable combination ie., integrated management of pests so as to keep their populations below the economic injury level for successful cocoon crop production. The above knowledge among Ph.D students is essential and hence this courses assumes importance.

V. Aim of the course

The course is structured to improve knowledge on pests, factors affecting their biotic potential, damage caused, bio-ecology and integrated managements of pests of mulberry and non-mulberry silkworm food plants and mulberry as well as non-mulberry silkworms. In addition,the eco-friendly management practices for these pests will also be taught.

The course is organised as under:

No.	Blocks	Units
1	Pest and pest outbreak	1. Pests, classification and Damage 2. Pest outbreaks and pest surveillance and forecasting
2.	Pest management	1. Principles and methods 2. Eco-friendly pest management
3.	Bio-ecology and management	1. Mulberry pests 2. Mulberry silkworm uzifly 3. Grainage pests 4. Pests of non-mulberry silkworm food plants 5. Pests of non-mulberry silkworms

VI. Theory

BLOCK 1: Pest and Pest Outbreak

Unit 1: Pests, classification and damage

Concept of pests, classification of insect pests. Types of damage caused to host plants of silkworms and assessment of extent of damage.

Unit 2: Pest outbreaks and pest surveillance and forecasting

Causes for insects assuming pest status. Factors affecting the natural balance of insects in mulberry eco-system. Pest surveillance and forecasting of outbreaks.

Block 2: Pest Management

Unit 1: Principles and methods concept of pest management

Principles and methods of pest management. Integrated pest management – Meaning, practical utilization and merits.

Unit 2: Eco-friendly pest management

Eco-friendly pest management – concept, incorporation in IPM package, benefits. Development of cultural and mechanical methods, botanicals, other animal derived insecticides and biological control means in IPM.

Block 3: Bio – Ecology And Integrated Management Of Pests

Unit 1: Mulberry Pests

Bio-ecology and IPM of root feeding, steam boring, leaf eating and sap sucking pests of mulberry.

Unit 2: Mulberry silkworm uzifly

Biology of mulberry silkworm uzifly in relation to the biotic and abiotic environment and IPM package for the pest.

Unit 3: Grainage pests

Pests eccountered in mulberry silkworm egg production centres, damage caused and their management.

Unit 4: Pests of non-mulberry silkworm food plants

Incidence and extent of damage caused by pests on castor, terminalia and som. Biology of important defoliators and effect of ecological factors and IPM of important pests.

Unit 5: Pests of non-mulberry silkworms

An account of biology of pests and predators of tropical and temperate tasar silkworms and muga silkworm. Pests of eri silkworm. IPM of *Blepharipa zebra, Canthecona furcellata* and bird predators of tropical tasar.

VII. Practicals

- Survey and collection of insect pests of mulberry and their classification;
- Observations on nature and extent of damage and loss occurred to mulberry;
- Sampling methods for pest surveillance;
- Incidence of termites on different varieties of mulberry;

- Incidence of jassids, black headed hairy caterpillar and leaf folder on mulberry;
- Incidence of white mealy bug on different mulberry varieties;
- Life cycle of black headed hairy caterpillar on mulberry and castor;
- Biology of mulberry leaf webber and its varietal preference and IPM;
- Study of botanical pesticides and bio-agents used in mulberry pest management;
- Study of biological control agents used in mulberry eco-system and uzifly management;
- Forms, formulations and application of pesticides;
- Safety insecticides, their permissible limits and safety periods in mulberry pest management;
- Integrated management of rootknot nematode of mulberry;
- Incidence and biology of uzifly on mulberry silkworm;
- Construction of life table for indian uzifly based on the available data;
- Integrated management of mulberry silkworm uzifly;
- Survey for insect and non-insect pests in mulberry silkworm grainage;
- Study of pests of castor and *Terminalia* spp. and their management;
- Visit to CSGRC, Hosur/ R & D instiutions.

VIII. Teaching Methods/ Activities

- Lectures
- Providing study materials/ lecture materials
- Practical manuals
- Assignments (writing/ reading)
- Text books/ publications/ reviews/ technical bulletins/ manuals/ proceedings of scientific seminars
- Students presentations
- Group discussions
- Visits to silkworm rearing house/ silkworm pathology laboratories

IX. Learning outcome

After undergoing this course the students will acquire knowledge on the concept of pest, damage caused, outbreaks, pest management principles and methods, IPM and eco-friendly measures. In addition, they will have detailed information on the bio-ecology and management of pests encountered in sericulture which certainly helps them for effective advocation to the rearers and graneurs. This inturn ensures sustainability of sericulture.

X. Suggested Reading

Dandin SB, Jayant Jayaswal and Giridhar K. 2003. *Handbook of Sericulture Technologies*. CSB, Bangalore.

Dent DR and Walton MP. 1997. *Methods in Ecological and Agricultural Entomology*. CAB International, Cambridge.

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- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural Sciences*
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Minor Course Contents
Ph.D. (Agri) Sericulture

I. Title : Physiology and Nutrition of Silkworm

II. Course Code : SER 603

III. Credit : 1+1

IV. Why this course ?

Present Sericulture and allied sectors face tremendous challenges on multiple points, quality silk production, disease management, nutritional and ecological security to silkworms. Researchers, stake holders are benefited with knowledge and skill so as to reduce the risks in silk production.

V. Aim of the course

The course is designed to provide both basic and applied knowledge to avoid risks in silkworm rearing. It aims to equip students to indentify, evaluate and evolve ways to address risks in silkworm rearing, quality silk production and to evolve artificial nutritional diets for silkworms.

The course is organized as follows:

No	Blocks	Units
1.	Importance and scope	1. Importance of physiology
2.	Physiological studies	1. Physiology of digestion and excretion
		2. Physiology of circulation and respiration
		3. Physiology of endocrine system, egg diapauses and its role in growth and development
		4. Physiology of silk synthesis.
		5. Nutrition of silkworms
3.	Applied aspect of physiological	1. Hormone and enzyme applications
		2. Preparation of artificial diets for productivity of silk

VI. Theory

BLOCK 1: Importance and Scope

Unit 1: Importance of physiology

Study the importance, progress in developed countries Japan, China, Korea and the importance in India.

Unit 2: Study the scope and development of physiological studies and its applications in sericulturally advanced countries

BLOCK 2: Physiological studies

Unit 1: Physiology of digestion and excretion

Physiology of digestion and excretion enzymes, metabolism and various nutrients carbohydrates, proteins amino acids, vitamins, minerals excretory physiology, water conservation and utilization in the body.

Unit 2: Physiology of circulation and respiration

Physiology of circulation and respiration. Haemolymph its composition various cells in haemolymph phagocytes, leucocytes, etc. amylase, synthesis of blood role of enzymes and hormones on circulation. Physiology of respiration, O_2 supplementation, purification of haemolymph.

Unit 3: Physiology of endocrine system, egg diapauses and its role in growth and development

Physiology of endocrine system, Brain hormone, prothoracic gland hormone, corpora allata, corpora cardiac, sub-oesophageal glands, growth and development, moulting, diapauses prio synthesis of pheromones and their role in regulating silkworm behaviour. PTTH, JH analogues physiology of moulting and spinning.

Unit 4: Physiology of silk synthesis

Physiology of silk synthesis, Prio synthesis and fibroin sericin role of lyonet/ pilippis gland, Molecular basis of silk protein synthesis, sericin and fibroin.

Unit 5: Nutrition of silkworms

Utilizing of mulberry leaves, nutritional requirements of silkworms, digestion and utilization of various nutrients digestive enzymes, metabolism of various kinds of nutrients, carbohydrates, proteins, amino acids, vitamins and minerals.

BLOCK 3: Applied aspect of physiological studies:

Unit 1: Hormone and enzyme applications

Hormone and enzyme application tricontinol, serimore, sampoorna JH analogues, moulting hormones.

Unit 2: Preparation of artificial diets for productivity of silk

Preparation of artificial clients for silk productivity. Diets with mulberry composition, diet without mulberry and classification of diets. Nutrient supplementation.

VII. Practicals

- Study of consumption indices of carbohydrates utilization;
- Study of consumption indices of proteins and lipids utilization;
- Study of amylase activity in digestive juice of different breads of silkworm;
- Study of esterese activity in egg, haemolymph and silkglands of different breads of silkworm;
- Study of acid phosphatase activity in haemolymph and alkaline phosphatase digestive juice of different breads of silkworm;
- Determination of free amino acids in the haemolymph of silkworm;
- Determination of trehlose content in the haemolymph of silkworm;
- Application of hormones on growth and development of silkworms;
- Testing of plant products for growth and productivity in silkworm;

- Application of JH analogues and study its influence on growth and development of mulberry silkworm;
- Application of MH analogues and study of its influence on growth and development of mulberry silkworm;
- Determination of NAD-dependent sorbitol dehydrogenase activity during egg diapause;
- Nutrition supplementation through leaf fortification and its studies on growth and development;
- Preparation of artificial diets with mulberry component;
- Preparation of artificial diets (synthetic) without mulberry components;
- Visit to CSTRI/ NSSO;
- Visit to SERICARE/ Crop Physiology lab;
- Visit to SRBL Kodathi, Karnataka.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to

- Understand the basic aspects of physiological studies to apply it for research work in P.G.
- Learning to establish skills and tools of physiological studies to apply on growth and development of silkworms and silk productivity.
- Utilize the knowledge for its application of entrepreneur development for production of products related to growth and development of silkworm and silk productivity and quality.

X. Suggested Reading

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Beck SD. 1963. *Animal Photoperiodism*. Holt, Holt Library of Science Series, New York.

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I. Course Title : Sericulture Biotechnology

II. Course Code : SER 607

III. Credit Hours : +1

IV. Why this course ?

Hybridization and selection in segregating progenies of mulberry are very difficult because of its heterozygosity. In order to aid the selection in mulberry, biotechnological tools, viz., Tissue culture techniques, molecular markers and recombinant DNA technology are more useful to aid in selection. Application of these techniques will shorten the breeding procedure. Hence this course.

V. Aim of the course

The course is designed to equip the PG students with recent developments in the field of Tissue culture techniques, molecular markers, mapping and sequencing and recombinant DNA technologies applied both in mulberry and silkworm improvement.

The course is organised as follows:

No.	Blocks	Units
1	Biotechnology in Sericulture	1. Perspective, scope and current status of biotechnology in Sericulture 2. Mapping and sequencing of mulberry and silkworm
2	Tissue culture and Recombinant DNA techniques	1. Tissue culture in mulberry 2. Recombinant DNA techniques in mulberry and silkworm 3. Seri bioinformatics

VI. Theory

BLOCK 1: Biotechnology in sericulture

Unit 1: Perspective, scope and current status of biotechnology in Sericulture

Perspective, scope and current status of biotechnology. Techniques adopted in Restricted Fragment Length Polymorphism (RFLP), Random Amplified Polymorphic DNA (RAPD),Amplified Fragment Length Polymorphism (AFLP) and Simple Sequence Repeats (SSR). Applications of PCR (Polymerase chain reaction) and agarose gel electrophoresis.

Unit 2: Mapping and sequencing of mulberry and silkworm

Mapping and sequencing of mulberry and silkworm. Genome of mulberry and silkworm. Molecular basis for improvement of yield components in mulberry and silkworm.

BLOCK 2: Tissue culture and Recombinant DNA techniques

Unit 1: Tissue culture in mulberry

Micro propagation in mulberry, Production of haploids and Double haploids (DH) lines, Synthetic seeds, Induction of *in-vitro* flowering, *In-vitro* screening of mulberry for different stress conditions. Somaclonal and Gametoclonal variations - their scope and applications.Cryopreservation in mulberry for germplasm preservation. Protoplast culture and somatic hybridization.

Unit 2: Recombinant DNA techniques in mulberry and silkworm

Recombinant DNA techniques in mulberry and silkworm. Role of agents and microorganisms with emphasis to common vectors for gene transfer. Stability and expression of transferred genes in mulberry and silkworm. Germline transformation and scope of genetic manipulation between silkworm breeds. Application of molecular techniques in gene identification for further breeding programmes. Application of site directed mutagenesis, gene targeting and gene therapy. Silkgland genetics.

Units 3: Seri bioinformatics

Seri bioinformatics- introduction, branches of bioinformatics, computer programmes used. application in crop improvement. Studies on Genomics- genomics in crop improvement, types of genomics: structural, functional and applications, achievements and limitations. Studies on proteomics, Metabolomics. Nano technology- introduction, main features, Application of nano technology in mulberry improvement.

VII. Practical

- RFLP marker technique as applied to mulberry crop;
- RFLP marker technique as applied to silkworm improvement programmes;
- RAPD marker technique as applied to mulberry crop;
- AFLP marker technique as applied to mulberry crop;
- SSR marker technique as applied to mulberry crop;

- Equipments and chemicals used in RFLP and RAPD techniques;
- Equipments and chemicals used in PCR technique;
- Hands on training in mulberry DNA extraction, isolation, purification and concentration;
- Hands on training in silkworm DNA extraction, isolation, purification and concentration;
- DNA quantification and quality assessment in mulberry;
- DNA quantification and quality assessment in silkworm;
- Procedure of Agarose gel electrophoresis;
- Application of PAGE in silkworm;
- PCR reaction; PCR amplification;
- Estimation of genetics distances- cluster analysis in mulberry;
- Estimation of genetics distances- cluster analysis in silkworm;
- Visit to Seribiotech. Lab. of CSB at Kodathi;
- Visit to MAS lab and biotechnology lab of UAS (B);
- Visit to CSR&TI, Mysore- biotechnology division.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to

- Utilize the methods and tools of tissue culture and recombinant DNA technologies for mulberry and silkworm improvement.

X. Suggested Reading

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I. Course Title : Silk Technology-II

II. Course code : SER 608

III. Credit Hours : 1+1

IV. Why this course ?

Next to mulberry silk the other source of natural silk is from non-mulberry sector which is considered to be more profitable in India. Among four commercially exploited silkworm species Tasar, Muga and Eri are having vast diversity and uniqueness in silk quality which provide ancient customary rural employment and remunerative income to huge number of people mainly focusing on tribals. Information on this to students enlightens more on their distribution and characteristic features along with extraction of these silks. Hence this course attains importance.

V. Aim of the course

Non-mulberry sericulture has a glorious heritage. India is the largest user of silk and ranks next to China in global production. Tasar silk industry in India provides rural employment and remunerative income to the tribal population because it requires least investment to get high return. Non-mulberry sericulture has multi-tier earning potential to support rural enterprises/ entrepreneurs, especially in the area of silkworm seed production, commercial cocoon production, Yarn preparation and fabric making besides huge potentials in waste utilization. Therefore, greater emphasis and thrust should be laid on over all development of non-mulberry sericulture. The students after undergoing this course will have the benefit of all recent innovations in reeling technology of Tasar, Muga and spinning technology of Eri and their by-products that will throw light on present scenario of non-mulberry sericulture (Vanya silk) with present facts and figures.

This course is organised as follows

No.	Blocks	Units
1	Scope of non-mulberry sericulture	1. Introduction and spread of non-mulberry sericulture 2. Non-mulberry sericigenous insects
2	Commercially exploited	1. Physical characteristics – Eri, tasar and muga cocoons 2. Commercial characteristics- Eri, tasar and muga cocoons
3	Reeling technology for non-mulberry silk cocoons	1. Reeling technology for non-mulberry silk cocoons
4	Spinning of Eri silk cocoons and By-product utilization	1. Spinning of Eri silk cocoons 2. By-products of non-mulberry silk industry and their utilization
5	Economics of non-mulberry silk reeling unit establishments	1. Organization of non- mulberry silk reeling units
6	Conventional and non- conventional energy, health and environmental hazards	1. Use of conventional and non-conventional energy in silk Reeling industry 2. Health and environmental hazards in silk reeling

VI. Theory

BLOCK 1: Scope of non-mulberry sericulture

Unit 1: Introduction and spread of non-mulberry sericulture

Introduction, spread of non-mulberry sericulture in world and India and its utility to tribal people.

Unit 2: Non-mulberry sericigenous insects

Different non-mulberry sericigenous insects - fagara silk, coan silk and anaphe silk.

BLOCK 2: Commercially exploited non-mulberry silks

Unit 1: Physical characteristics – Eri, tasar and muga cocoons

Cocoon colour, shape, size, compactness, peduncle and ring in respect of Eri, tasar, muga, anaphe, fagara and coan silk cocoons.

Unit 2: Commercial characteristics- Eri, tasar and muga cocoons

Cocoon weight, shell weight, shell percentage, filament length, denier, kakame, non-breakable filament length, reelability, raw silk percentage in respect of Eri, tasar, muga, anaphe, fagara and coan silk cocoons.

BLOCK 3: Reeling technology for non-mulberry silk cocoons

Unit 1: Reeling technology for non-mulberry silk cocoons

Cocoonstifling and cooking methods, brusing, processing, wet and dry reeling of tasar and muga cocoons. Various equipments for reeling-Tevedi, N.R. Das, CTRS imporved reeling machine for tasar cocoon reeling and Choudhari reeling machine for muga silk cocoons, drying and skein making.Semi-automatic reeling machine and Automatic Reeling Meachine. Testing and grading ofnon-mulberry silks.

BLOCK 4: Spinning of Eri silk cocoons and By-product utilization

Unit 1: Spinning of Eri silk cocoons

Definition of spun silk, Various steps involved in spun silk industry (processing, degumming, washing and drying), Eri cocoons as raw material for spun silk industry- spinning of eri cocoons, hand spinning using Natwa, Takli, machine spinning using Amber charaka, madleri charaka and finished products, characteristic features, production of spun silk from pierced tasar and muga cocoons on takli, bhir and N.R. Das spinning wheel.

Unit 2: By-products of non-mulberry silk industry and their utilization

Use of different types of tasar wastes, by-products of tasar reeling - gicha, katia and matka silks. Use of pierced cocoons of tasar and muga, cooking waste, reeling waste and pelade layer. Silk wastes, extraction of pupa oil and its use in various fields. Pupa oil mill.

BLOCK 5: Economics of non-mulberry silk reeling unit establishments

Unit 1: Organization of non- mulberry silk reeling units

Organizational set up of reeling and spinning establishments for tasar, muga and Eri. Site for reeling, facilities for reeling and requirement of human skill and resources for reeling and spinning.Calculation of quantity of cocoons for different reeling and spinning units based on the raw material required for the available appliances. Working out of economics of reeling taking into account the cost of production and returns from resultant raw silk in respect of tasar and muga. Economics of eri spinning.

BLOCK 6: Conventional and non- conventional energy, health and environmental hazards in silk reeling industry

Unit 1: Use of conventional and non-conventional energy in silk Reeling industry

Overview, energy/ wood/ fuel/power consumption in cocoon stifling, cooking and reeling- release of smoke, constituents of smoke – effect of smoke on human health and rearing environment. Effluents from silk production. Solid waste, dust, smoke and effluents from silk weaving factory and spun silk mills.

Unit 2: Health and environmental hazards in silk reeling

Effect of reeling industry on ecosystem. Occupational health risk on reelers/ workers – skin and lungs related problems in reeling units due to release of smoke. Constituents and effect of smoke on human health and environment. Effluents from silk production. Solid waste, dust, smoke and effluents from silk weaving factory and spun silk mills. Policies on pollution control programmes on health hazards – risk and proposed options.

VII. Practicals

- Collection and preservation of non-mulberry silk cocoons in wild;
- Study of biodiversity of non-mulberry silk fauna on different hosts;

- Study of marketing system of cocoon transaction of Tasar;
- Study of marketing system of cocoon transaction of Muga;
- Study of marketing system of cocoon transaction of Eri;
- Study of physical parameters of the Tropical Tasar and Muga cocoons;
- Study of physical parameters of the Eri cocoons;
- Study of physical parameters of Japanese, Chinese and temperate Tasar cocoons;
- Study of commercial parameters of different ecoraces of tropical tasar;
- Study of commercial parameters of Muga and Eri silk cocoons;
- Study of different methods of stifling for Tasar and Muga Cocoons;
- Study of different methods of cooking for Tasar and Muga Cocoons;
- Study of use of enzymes in Tasar cocoon cooking;
- Study of different reeling machinery for Tasar and Muga;
- Study of different spinning appliances for Eri cocoons;
- Visit to spun silk mill to got acquainted with steps of silk spinning;
- Visit to Central Silk Technological Research Institute, Bengaluru;
- Estimation of cost and returns of establishment of reeling units and spun silk unit.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books/ Publications/ Technical bulletins/ Manuals/ Scientific journals and periodicals
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises

IX. Learning outcome

After undergoing this course the students are exposed to recent reeling techniques adopted in extraction of all non-mulberry silks and the ill effects of reeling industry and it helps in managing both the effluents and smoke and their proper disposal for building up of eco-friendly environment.

X. Suggested Reading

Bhaskar RN and Govindan R. 2005. *Techniques in Silk Reeling*, Department of Sericulture, UAS,GKVK, p. 50.

Ganga G. 2003. *Comprehensive Sericulture*. Volume 2. *Silkworm Rearing and Silk Reeling.* Oxford & IBH, New Delhi, p.429.

Jolly MS, Sen SK, Sonwalkar TN and Prasad GK. 1972. *Manual on Sericulture-IV.Non mulberry silks,* FAO, Rome, p.178.

Kim BH. 1978. *Raw Silk Reeling,* Korean edition Seoul Publishing Company, p. 275.

Manual on Bivoltine silk Reeling Technology, 2003, Published by JICA, PPP BST Project, p-122.

Journals

- *Indian Journal of Sericulture*, Central Silk Board, Bangalore
- *Indian Silk*, Central Silk Board, Bangalore
- *Seridoc*, Central Silk Board, Bangalore
- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural Sciences*

- *Sericologia*, International Sericultural Commission, India.
- *Bulletin of Indian Academy of Sericulture.*

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in
- www.csrtimys.res.in/

I. Course Title : Seri-Business Management

II. Course Code : SER 609

III. Credit Hours : 1+1

IV. Why this course ?

Sericulture industry possesses a vast opportunity for entrepreneurship at different stages of activities for rural and urban India inturn opening a huge business opportunities, viz., raising saplings in nursery, Grainage, Chawki rearing centre, Silkworm rearing, silk reeling, re-reeling, twisting, doubling and weaving fabric. The present course is designed to make the students to understand the vast entrepreneurship and business management opportunities and risk and non-cash input management associated in sericulture.

V. Aim of the course

The students will know and understand the business opportunities and their management in various activities of sericulture, their constraints, risk management, etc.

The course is organised as follows:

No.	Blocks	Units
1.	Silkworm seed production management	1. Sericulture industry-An overview. 2. Management of silkworm seed production and the associated resources
2.	Leaf production and silkworm rearing programme management	1. Leaf production and supply management, 2. Synchronized silkworm rearing programme management
3.	Silk reeling unit management	1. Management of reeling unit 2. Constraints and risk management

VI. Theory

BLOCK 1: Silkworm seed production management

Unit 1: Sericulture industry-An overview

Sericulture industry – overview, concept and principles of management, personal and resource management.

Unit 2: Management of silkworm seed production and the associated resources

Silkworm seed production management – organizational set up, selection of site, ground plan and establishment of grainage, production planning, raw material, manpower, seed storage programme, marketing, record maintenance; case studies.

BLOCK 2: Leaf production and silkworm rearing programme management

Unit 1: Leaf production and supply management

Quality mulberry leaf production and supply management

Unit 2: Synchronized silkworm rearing programme management

Synchronized silkworm rearing programme – manpower, community rearing, house management, marketing of cocoons.

BLOCK 3: Silk reeling unit management

Unit 1: Management of silk reeling unit

Reeling unit management – organization set up, raw materials- cocoons, fuel, water.

Unit 2: Constraints and risk management

Manpower, procurement skills – constraints, marketing – case studies of charka, cottage basin and filature basin, management of by-products of sericulture – risk management/ non-cash input management.

VII. Practicals

- Study of concept, principals, management and resource management in sericulture;
- Study of organizational set up in Sericultural organizations;
- Producing planning for grainage;
- Raw material management;
- Reeling unit management: man power, raw material, fuel and water;
- Planning for establishment of Chawki Rearing Centre (CRC);
- Planning for establishment of grainage;
- Study of by-products in sericulture;
- Record maintenance in sericulture activities;
- Study of leaf production and supply chain management;
- Risk management/ non cash management in sericulture;
- Visit to grainage and CRC;
- Case study: chawki rearing unit and silk cocoon production;
- Case studies: silkworm seed production unit;
- Case studies: filature and cottage basin units;
- Case studies: Charaka unit, improved Charaka units;
- Visit to seed cocoon markets;
- Visit to silk reeling units.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books/ Publication reviews
- Class presentations and assignments
- Experimentation
- Group discussion
- Group work
- Laboratory exercises

– Scientific journals and periodicals
– Study visits

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the Business opportunities in sericulture and their constraints and risk management during different activities of sericulture that helps for earning their livelihood.

X. Suggested Reading

Anonymous. 2002. *Silk Weaving*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Anonymous. 2002. *Colours from Nature – Silk Dyeing Using Natural Dyes*. Vol. I and II, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Bernard P and Corbman. 1983. *Textiles: Fiber to Fabric*. 6th Edition, Mc. Graw-Hill International Editions, Home Economic Series, Singapore, p. 594.

Charles J Huber. 1929. *The Raw Silk Industry of Japan*. The Silk Association of America, Inc., New York.

Dandin SB and Gupta VP. 2002. *Advances in Indian Sericulture Research*. CSR&TI, Mysore.

Dandin SB, Jayant Jayaswal and Giridhar K. (Eds.). 2003. *Handbook of Sericulture Technologies*. CSB, Bangalore.

Datta RK. 1996. *Global Silk Scenario–2001. Proceedings of the International Conference on Sericulture – 1994.* Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Govindan R, Chinnaswamy KP, Krishnaprasad NK and Reddy DNR. 2000. *Non-Mulberry Sericulture, Silk Technology and Sericulture Economics and Extension. Vol. 3—Proceedings of NSTS*–1999, UAS, Bangalore.

Sinha S. 1990. *The Development of Indian Silk*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Tripurari Sharan. 1984. *Sericulture and Silk Industry*. Published by Y.K. Sharma, Consortium on Rural Technology, Delhi.

Journals

- *Bulletins of Sericultural Experimental Station* – Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* – Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* – Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* – CSR & TI, Mysore.
- *Journal of Sericulture and Technology* – Published by NASSI, Bangalore.
- *Indian Silk* – Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* – Bhubaneshwar, Orissa.
- *Current Science* – C.V. Raman Institute of Science, Bangalore.
- *Reshme Krishi* (Kannada) – Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in
- www.csrtimys.res.in

ANNEXURE I

List of BSMA Committee Members for Sericulture

(Silk Worm Host Plant Sciences/Silk Worm Cocoon Production/Silk Worm Improvement/Silk Reeling, Post Reeling Technology and Value Addition)

S.No.	Name and Address	Specialization
1.	**Dr P Venkataravana** **Professor of GPB & Dean (Sericulture)** College of Sericulture, Chintamani-563 125 deanseri@uasbangalore.edu.in; Mob: 09449866914	**Chairman**
2.	**Dr V Shankaranarayan** **Former Dean** PB No. 29, Chintamani-563 125 shankaranarayana@gmail.com; Mob: 09448158763	**Convener**
3.	**Dr Fatima Sadatulla** **Professor & Head** Department of Sericulture, University of Agricultural Sciences,GKVK, Bangalore-560 065 fatimasadatulla@yahoo.com; Mob: 9740056596	**Silk Worm Pest Management**
4.	**Dr RN Bhaskar** **Professor** Department of Sericulture, University of Agricultural Sciences,GKVK, Bangalore-560 065 rnbhaskar@rediffmail.com Mob: 09448359151, 08154290547	**Silk Worm Management and Disease Management**
5.	**Dr Ramakrishna Naika** **Professor** College of Sericulture University of Agricultural, Chintamani-563 125 rnaika@gmail.com; Mob: 09448134789	**Crop Protection and Sericulture**
6.	**Dr Virendra Koul** **Professor & Head** Division of Sericulture Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K-180 009 koulvirendra@gmail.com; Mob: 09419181918	**Plant Protection**

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VOL. 2

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

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- Social Sciences
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त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the

syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language.*
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing.*
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition.* S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

  (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

  (b) An application is made by the student concerned duly supported by the Advisory Committee;

  (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

  (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Physical Sciences

- Agricultural Meteorology
- Agronomy
- Soil Science
- Agricultural Physics
- Organic Farming

Contents

Acknowledgements

In order to obtain inputs from academia and representatives of related stakeholders, the committee met with various Vice Chancellors, Deans, Directors, Faculty members, Students of various State agricultural universities, Farmers and education/ teaching related stakeholders. To do so, the committee organized meetings in different regions of the country. It had its first meeting at Assam Agricultural University, Jorhat. The second meeting and the first workshop was held at Bihar Agricultural University, Sabour. The third meeting was held at Maharana Pratap University of Agriculture and Technology, Udaipur and the fourth meeting cum final workshop was held at Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The committee acknowledges the support and guidance provided by honorable Vice Chancellors of above Universities Dr K.M. Bujarbaruah, Dr A.K Singh, Dr Uma Shankar Sharma and Dr Praveen Rao Velchala, respectively and the co-ordinators for their contributions as well as facilitating the input gathering. The committee also places on record participation of enumerable faculty from various colleges and universities from across length and breadth of country who provided very useful inputs for preparing the curriculum.

Organic farming in its modern shape with science-based practices and the entire value chain moderated through standards for organic production and backed with robust certification system is fast catching up as an alternative commercial agricultural enterprise. Keeping in view of its growing importance and growing interest of farmers, trade and industry, a need was being felt by ICAR to initiate a postgraduate course in "Organic Farming". ICAR, therefore, constituted a committee for developing the course curriculum for M.Sc.Agriculture in Organic Farming and the committee after due deliberations has developed the syllabus and other requirements and is being presented along with Physical Science group as per the decision of the National Core Committee.

We express our sincere thanks to the committee members Dr A.K. Yadav, Chairman of the committee and Former Director, National Centre of Organic Farming and Currently Advisor (MOVCDNER), DAC&FW, New Delhi; Dr N. Ravishankar, Principal Coordinator NPOF Research, ICAR-IIFSR, Modipuram; Dr R.K. Awasthe, Jt. Director, ICAR-NOFRI, Sikkim; Dr J.P. Saini, Head, Centre of Excellence on Organic Farming, CSKHPKVV, Palampur, Himachal Pradesh; Dr N. Devakumar, Dean, UAS, Bangalore, Karnataka and Dr Mahesh Chander, Head EE, ICAR-IVRI, Izzatnagar, UP constituted for development of course syllabus of "Organic Farming".

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Dr Laxman Singh Rathore, Chairman
Dr Dipti Kumar Borah, Convener
BSMA Committee, Physical Science

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agricultural Meteorology

Preamble

Agricultural Meteorology deals with the effects and impacts of weather and climate on agriculture and allied sectors. Climate, with its spatial and temporal variability, is a major influencing factor of crop production. Thus, any change in climatic elements is bound to have either positive or negative impacts on agricultural production. Along with this, climate change has led to increased intensity and frequency of extreme weather events such as heavy precipitation, cloud bursts, hail storm events, drought, etc. Here comes the importance of this discipline, which explores the principles of interaction of crops, livestock, fisheries, etc., with weather on a daily basis and with climate on a long-term basis. The relevance of the discipline is increasing over time, mainly due to the threats posed by climate variability and change in the present and future time. Considering the background and to promulgate the knowledge on role of weather for crop growth and development, new courses on Crop-weather relationship and Fundamentals of Agricultural Physics are included in the syllabus. Major changes are made in some courses considering the need of inclusion of recent advances and the new national initiatives. The repetition of content has been minutely scrutinized and modification has been done accordingly.

The provision of reliable weather information can be of great help for the decision making of farmers before and during the crop season for arranging the inputs and their optimum utilization. A well-timed agromet advisory can save inputs (fertilizers, seeds, plant protection chemicals, etc.), labour as well as the crop (especially at the harvest time after the crop reaches physiological maturity). Knowledge of Agricultural Meteorology helps in the efficient management of agro-climatic resources and crop microclimate modifications for the sustainability of agricultural production system. The students of this discipline should be sensitized towards the recent developments in information-communication technologies (ICT), which enables a faster, wider and timely dissemination of agromet advisories to the farmers of the country. Establishment of District-level Agromet Unit at different KVK is a great initiative by the Central Government and newly designed syllabus will empower the students to work in such types of project most efficiently.

The Agro-meteorologist requires not only a sound knowledge of Meteorology, but also of Agricultural Scince (Agronomy, Soil Science, Plant Sciences, and Animal Sciences), in addition to common agricultural practices. This branch ofscience is of particular relevance to India because of the high dependence of our agriculture on monsoon rainfall which has its own vagaries. A collective effort of agrometeorologist, agronomist, entomologist, pathologist and soil scientist make an information-rich agromet advisory, which will be of great help to the farmers. Another important area is the micrometeorology, which enables the farmers to modify the microclimate favourably to enhance the production.

Recent advances in space-borne (satellites), air-borne (UAVs) and ground remote sensing (spectro-radiometer) have improved the spatial and temporal capacity of the discipline for crop health monitoring, crop loss assessment, crop acreage estimation, etc. We are living in a world where tremendous advancement in computing power is enabling us to collect big data in agriculture, analyse it and arrive at conclusions, which helps to make farming a profitable business. The new syllabus will expose the students to the principles and practices of exploring remote sensing data, spatial analysis using Geographic information system (GIS), data analysis using computer programming with open source software like 'R' or/and 'Python'.The overall objective of this discipline is to educate students on the understanding of climate and weather elements, principles and processes, and their impact on agricultural activities and restructured course will help the students to achieve their goal.

Course Title with Credit Load
M.Sc. in Agriculture Meteorology

Course Code	Course Title	Credit Hours
AGM 501*	Fundamentals of Meteorology	2+1
AGM 502*	Fundamentals of Agricultural Meteorology	2+1
AGM 503	Crop-weather Relationships	2+0
AGM 504*	Agro-meteorological Measurements and Instrumentation	1+2
AGM 505	Crop Micrometeorology	2+1
AGM 506	Evapotranspiration and Soil Water Balance	2+1
AGM 507	Crop weather models	1+2
AGM 508	Applied Agricultural Climatology	1+2
AGM 509	Weather forecasting	2+1
AGM 510	RS and GIS Applications in Agricultural Meteorology	2+1
AGM 511	Strategic use of climatic information	2+1
AGM 512	Weather and climate risk management	2+0
AGM 513	Aerobiometeorology	2+1
AGM 591	Master's Seminar	1+0
AGM 599	Master's Research	30

*Indicates core courses for M.Sc.

Course Contents
M.Sc. in Agriculture Meteorology

I. Course Title : Fundamentals of Meteorology

II. Course Code : AGM 501

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of physical processes occurring in atmosphere and techniques used in meteorology.

V. Theory

Unit I

Solar radiation and laws of radiation; greenhouse effect, albedo, and heat balance of the earth and atmosphere; variation in pressure and temperature with height, potential temperature, pressure gradient, cyclonic and anticyclonic motions; geostropic and gradient winds; equations of motion; general circulation, turbulence, vorticity, atmospheric waves.

Unit II

Gas laws, laws of thermodynamics and their application to atmosphere; water vapour in the atmosphere, various humidity parameters and their interrelationships; vapour pressure, psychrometric equation, saturation deficit, Lapse rates-ascent of dry and moist air, stability and instability conditions in the atmosphere.

Unit III

Agromet observatory and analysis of weather data; Condensation; clouds and their classification; evaporation and rainfall; the hydrological cycle; precipitation processes, artificial rainmaking, thunderstorms and dust storm; haze, mist, fog, and dew; air masses and fronts; tropical and extra-tropical cyclones.

Unit IV

Effect of Earth's rotation on zonal distribution of radiation, rainfall, temperature, and wind; the trade winds, equatorial trough and its movement;

Unit V

Monsoon and its origin; Indian monsoon and its seasonal aspects: Onset, advancement and retreat of monsoon in different parts of India, Walker and Hadley cell, El Nino, La Nina, Southern Oscillation Index and their impact on monsoon.

VI. Practical

- Agromet observatory- different classes of observatories (A, B, C)
- Site selection and installation procedures for meteorological instruments
- Measurement of weather parameters.
- Reading and recording, calculation of daily, weekly, monthly means.
- Totals of weather data.
- Weather chart preparation and identification of low pressure systems and ridges.
- Statistical technique for computation of climatic normals, moving average, etc.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

- Ahrens. 2008. *Meteorology today*, 9th Edition. Wadsworth Publishing Co Inc.
- Barry RG and Richard JC. 2003. *Atmosphere, Weather and Climate*. Tailor & Fransics Group.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Ghadekar SR. 2001. *Meteorology*. Agromet Publishers (Nagpur).
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- Mcllveen R. 1992. *Fundamentals of Weather and Climate*. Chapman & Hall.
- Petterson S. 1958. *Introduction to Meteorology*. McGraw Hill.
- Trewartha Glenn T. 1954. *An Introduction to Climate*. McGraw Hill.
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Mausam*
- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Theoretical and Applied Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Fundamentals of Agricultural Meteorology

II. Course Code : AGM 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of physical processes occurring in relation to plant and atmosphere with advanced techniques.

V. Theory

Unit I

Meaning and scope of agricultural meteorology; components of agricultural meteorology; role and responsibilities of agricultural meteorologists.

Unit II

Importance of meteorological parameters in agriculture; efficiency of solar energy conversion into dry matter production; meteorological factors in photosynthesis, respiration and net assimilation; basic principles of water balance in ecosystems; soil-water balance models and water production functions.

Unit III

Crop weather calendars; weather forecasts for agriculture at short, medium and long range levels; agromet advisories, preparation, dissemination and economic impact analysis; use of satellite imageries in weather forecasting; synoptic charts and synoptic approach to weather forecasting.

Unit IV

Concept, definition, types of drought and their causes; prediction of drought; crop water stress index, crop stress detection; air pollution and its influence on vegetation, meteorological aspects of forest fires and their control.

Unit V

Climatic change, green house effect, CO_2 increase, global warming and their impact on agriculture; climate classification, agro-climatic zones and agro-ecological regions of India.

VI. Practical

- Preparation of crop weather calendars
- Development of simple regression models for weather, pest and disease relation in different crops.
- Preparation of weather based agro-advisories
- Use of automated weather station (AWS)

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Overall and basic knowledge on Agrometeorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Kakde JR. 1985. *Agricultural Climatology*. Metropolitan Book Co.
- Mahi and Kingra. 2014. *Fundamentals of agrometeorology*. Kalyani publishers.
- Mavi HS and Tupper. 2004. *Principles and applications of climate studies in agriculture*. CRC Press
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*
- *Current Science*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/
- www.wmo.org
- www.ipcc.org

I. Course Title : Crop-weather Relationships

II. Course Code : AGM 503

III. Credit Hours : 2+0

IV. Aim of the course

To study and understand the role of weather on crop growth and development.

V. Theory

Unit I

Understanding the influence of weather elements on crop growth, impact of climatic variability and extremes on crop production, climatic normals for crop production.

Unit II

Climatic requirements of major crops, temperature effect on crop growth, radiation impact and radiation utlilization efficiency, humidity effect on crop performance, effect of soil temperature on seed germination and root growth, wind variation and crop growth.

Unit III

Meteorological indices to predict crop production, Interpretation of weather forecasts for various agricultural operations towards improved productivity, crop-weather relationship in dryland areas. Crop weather relationship of major horticultural crops of the region and agroforestry system.

Unit IV

Rhizosphere and microorganisms in relation to weather, fertilizer and water use efficiency in relation to weather.

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

To enhance the knowledge on intricate relationship between crop and weather.

VIII. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jerry L. Hatfield, Mannava VK, Sivakumar and John H. Prueger. 2017. *Agroclimatology: Linking Agriculture to climate*. Agronomy Monographs 60.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Prasada Rao GSLHV. 2008. *Agricultural Meteorology*. PHI Learning Publishers.

Journals

- *Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/

I. Course Title : Agro-meteorological Measurements and Instrumentation

II. Course Code : AGM 504

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of instruments/equipments used for measurement of agro-meteorological variables.

V. Theory

Unit I

Fundamentals of measurement techniques; theory and working principles of barometer, thermometer, psychrometer, hair hygrometer, thermohygrograph; exposure and operation of meteorological instruments/ equipments in agromet observatories.

Unit II

Radiation and temperature measuring instruments: working principles of albedometer, photometer, spectro-radiometer, sunshine recorder, dew recorder, quantum radiation sensors, pressure bomb apparatus, thermographs, and infra-red thermometer.

Unit III

Precipitation and dew instruments: working principles of rain gauge, self recording rain gauge, Duvdevani dew gauges. Wind instruments: working principles of anemometer, wind vane, anemograph.

Unit IV

Evapotranspiration and photosynthesis instruments: working principles of lysimeters, open pan evaporimeters, porometer, photosynthesis system, leaf area meter.

Unit V

Boundary layer fluxes, Flux tower, soil heat flux plates, instruments to measure soil moisture and soil temperature.

Unit VI

Automatic weather station – data logger and sensors, nano-sensors for measurement of weather variables; computation and interpretation of data.

VI. Practical

- Working with the above instruments in the meteorological observatory, fields and laboratory, Recording observations of relevant parameters.
- Computation and interpretation of the data.
- Analysis of AWS data.

VII. Teaching methods/activities

Mostly practical classes with demonstration and hands-on use of met-instruments

VIII. Learning outcome

Practical classes and theory

IX. Suggested Reading

- Anonymous. 1987. *Instructions to Observers at Surface Observatories*. Part I, IMD, New Delhi.
- Byers HR. 1959. *General Meteorology*. McGraw Hill.
- Ghadekar SR. 2002. *Practical Meteorology: Data Acquisition Techniques, Instruments and Methods*. Agromet Publ.
- Middleton WE and Spilhaws AF. 1962. *Meteorological Department*. University of Toronto Press.
- Tanner CB. 1973. *Basic Instrumentation and Measurements for Plant Environment and Micrometeology*. University of Wisconsin, Madison.
- WMO. 2008. *Guide to Meteorological Instruments and Methods of Observation*. WMO-No.8

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

https://public.wmo.int/en

I. Course Title : Crop Micrometeorology

II. Course Code : AGM 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of physical processes occurring in lower atmosphere and within crop canopy concerning crop growth.

V. Theory

Unit I

Properties of atmosphere near the Earth's surface; exchange of mass momentum and energy between surface and overlaying atmosphere, exchange coefficient, similarity hypothesis, shearing stress, forced and free convection.

Unit II

Molecular and eddy transport of heat, water vapour and momentum, frictional effects, eddy diffusion, mixing; zero plane displacement, temperature instability, eddy covariance technique, microclimate near the bare ground, unstable and inversion layers, variation in microclimate under irrigated and rainfed conditions, soil moisture and temperature variation with depth; Richardson number, Raymonds analogy, Exchange coefficients.

Unit III

Micrometeorology of plant canopies; distribution of temperature, humidity, vapour pressure, wind and carbon dioxide; modification of microclimate due to cultural practices, intercropping; radiation distribution and utilization by plant communities, leaf temperature and its biological effects; influence of topography on microclimate; shelter belts and wind breaks, microclimate in low plant area of meadows and grain fields, microclimate within forests, glass house and plastic house climates; instruments and measuring techniques in micrometeorology.

Unit IV

Effects of ambient weather conditions on growth, development and yield of crops; measurement of global and diffuse radiation; measurement of albedo over natural surfaces and cropped surfaces; net radiation measurement at different levels; PAR distribution in plant canopies and interception; wind, temperature and humidity profiles in (a) short crops and (b) tall crops; energy balance over crops and LAI and biomass estimation; remote sensing and its application in relation to micrometeorology.

VI. Practical

- Micrometerological measurements in crop canopies
- Quantification of crop microclimate
- Determination of ET and its computation by different methods.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge of microclimatic conditions governing crop growth

IX. Suggested Reading

- Pal AS. 1988. *Introduction to Micrometeorology*. Academic Press.
- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Chang, Jen-Hu. 1968. *Climate and Agriculture: An Ecological Survey*. Aldine Publishing Company.
- Gates DM. 1968. *Energy Exchange in the Biosphere*. UNESCO.
- Goudriaan J. 1983. *Crop Micrometeorology: A Simulation Study*. Scientific Publ.
- Grace J. 1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Gupta PL and Rao VUM. 2000. *Practical Manual on Micrometeorology*. Dept. of Agril. Meteorology, CCS HAU Hisar, India.
- Jones HG. 1992. *Plants and Microclimate*. Cambridge Univ. Press. Munn RE. 1970. Biometeorological Methods. Academic Press.
- Monteith and Unsworth. 2013. *Principles of Environmental Physics*. Elsevier.
- Rosenberg NJ. 1974. *Microclimate – The biological Environmet*. John Wiley & Sons.
- Sellers W. 1967. *Physical Climatology*. The University of Chicago Press.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://public.wmo.int/en

I. Course Title : Evapotranspiration and Soil Water Balance

II. Course Code : AGM 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of ET estimation and determination of the components of soil water balance

V. Theory

Unit I

Energy concept of soil water, hydraulic conductivity and soil water flux; theory on hydraulic conductivity in saturated and unsaturated soils; physical factors concerning water movement in soil; concepts on evaporation, evapotranspiration, potential and actual evapotranspiration.

Unit II

Theories of evapotranspiration and their comparison; aerodynamic, eddy correlation, energy balance, water balance and other methods, their application under different agroclimatic conditions; concepts of potential, reference and actual evapotranspiration - modified techniques.

Unit III

Influence of microclimatic and cultural factors on soil water balance; techniques of lysimetry in measuring actual evapotranspiration. water use efficiency and scheduling of irrigation based on evapotranspiration; water use efficiency and antitranspirants, computation of Kc values and their use; irrigation scheduling based on climatological approaches.

Unit IV

Yield functions; water use efficiency and scheduling of irrigation based on evapotranspiration; dry matter yield ET functions; radiation instruments; advanced techniques for measurement of radiation and energy balance; estimation of evapotranspiration through remote sensing.

VI. Practical

- Measurement of various components of soil water balance
- Evaluation of hydraulic conductivity vs. soil moisture relationship by water balance approach
- Computation and comparison of evapotranspiration by different methods - energy balance method, aerodynamic method, Penman method, remote sensing and other methods
- Soil moisture retention characteristics by pressure plate method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

To know the estimation procedures and interlinkages among different components of field water balance

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Burman R and Pochop LO. 1994. *Evaporation, Evapotranspiration and Climatic Data*. Elsevier.
- Grace J.1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Mavi HS and Tupper GJ. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Murthy VRK. 2002. *Basic Principles of Agricultural Meteorology*. BS Publ.
- Niwas R, Singh D and Rao VUM. 2000. *Pratical Manual on Evapotranspiration*. Dept. of Agril. Meteorology, CCS HAU Hisar.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate –The Biological Environment*. John Wiley & Sons.
- Subramaniam VP. 1982. *Water balance and its application*. Andhra University Press, Waltair, India.

Journals

- *Journal of Agrometeorology*
- *Archives of Agronomy and Soil Science*
- *Agricultural Water Management*
- *Journal of Hydrology*
- *Journal of Plant Ecology*

Websites

- https://www.icrisat.org/
- http://www.iwmi.cgiar.org/
- http://www.iiwm.res.in/

I. Course Title : Crop Weather Models

II. Course Code : AGM 507

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of various models for estimation of crop weather responses.

V. Theory

Unit I

Principles of crop production; effect of weather elements on crop responses; impact of natural and induced variability of climate on crop production.

Unit II

Introduction and application to crop modeling, types of models, Empirical and statistical crop weather models their application with examples; concept of crop growth model in relation to weather, soil, plant and other environmental related parameters and remote sensing inputs; growth and yield prediction models;

Unit III

Dynamic crop simulation models, e.g. DSSAT, InfoCrop, APSIM, CropSyst, etc.; optimization, calibration and validation of models. Weather data and physiology-based approaches to modeling of crop growth and yield; forecasting of pests and diseases; stochastic models; advantages and limitation of modeling.

VI. Practical

Working with statistical and simulation models, DSSAT models, InfoCrop, Oryza, etc.

VII. Teaching methods/activities

Theory and practical classes. Demonstration and hands-on practicals using crop models

VIII. Learning outcome

To utilize the crop weather model for observing weather influence on crop growth

IX. Suggested Reading

- Wallach D *et al*. *Working with dynamic crop models*.
- DeWit CT, Brouwer R and de Vries FWTP. 1970. *The Simulation of Photosynthetic Systems*. pp. 7-70. In. Prediction and Measurement of Photosynhetic Activity. Proc. Int. Biological Programme Plant Physiology Tech. Meeting Trebon PUDOC. Wageningen.
- Duncan WG. 1973. *SIMAI- A Model Simulating Growth and Yield in Corn*. In: The Application of Systems Methods to Crop Production (D.N. Baker, Ed.). Mississippi State Univ. Mississipi.
- Frere M and Popav G. 1979. *Agrometeorological Crop Monitoring and Forecasting*. FAO.
- Hanks RJ. 1974. *Model for Predicting Plant Yield as Influenced by Water Use*. Agron. J. 66: 660-665.
- Hay RKM and Porter JR. 2006. *The physiology of crop yield* (2nd Edition).
- Keulen H Van and Seligman NG. 1986. *Simulation of Water Use, Nitrogen Nutrition and Growth of a Spring Wheat Crop*. Simulation Monographs. PUDOC, Wageningen.
- Singh P. *Modelling of crop production systems: Principles and applications*.
- Weixing Cao *et al*. *Crop modeling and decision support*.

Journals

- *Journal of Agrometeorology*

- *Global Environmental Change*
- *Global Change Biology*
- *Mitigation and Adaptation Strategies for Global Change*

Websites

- https://www.apsim.info/
- https://dssat.net/

I. Course Title : Applied Agricultural Climatology

II. Course Code : AGM 508

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of computation of different bio-parameters and their applications in the agriculture.

V. Theory

Unit I

Climatic statistics: measures of central tendency and variability, skewness, kurtosis, homogeneity, correlation, regression and moving averages; probability analysis using normal, binomial, Markov-chain and incomplete gamma distribution; parametric and non parametric tests; assessment of frequency of disastrous events.

Unit II

Precipitation indices; Climatic water budget: potential and actual evapotranspiration and their computation; measurement of precipitation, calculation of water surplus and deficit; computation of daily and monthly water budget and their applications; assessment of dry and wet spells, available soil moisture, moisture adequacy index and their applications.

Unit III

Thermal indices and phenology: cardinal temperatures; heat unit and growing degree day concepts for crop phenology, crop growth and development; insect-pest development; crop weather calendars; agroclimatic requirement of crops.

Unit IV

Bioclimatic concepts: evaluation of human comfort, comfort indices (temperature, humidity index and wind chill) and clothing insulation; climate, housing and site orientation; climatic normals for animal production.

VI. Practical

- Use of statistical approaches in data analysis
- Preparation of climatic water budget
- Estimation of agro-meteorological variables using historical records
- Degree day concept and phenology forecasting and preparation of crop calendar
- Evaluation of radiation, wind and shading effects in site selection and orientation
- Study of weather-pest and disease interactions, calculation of continentality factors; calculation of comfort indices and preparation of climograph.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge on how to use the meteorological observations and derived indices are applied in agricultural field

IX. Suggested Reading

- Anonymous 1980. *ICRISAT Climatic Classification – A Consultation Meeting*. ICRISAT.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Lal DS. 1989. *Climatology*. Chaitanya Publ. House.
- Mather JR. 1977. *Work Book in Applied Climatology*. Univ. of Delware, New Jersey.
- Mavi HS and Tupper Graeme J. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Stigter K (Ed.). 2010. *Applied Agrometeorology*. Springer
- Subramaniam VP. 1977. *Incidence and Spread of Continental Drought*. WMO/IMD Report No. 2, WMO, Geneva, Switzerland.
- Thompson R. 1997. *Applied Climatology: Principles and Practice*. Routledge.
- Walter J Saucier. 2003. *Principles of Meteorological Analysis*. Dover Phoenix Eds.

Journals

- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agricultural Climatology and Meteorology*
- *Journal of Applied Meteorology and Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Weather Forecasting

II. Course Code : AGM 509

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of forecasting techniques used for weather prediction and preparation of agro-advisories.

V. Theory

Unit I

Weather forecasting system: definition, scope and importance; types of forecasting: short, medium and long-range; study of synoptic charts with special reference to location of highs and lows, jet streams, synoptic features and weather anomalies and zones of thermal advection and interpretation of satellite pictures of clouds in visible and infra-red range; weather forecasting network.

Unit II

Approaches for weather forecasts: methods of weather forecasts - synoptic, numerical prediction, statistical, analogue, persistence and climatological approach, nano-technological approach, Indigenous Technical Knowledge (ITK) base- signals from flora, fauna, insects, birds, animals behavior; various methods of verification of location-specific weather forecast.

Unit III

Special forecasts: special forecasts for natural calamities such as drought, floods, high winds, cold (frost) and heat waves, hail storms, cyclones and protection measures against such hazards.

Unit IV

Modification of weather hazards: weather modification for agriculture; scientific advances in artificial rain making, hail suppression, dissipation of fog and stratus clouds, modification of severe storms and electric behavior of clouds.

Unit V

Weather based advisories: interpretation of weather forecasts for soil moisture, farm operations, pest and disease development and epidemics, crops and livestock production; preparation of weather-based advisories and dissemination.

VI. Practical

- Exercise on weather forecasting for various applications
- Preparation of weather-based agro-advisories based on weather forecast using various approaches and synoptic charts.

VII. Teaching methods/ activities

Theory and practical classes

VIII. Learning outcome

Enhancing knowledge on weather forecast and its use

IX. Suggested Reading

- Watts A. 2005. *Instant Weather Forecasting*. Water Craft Books.
- Ram Sastry AA. 1984. *Weather and Weather Forecasting*. Publication Division, GOI, New Delhi.
- Singh SV, Rathore LS and Trivedi HKN. 1999. *A Guide for Agrometeorological Advisory Services*. Department of Science and Technology, NCMRWF, New Delhi.
- Wegman and Depriest. 1980. *Statistical Analysis of Weather Modification Experiments*. Amazon Book Co.

Journals

- *Journal of Climatology and Weather Forecasting*
- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agroclimatology*

Websites

- https://www.ipcc.ch/
- https://www.imd.gov.in/pages/main.php

I. Course Title : RS and GIS Applications in Agricultural Meteorology

II. Course Code : AGM 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of remote sensing principles and their use to estimate of agro-meteorological variables.

V. Theory

Unit I

Basic components of remote sensing- signals, sensors and sensing systems; active and passive remote sensing.

Unit II

Characteristics of electromagnetic radiation and its interaction with matter; spectral features of earth's surface features; remote sensors in visible, infrared and microwave regions.

Unit III

Imaging and non-imaging systems; framing and scanning systems; resolution of sensors; sensor platforms, their launching and maintenance. Drone technology.

Unit IV

Data acquisition system, data preprocessing, storage and dissemination; digital image processing and information extraction.

Unit V

Microwave remote sensing; visual and digital image interpretation; introduction to GIS and GPS.

Unit VI

Digital techniques for crop discrimination and identification; crop stress detection - soil moisture assessment, inventory of ground water and satellite measurement of surface soil moisture and temperature; drought monitoring, monitoring of crop disease and pest infestation. Use of satellite data in weather forecasting.

Unit VII

Soil resource inventory; land use/land cover mapping and planning; integrated watershed development; crop yield modeling and crop production forecasting.

VI. Practical

- Acquisition of maps
- Field data collection
- Map and imagery scales
- S/W and H/W requirements and specifications for remote sensing
- Data products, their specifications, media types, data inputs, transformation, display types, image enhancement
- Image classification methods
- Evaluation of classification errors
- Crop discrimination and acreage estimations
- Differentiation of different degraded soils
- Time domain reflectometry
- Use of spectrometer and computation of vegetation indices
- Demonstration of case studies
- Hands on training

VII. Teaching methods/activities

Hands on practicals and theory

VIII. Learning outcome

Knowledge on RS-GIS technique for application in Agricultural Meteorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Campbell JB. 1996. *Introduction to Remote Sensing*, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.). *Manual of Remote Sensing*. Vols. 1, II. Am. Soc. Photogrammetry, Virginia.
- Curan PJ. *Principles of Remote Sensing*. ELBS/Longman.
- Georg Joseph 2005.*Fundamentals of Remote Sensing*. University Press (India).
- Jain AK. 1989. *Fundamentals of Digital Image Processing*, Prentice Hall of India.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. *Remote Sensing and Image Interpretation*, 5th ed., John Wiley & Sons, Inc., New York.
- Narayan LRA. 1999. *Remote Sensing and its Applications*. Oscar Publ.
- Panda BC. 2008. *Principles and Applications of Remote Sensing*, Viva Publications.
- Patel AN and Surender Singh. 2004. *Remote Sensing: Principles and Applications*. Scientific Publ.

Journals

- *Journal of Global Environmental Change*
- *Journal of Remote Sensing and GIS*
- *Journal of Agrometeorology*

Websites

- https://www.nrsc.gov.in/
- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Strategic Use of Climatic Information

II. Course Code : AGM 514

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of climatic hazards and their mitigations.

V. Theory

Unit I

Increasing awareness on potential climate hazards and mitigations: history of climate-related disasters in the concerned continent/ region/ country/ sub-region and their documented or remembered impacts; Climatic hazards and extreme weather events (Cyclone, Hailstorm, drought, flood, etc.), Impact of climatic hazard on agricultural production; efforts made in mitigating impacts of (future) disasters (prevention); trends discernible in occurrence and character of disasters, if any.

Unit II

Selection of appropriate land use and cropping patterns: types and drivers of agricultural land use and cropping patterns based on climatic situation; history of present land use and cropping patterns in the sub-region concerned as related to environmental issues; successes and difficulties experienced by farmers with present land use and cropping patterns; outlook for present land use and cropping patterns and possible alternatives from an environmental point of view.

Unit III

Adoption of preparedness strategies: priority settings for preparedness strategies in agricultural production; preparedness for meteorological disasters in development planning; permanent adaptation strategies that reduce the vulnerabilities to hazards; preparedness as a coping strategy.

Unit IV

Making more efficient use of agricultural inputs: agro-meteorological aspects of agricultural production inputs and their history; determination of input efficiencies based on weather conditions; other factors determining inputs and input efficiency; actual use of inputs in main land use and cropping patterns of the region.

Unit V

Adoption of microclimate modification techniques: review of microclimate management and manipulation methods; history of microclimate modification techniques practiced in the continent/ country/ sub-region concerned; possible improvements in adoption of microclimate modification techniques, given increasing climate variability and climate change; local trends in adoption of such techniques.

Unit VI

Protection measures against extreme climate: history of protection measures against extreme climate in the continent/ region/ country/ sub region concerned; successes and difficulties experienced by farmers with present protection measures; outlook for present protection measures and possible alternatives; trends in protection methods against extreme climate.

Practical

- Outlook for present land use and cropping patterns and possible alternatives from environmental point of view
- Recent trends in land use and cropping patterns
- Agro-meteorological services to increase farmers design abilities of land use and cropping patterns
- Systematic and standardized data collection on protection measures against extreme climate.

VI. Teaching methods/activities

Theory and practical classes

VII. Learning outcome

Application of climatic information for agriculture and natural resource management

VIII. Suggested Reading

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol.* UNEP, UNDP Publ.
- Anonymous. *IPCC Assesment Reports on Climate Change Policy: Facts, Issues and Anlysis*. Cambridge Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.

Journals

- *Climate Risk Management*, *Journal* of *Climate* (JCLI),
- *International Journal of Climatology*
- *Journal of Agrometeorology*

Website

https://www.ncdc.noaa.gov/climate-information

I. Course Title : Weather and Climate Risk Management

II. Course Code : AGM 515

III. Credit Hours : 2+0

IV. Aim of the course

To impart the theoretical and practical knowledge of weather modification techniques with risk management strategies

V. Theory

Unit I

Risk characterization – definitions and classification of risks; characterization of weather and climate related risks in agriculture; water related risks; radiation/ heat related risks; air and its movement related risks; biomass related risks; social and economic risk factors related to weather and climate.

Unit II

Risks in agricultural production, history of weather and climate as accepted risk factors in agriculture in the continent/ region/ country/ sub-region concerned and the related documented risk concepts; preparedness for weather and climate risks.

Unit III

Risks of droughts; monitoring, prediction and prevention of drought; drought proofing and management; modern tools including remote sensing and GIS in monitoring and combating droughts.

Unit IV

Theories of weather modification; scientific advances in clouds and electrical behavior of clouds; hails suppression, dissipation of fog, modification of frost intensity and severe storms; shelter belts and wind breaks, mulches and anti-transpirants; protection of plants against climatic hazards; air and water pollution; meteorological conditions in artificial and controlled climates - green, plastic, glass and animal houses, etc.

Unit V

Approaches and tools to deal with risks - history of methods for weather and climate related risk assessments in the continent/ region/ country/ subregion concerned and their documented evidence of application to agricultural/farming systems; strategies of dealing with risks- mitigating practices before occurrence; preparedness for the inevitable; contingency planning and responses; disaster risk mainstreaming.

Unit VI

Perspectives for farm applications - farm applications not yet dealt with, such as making risk information products more client friendly and transfer of risk information products to primary and secondary users of such information; heterogeneity of rural people in education, income, occupation and information demands and consequences for risk information products and their transfer; livelihood-focused support, participation and community perspectives; challenges for developing coping strategies including transferring risks through insurance schemes.

Unit VII

Challenges to coping strategies-combining challenges to disaster risk mainstreaming, mitigation practices, contingency planning and responses, basic preparedness; preparedness approaches reducing emergency relief necessities; the role that insurances can play in risk spreading and transfer; application of methods that permit the incorporation of seasonal and long-term forecasts into the risk assessment models.

VI. Teaching methods/ activities

Theory classes

VII. Learning outcome

Knowledge on different weather extremes and how to modify weather to reduce risk

VIII. Suggested Reading

- Anonymous 2003. *Critical Issues in Weather Modification Research Board of Atmoshperic Science and Climate*. National Research Council, USA.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chritchfield HJ. 1994. *General Climatology*. Prentice Hall.
- Lenka D. 1998. Climate, Weather and Crops in India. Kalyani.
- Mavi HS and Graeme J Tupper. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Menon PA. 1989. *Our Weather*. National Book Trust.
- Pearce RP. 2002. *Meteorology at the Millennium*. Academic Press.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate – The Biological Environment.* John Wiley & Sons.
- Samra JS, Narain P, Rattan RK and Singh SK. 2006. *Drought Management in India*. Bull. Indian Society of Soil Science 24, ISSS, New Delhi.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://www.icrisat.org/

I. Course Title : Aerobiometeorology

II. Course Code : AGM 516

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical knowledge on insect, pest and plant biometeorology

V. Theory

Unit I

Definition and structure of Aerobiometeorology, role of Agrometeorology and Biogeography in forecasting pests and disease outbreak, insect movement in the atmosphere, intensification, Effect of weather and climate parameters on reproduction, growth, development, movements, food, habitat and dispersal of pests and diseases. Influence of weather and climate on Migratory pests (Desert locust, BPH etc.).

Unit II

Benevolent and malevolent weather conditions for salient pests & diseases of the concerned agro-climatic zones. Effects of sudden weather changes and extreme weather conditions on population built-up of the pest, heat stress and heat related mortality, climate change impact on pest and diseases.

Unit III

Biometeorology in integrated pest and disease management program, modification of plant canopy and its impact of plant diseases, management of segments of disease triangle: environment manipulation and host manipulation, weather based forewarning system for pest and diseases.

Unit IV

Soil borne pathogens, their biology, management and challenges, soil borne diseases and their control, abiotic factor in soil borne disease management, Managing of pests & diseases in controlled environment, Environmental management for pest and disease

VI. Practical

- Identification of different pests
- Pest population, observations and their index calculation
- Identification of various diseases
- Disease initiation and their intensity, percent disease index
- Relation between weather parameters and pests and disease

VII. Teaching methods/activities

Classroom teaching and practical, visit to fields

VIII. Learning outcome

Knowledge on interactions between atmospheric processes and living organisms, mainly pest and diseases

IX. Suggested Reading

- Yazdani, SS and Agarwal ML. 2002. *Elements of insect ecology*. Narosa Publishing House.
- Odum EP. *Fundamentals of insect ecology*.
- Dhaliwal GS and Arora R. *Integrated pest management*.
- Jerry L. Hatfield and Ivan J. Thomason. 1982. *Biometeorology in integrated pest management*, Academic press.

Journals

- *Aerobiologica*
- *Journal of Agrometeorology*
- *International Journal* of *Biometeorology*

Website

- http://www.imd.gov.in

Course Title with Credit Load
Ph.D. in Agricultural Meteorology

Course Code	Course Title	Credit Hours
AGM 601*	Climate change and sustainable development	2+1
AGM 602	Meteorology of air pollution	2+2
AGM 603	Livestock and fisheries meteorology	2+2
AGM 604	Hydrometeorology	2+1
AGM 605	Analytical tools and methods for Agro-meteorology	1+1
AGM 606	Research and publication ethics	2+0
AGM 607	Environmental Physics for Agricultural Meteorology	3+0
AGM 608*	Computer Programs and Software for Agrometeorological data Management	1+1
AGM 691	Doctoral seminar	1+0
AGM 692	Doctoral seminar	1+0
AGM 699	Doctoral research	75

*Indicates core courses for PhD

Course Contents
Ph.D. in Agricultural Meteorology

I. Course Title : Climate Change and Sustainable Development
II. Course Code : AGM 601
III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of climate change and the cause, effect, mitigation of climate change.

V. Theory

Unit I

Climate change and global warming: definitions of terms; causes of climate change and global warming; greenhouse gases, ozone depletion; past records, present trends, extreme weather events and future projections; Case studies on various climatic projections and consequences thereof in relation to agriculture.

Unit II

Impacts of climate change on various systems: impacts resulting from projected changes on agriculture and food security; hydrology and water resources; terrestrial and freshwater ecosystems; coastal zones and marine ecosystems; human health; human settlements, energy, and industry; insurance and other financial services; climate change and crop diversification, loss of biodiversity, microbes and pest dynamics; climate change and storage, climate change and weed management. Advance methodology of assessing the impact of climate change on crops.

Unit III

Sensitivity, adaptation and vulnerability: system's sensitivity, adaptive capacity and vulnerability to climate change and extreme weather events; regional scenarios of climate change and variability.

Unit IV

Mitigation strategies for sustainable development: international policies, protocols, treaties for reduction in greenhouse gases and carbon emissions; carbon sequestration; carbon credit; Clean Development Mechanism (CDM) and land use, Crop management options for low emission, land use change and forestry mechanism, alternate energy sources, etc.

Unit V

Agricultural food security: reduction in carbon and GHG emission; fuel conservation and reduction in energy use, conservation tillage, biofuels for fossil fuels, reduction in machinery use etc; increasing carbon sinks; resource conservation technologies, mixed rotations of cover and green manure crops, minimization of summer fallow and no ground cover periods, etc.

VI. Practicals

- Case studies on various climatic projections and consequences thereof in relation to agriculture
- Advance methodology of assessing the impact of climate change on crops

VII. Teaching methods/ activities

Classroom teaching, showing climatic models (GCMs and RCMs) though PPT, Hands on practical

VIII. Learning outcome

Will be aware on causes, impacts, mitigation and adaptations to climate change in the field of agriculture

IX. Suggested Reading

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol*. UNEP, UNDP Publ.
- Anonymous. *IPCC Assessment Reports on Climate Change* (2001, 2007). WMO, UNEP Publ.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jepma CJ and Munasinghe M. 1998. *Climate Change Policy: Facts, Issues and Analysis.* Cambridge Univ. Press.
- Mintzer IM. 1992. *Confronting Climate Change: Risks, Implications and Responses*. Cambridge Univ. Press.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.
- Salinger J, Sivkumar MVK and Motha RP. 2005. *Increasing Climate Variability of Agriculture and Forestry*. Springer.
- Sinha SK. 1998. *Dictionary of Global Climate Change*. Commonwealth Publ.

Journal

- *Mitigation and Adaptation strategies for Global Change*
- *Climate Change*
- *Climate Risk Management*
- *Journal of Agrometeorology*

Website

- https://www.ipcc.ch/
- www.environment.gov.au/climate-change/climate-science-data/climate-science/ipcc

I. Course Title : Meteorology of Air Pollution

II. Course Code : AGM 602

III. Credit Hours : 2+2

IV. Aim of the course

To impart the theoretical and practical knowledge of air pollutants.

V. Theory

Unit I

Introduction to air pollution- history, definition: clean air definition; natural versus polluted atmosphere; atmosphere before the industrial revolution, Real time air quality index and National air quality index.

Unit II

Sources of air pollution; classification and properties of air pollutants; emission sources, importance of anthropogenic sources; behaviour and fate of air pollutants; photochemical smog; pollutants and trace gases. Acid rain and development of Gas Washing

Unit III

Meteorological factors in the dispersion of air pollutants; topographical, geographical and large scale meteorological factors attached air pollution; Planetary Boundary Layer (PBL) and mixing layer; meteorological conditions and typical plume forms; air pollution forecasting – Gaussian diffusion models, Numerical dispersion models.

Unit IV

Air quality standards; effect of air pollution on biological organisms; ozone layer depletion; air pollution control technologies; management of air pollution; principles of diffusion of particulate matter in the atmosphere; air pollution laws and standards. Scales of air pollution: local, urban, regional, continental and global.

Unit V

Air pollution sampling and measurement: types of pollutant sampling and measurement, ambient air sampling, collection of gaseous air pollutants, collection of particulate pollutants, stock sampling; analysis of air pollutants - sulfur dioxide, nitrogen dioxide, carbon monoxide, oxidants and ozone, hydrocarbons, particulate matter.

VI. Practicals

- Measurement of different air pollutants
- Measurement of different air pollution gases
- Measurement of visibility
- Measurement of ozone and aerosol optical thickness (AOT)
- To study the temperature profile at different heights
- To study the stability of the atmosphere
- To determine height of partial flume through chimani
- To study the effect of temperature on vegetables, orchards and agricultural crops

VII. Teaching methods/activities

Classroom teaching and practical

VIII. Learning outcome

Knowledge of sources and dispersal of pollutants, indexing, the influence of meteorological activities and analysis of pollutants

IX. Suggested Reading

- Arya SP. 1998. *Air Pollution Meteorology and Dispersion*. Oxford Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chhatwa GR. 1989. *Environmental Air Pollution and its Control*. Anmol Publ.
- Mishra PC. 1990. *Fundamentals of Air and Water Pollution*. Ashish Publ.
- Mudd J Brian and Kozlowski TT. (Ed.). 1975. *Responses of Plants to Air Pollution*. Academic Press.
- Pickett EE. 1987. Atmopheric Pollution. Hemisphere Publ. Corp.
- Sharma SH and Khan TI. 2004. *Ozone Depletion and Environmental Impacts*. Pointer Publ.
- Weber E. 1982. *Air Pollution Assessment Methodology and Modeling*. Plenum Press.
- Yunus M and Iqbal M. (Eds.). 1996. *Plant Response to Air Pollution*. John Wiley & Sons.

Journals

- *Atmospheric Pollution* Research,
- *Environmental Pollution,*
- *Journal of Agrometeorology*

Website

- https://www.nationalgeographic.com/environment/global-warming/pollution/

I. Course Title : Livestock and Fisheries Meteorology

II. Course Code : AGM 603

III. Credit Hours : 2+2

IV. Aim of the course

To impart the theoretical and practical knowledge of weather, climate for livestock and fisheries management.

V. Theory

Unit I

Thermal balance in animals; energy exchange processes at the skin of the animals and the need for the maintenance of thermal balance in the animals. Animal traits and physiological responses.

Unit II

Effects of weather on animal production, loss of water from the body, growth rate and body weight, reproduction, grazing habit, food intake, milk production, sun burns and photosensitive disorders.

Unit III

Meteorological conditions prevailing in glass-house, green house, animal shed, poultry house and grain storage barns; heating, cooling and ventilation of these structures as governed by meteorological factors. Environmental modification within the shelters of livestock. Applications of biometeorological information for rational planning, design and management. Weather and animal diseases and parasites; diseases of poultry and its relation with weather and thermal comfort.

Unit IV

Livestock production and climate change, Management of livestock to reduce greenhouse gas emission.

Unit V

Weather effect on fish behaviour. Water temperature affecting fish activity. Marine weather and fishing. Climate change and fisheries production.

VI. Practical

- Measurement of meteorological parameters within the shelters of livestock
- Calculation of animal comfort zone index
- Radiation of animal farm house and body
- Estimation of enegy fluxes on body
- Measurements of CO_2 and methane in animal farm house.

VII. Teaching methods/activities

Class room teaching for theory part, visit to farm house for practical

VIII. Learning outcome

Enhanced knowledge on weather influence on livestock and farm environment

IX. Suggested Reading

- GSLHV Prasada Rao, GG Varma and Beena (Eds). 2017. *Livestock meteorology*. New India Publishing Agency- Nipa. 542 pages
- Kaiser HM and Drennen TE. (Eds). 1993. *Agricultural Dimensions of Global Climate Change*. St. Lucie Press, Florida.
- Monteith L and Unsworth M. 2007. *Principles of Environmental Physics*. 2nd Ed. Academic Press. Takahashi J, Young BA, Soliva CR and Kreuzer M. 2002. *Greenhouse Gases and Animal Agriculture*. Proc. 1st International Conference on Greenhouse Gases and Animal Agriculture.
- Tromp SW. 1980. *Biometeorology. The Impact of the Weather and Climate on Humans & their Environment*. (Animals and Plants). Heyden & Son Ltd.

Journals

- *Agricultural and Forest Meteorology,*
- *Journal* of *Animal Behaviour and Biometeorology,*
- *Journal of Agrometeorology*

Website

- www.wmo.org

I. Course Title : Hydrometeorology

II. Course Code : AGM 604

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of different components of hydrologic cycle.

V. Theory

Unit I

Hydrologic cycle and its modification; rainfall and its interception by plants and crops. Interpolation and measurement of missing rainfall data; adequacy of rain gauges; average rainfall on an area depth basis; presentation and processing of precipitation data.

Unit II

Measurement of runoff, infiltration, moisture retention of soil, percolation, evaporation, evapotranspiration and its importance to agriculturists, irrigation engineers and flood forecasting personnel; water holding capacity of soils, plant available water, cultural practices on soil moisture in relation to different phases of crop growth; evaporation from snow, lakes, reservoirs and crop fields.

Unit III

Classifying rainfall data into class interval; ranking of rainfall data; relationship between intensity and duration; methods of predicting runoff rate; factors affecting runoff; rainfall-runoff relation; estimation of evapotranspiration from water balance methods; response of crops to water stresses under different agroclimatic situation on India.

Unit IV

Moisture availability indices and their application for Indian condition; wet and dry spell by Markov-chain model; drought and its classification, hydrological drought, drought indices and their applications under Indian conditions.

VI. Practical

- Analysis of rainfall data
- Determination of effective rainfall
- To estimate missing rainfall data for a given station.
- To find out the optimum number of rain gauges for a given catchment.
- To find out the mean rainfall for a given drainage basin by Thiessen polygon method and isohyetal method.
- To estimate the volume of runoff by SCS method.
- Estimation of evopotranspiration from field based water balance method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge on rainfall analysis, runoff estimation, calculation of evaporation and the relationship among different hydrological parameters

IX. Suggested Reading

- Chow, Ven Te (Ed.). 1964. *Handbook of Applied Hydrology*. McGraw-Hill.
- Hillel D. 1971. *Soil and Water*. Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.

Journal

- *Journal* of *Hydrology, Journal* of *Hydrology and Meteorology,*
- *Agricultural Water Management,*
- *Journal of Agrometeorology*

Website

- https://has.arizona.edu/meteorology-hydrology-and-hydrometeorology
- www.abb.com/cawp/seitp161/4f39ac092c0598c9c1256fb8004f7726.aspx

I. Course Title : Analytical Tools and Methods for Agro-meteorology
II. Course Code : AGM 605
III. Credit Hours : 1+1

IV. Aim of the course

To impart the theoretical and practical knowledge of new tools for analysis of agro-climatic features.

V. Theory

Unit I

Review of agro-climatic methods; characterization of agroclimatic elements; sampling of atmosphere; temporal and spatial considerations; micro-meso-macro climates.

Unit II

Network spacing; spatial and temporal methods; GIS fundamentals and applications; numerical characterization of climatic features; crop response to climate, time lags, time and distance constants, hysteresis effects.

Unit III

Influence of climate on stress-response relations; thermal time approach in agroclimatology- heat and radiation use efficiency in crop plants; applications to insect-pest development and prediction; comfort indices for human and animals; impact of natural and induced variability and change of climate on crop production.

Unit IV

Instrumentation and sampling problems; design of agro-meteorological experiments.

Unit V

Basic knowledge of application of computers in agriculture; theories of computer language BASIC, FORTRAN, C, C++ and Visual basic.

Unit VI

Empirical and statistical crop weather models and their application with examples; incorporating weather, soil, plants and other environment related parameters as subroutine and remote sensing inputs in models; growth and yield prediction models; crop simulation models; forecasting models for insects and diseases.

VI. Practical

- Calculation of continentality factors.
- Climatic indices and climogram.
- Agrometeorological indices: Degree-days, photothermal units, heliothermal units, phenothermal index.
- Heat and radiation use efficiency and other indices of crops.
- Crop growth rates.
- Analysis of thermogram, hygrogram, hyetogram, sunshine cards etc. stream lines and wind roses and statistical analysis of climatic data.
- Working with statistical models: crop yield forecasting, crop weather relationship and insect & disease forecasting models.
- Working with crop simulation models
- Small programme writing in computer languages like BASIC, FORTRAN, C, C++ and Visual basic.
- Geographical Information System.

VII. Teaching methods/activities

Theory and practical classes, learning of computer language

VIII. Learning outcome

Knowledge on collection of agromet data, sampling design for agrometeorology, calculation of different indices and analysis of data

IX. Suggested Reading

- Cooper M. 2006. *The Spirit of C. An Introduction to Modern Programming*. Jaico Publ.
- Malczewski J. 1999. *GIS & Multicriteria Decision Analysis*. John Wiley & Sons.
- WMO. 2010. *Guide to agricultural meteorological practices*. Chapter 3: agricultural meteorological data, their presentation and statistical analysis

Journals

- *The International Journal* of *Database Management* Systems
- Journal of Agrometeorology

Website

- https://www.tropmet.res.in/~icrp/icrpv12/adach.html
- www.wmo.int/pages/prog/wcp/agm/gamp/documents/WMO_No134_en.pdf

I. Course Title : Research and Publication Ethics
II. Course Code : AGM 606
III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/ standard setting initiatives and guidelines: COPE, WAME etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools.

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, Gindex, i 10 index altmetrics

V. Teaching methods/activities

Classroom teaching and field and laboratory activities

VI. Learning outcome

To familiarize the students about field and laboratory activities to be performed during the study period

I. Course Title : Weather and Climate Risk Management
II. Course Code : AGM 607
III. Credit Hours : 3+0

IV. Aim of the course

To impart the theoretical knowledge of Physics applied to atmosphere and meteorology

V. Theory

Unit I

Thermodynamics of the atmosphere. Physics of radiation: origin and nature of radiation, radiation geometry in Cartesian, spherical cylindrical coordinate systems, conservation principles for radiant energy; fluid motion: laminar and turbulent transfer, fluctuation theory for turbulent transfer of momentum, heat and water vapour.

Unit II

Physics of evaporation: aerodynamic approach, energy balance approach and combination approach for evaporation estimates.

Unit III

Physics of soil water system: the concept of potential as applied to soil water system, total potential and components, movements of water on soil, fundamental equation, hydraulic conductivity, infiltration, field drainage and water vapour movement in soil.

Unit IV

Physics of water use: a physical introduction to plant-water system and relationships, water transport through soil-plant-atmosphere systems, measurement of crop water use in terms of water conservation equation.

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

Knowledge and application of physical laws governing the agrometeorological parameters

VIII. Suggested Reading

- Hillel D. 1971. *Soil and Water*. Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.
- Monteith JL .1973. *Principles of Environmental Physics.* Edward Arnold.
- Rose CW. 1966. *Agricultural Physics.* Pergamon Press.
- Sellers WD. 1965. *Physical Climatology*. University of Chicago Press.
- Van Wizk WR. 1963. *Physics of Plant Environment.* North-Holland Publishing.
- Waggoner PE. (Ed.). 1965. *Agricultural Meteorology*. American Meteorological Society.

Journals

- *Journal of Meteorological Research,*
- *Agricultural and Forest Meteorology*

Website

- https://fmph.uniba.sk/.../enviromentalna-fyzika-obnovitelne-zdroje-energie-meteorolo...

I. Course Title : Computer Programs and Software for Agrometeorological Data Management

II. Course Code : AGM 608

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on management of agromet data and train the students in commercialization of agrometeorological data through e-services.

V. Theory

Unit I

Data and information; types of data; climate, soil and crop data; Importance of database management, Softwares related to database management; data requirements; data collection and recording (Automatic and manual).

Unit II

Data structure/format; quality control of data through computer software; techniques of climatic data generation; missing data; introduction to different software for database management.

Unit III

Processing and analysis of data and data products; value addition of data and data products; data users, public, commercial, academic or research. Availability, accessibility and security of data; evaluating the cost of data; e-management of data. Meta analysis: Advantages and problems, Steps, Approaches and methods, Applications.

Unit IV

Computer Programming: History, Quality requirements, Readability of source code, Algorithmic complexity, Debugging, Programming languages

VI. Practical

- Types of instruments and data recording
- AWS data retrieval, storage and transfer
- Exposure to different software for Agromet data analysis; exposure to Statistical software
- Temporal and spatial analysis of data; exposure to GIS
- Value addition to data
- Introduction to internet protocols
- Uploading and downloading data, password and security of data
- E-management of data
- Introduction to computer programming

VII. Teaching methods/activities

Hands on practical and theory

VIII. Learning outcome

Learning computer programming to manage and analyze agromet data

IX. Suggested Reading

- Ghadekar R. 2002. *Practical Meteorology – Data Acquisition Techniques, Instruments and Methods*. 4th Ed. Agromet Publ.
- IMD/ WHO. 1988. *Users Requirements for Agrometeorological Services*. IMD.
- Miles MB and Huberman AM. 1994. *Qualitative Data Analysis*. Sage Publ.
- Panse VG and Sukhatme PV. 1983. *Statistical Methods for Agricultural Workers*, ICAR.
- Potter GB. 1994. *Data Processing: An Introduction*. Business Publ.
- Ramakrishnan R and Gehrke J. 2003. *Database Management System*. McGraw-Hill.
- Sinha PK and Sinha P. 2004. *Computer Fundamentals*. BPB Publications. (6^{th} Edn).

Journals

- *The Journal* of *Database Management*
- *International Journal* of Data Mining
- *Modelling and Management*

Websites

- https://www.cics.umass.edu/research/area/data-management
- https://www.referenceforbusiness.com/management/.../Data-Processing-and-Data-Man.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agronomy

Preamble

Agronomy is a discipline which deals with various processes such as cultivation, interculture, management of field through various measures like weed management, soil fertility development, proper use of water resources and so on. Agronomy has a major component of agro ecology which includes several activities that affect the environment and human population. An Agronomist remains in the centre of effort to work with issues related to environmental and ecological concerns and to increase the production of food, feed, fuels and fibre for growing population in world. Agronomist today are involved with many issues including producing food, creating healthier food, managing environmental impacts and creating energy from plants. Research activities in Agronomy focus on system analysis and simulation modeling of environmental and management impacts on agricultural production, these are key to the sustainability of agricultural production system.

Hence, it is very much essential to revise the course curriculum of Agronomy so that students even teachers may be well acquainted with the present concept of development of the discipline. This will help bringing competency in students along with confidence so as to develop himself/ herself for being tackling field problems and management of land.The existing M.Sc. (Ag) courses of Agronomy have been modified taking into account of present day need by incorporating the necessary and important topics in the respective courses.

Minor changes have been made in most of the existing courses. As a part of course curriculum, M. Sc.(Ag) Agronomy was restructured to equip students to tackle emerging issues by inclusion of one new course on "Conservation agriculture". All the Ph.D courses of Agronomy was slightly revised by adding/ deleting some some portion in the existing courses. The course "Fundamentals of Meteorology" is dropped from Agronomy department and interested students can take the course from department of Agril.Meteorology. The course "Agroecology" offered by the department for Ph D programme is also dropped. Similarly, the Ph.D. course "Crop production and system modeling" is also deleted and the contents are merged with Agron 601, i.e. "Current trends in Agronomy".

It was proposed by some members to include new courses like "Seed production technology", "Experimental technique in Agronomy" and "Management of Problem soils and water". But finally, it was decided that these courses should be offered by the core departments such as Department of Seed Technology, Department of Statistics and Department of Soil Science, respectively. There are few courses in the existing syllabus which are not offered by in many universities. Hence these courses are merged and thereby reduced the number of courses to limit choice so that complete knowledge of the subject can be given to the students. In all the courses, the practical aspects are strengthened.

Topics such as automated irrigation systems, value chain addition/ post harvest processing, variable rate application, precision farming, protected agriculture, soil less farming, farm mechanization of practical operations, practical applications of advanced tools for big data analysis and interpretation, artificial intelligence, drones etc are included in the revised syllabus so that students can show competency at national and international level.

Course Title with Credit Load
M.Sc. in Agronomy

Course Code	Course Title	Credit Hours
Agron 501*	Modern Concepts in Crop Production	3+0
Agron 502*	Principles and practices of soil fertility and nutrient management	2+1
Agron 503*	Principles and Practices of Weed Management	2+1
Agron 504*	Principles and Practices of Water Management	2+1
Agron 505	Conservation Agriculture	1+1
Agron 506	Agronomy of major Cereals and Pulses	2+0
Agron507	Agronomy of oilseed, fibre and sugar crops	2+1
Agron 508	Agronomy of medicinal, aromatic & underutilized crops	2+1
Agron 509	Agronomy of fodder and forage crops	2+1
Agron 510	Agrostology and Agro- Forestry	2+1
Agron 511	Cropping System and Sustainable Agriculture	2+0
Agron 512	Dryland Farming and Watershed Management	2+1
Agron 513	Principles and practices of organic farming	2+1
Agron-550	Master’s Seminar	(1+0)
Agron -560	Master’s research	-30

*Indicates core course which is Compulsory course for M Sc.(Agri)

Course Contents
M.Sc. in Agronomy

I. Course Title : Modern Concepts in Crop Production
II. Course Code : Agron 501
III. Credit Hours : 3+0

IV. Aim of the course

To teach the basic concepts of soil management and crop production.

V. Theory

Unit I

Crop growth analysis in relation to environment; geo-ecological zones of India.

Unit II

Quantitative agro-biological principles and inverse yield nitrogen law; Mitscherlich yield equation, its interpretation and applicability; Baule unit.

Unit III

Effect of lodging in cereals; physiology of grain yield in cereals; optimization of plant population and planting geometry in relation to different resources, concept of ideal plant type and crop modeling for desired crop yield.

Unit IV

Scientific principles of crop production; crop response production functions; concept of soil plant relations; yield and environmental stress, use of growth hormones and regulators for better adaptation in stressed condition.

Unit V

Integrated farming systems, organic farming, and resource conservation technology including modern concept of tillage; dry farming; determining the nutrient needs for yield potentiality of crop plants, concept of balance nutrition and integrated nutrient management; precision agriculture.Modern crop production concepts: soil less cultivation, Aeroponic, Hydroponic, Robotic and terrace farming. use of GIS, GPS and remote sensing in modern agriculture, precision farming and protected agriculture.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VII. Learning outcome

Basic knowledge on soil management and crop production

VIII. Suggested Reading

- Balasubramaniyan P and Palaniappan SP. 2001. *Principles and Practices of Agronomy*. Agrobios.
- Fageria NK. 1992. *Maximizing Crop Yields*. Marcel Dekker.
- Havlin JL, Beaton JD, Tisdale SL and Nelson WL. 2006. *Soil Fertility and Fertilizers*. 7th

Ed. Prentice Hall.
- Paroda R.S. 2003. *Sustaining our Food Security*. Konark Publ.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani Publ.
- Sankaran S and Mudaliar TVS. 1997. *Principles of Agronomy*. The Bangalore Printing & Publ.
- Singh SS. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Alvin PT and kozlowski TT (ed.). 1976. *Ecophysiology of Tropical Crops*. Academia Pul., New York.
- Gardner PP, Pearce GR and Mitchell RL. 1985. *Physiology of Crop Plants*. Scientific Pub. Jodhpur.
- Lal R. 1989. *Conservation tillage for sustainable agriculture: Tropics versus Temperate Environments. Advances in Agronomy* 42: 85-197.
- Wilsie CP. 1961. *Crop Adaptation and Distribution*. Euresia Pub., New Delhi.

I. Course Title : Principal and Practices of Soil Fertility and Nutrient Management

II. Course Code : Agron 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge of fertilizers and manures as sources of plant nutrients and apprise about the integrated approach of plant nutrition and sustainability of soil fertility.

V. Theory

Unit I

Soil fertility and productivity - factors affecting; features of good soil management; problems of supply and availability of nutrients; relation between nutrient supply and crop growth; organic farming - basic concepts and definitions.

Unit II

Criteria of essentiality of nutrients; Essential plant nutrients – their functions, nutrient deficiency symptoms; transformation and dynamics of major plant nutrients.

Unit III

Preparation and use of farmyard manure, compost, green manures, vermicompost, biofertilizers and other organic concentrates their composition, availability and crop responses; recycling of organic wastes and residue management. Soil less cultivation.

Unit IV

Commercial fertilizers; composition, relative fertilizer value and cost; crop response to different nutrients, residual effects and fertilizer use efficiency; agronomic, chemical and physiological, fertilizer mixtures and grades; methods of increasing fertilizer use efficiency; nutrient interactions.

Unit V

Time and methods of manures and fertilizers application; foliar application and its concept; relative performance of organic and inorganic nutrients; economics of fertilizer use; integrated nutrient management; use of vermincompost and residue wastes in crops.

VI. Practical

- Determination of soil pH and soil EC
- Determination of soil organic C
- Determination of available N, P, K and S of soil
- Determination of total N, P, K and S of soil
- Determination of total N, P, K, S in plant
- Computation of optimum and economic yield

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on soil fertility and management

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils.* 13th Ed. Pearson Edu.
- Fageria NK, Baligar VC and Jones CA. 1991. *Growth and Mineral Nutrition of Field Crops.* Marcel Dekker.
- Havlin JL, Beaton JD, Tisdale SL and Nelson WL. 2006. *Soil Fertility and Fertilizers.* 7th Ed. Prentice Hall.
- Prasad R and Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture.* CRC Press.
- Yawalkar KS, Agrawal JP and Bokde S. 2000. *Manures and Fertilizers.* Agri-Horti Publ.

I. Course Title : Principles and Practices of Weed Management

II. Course Code : Agron 503

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize the students about the weeds, herbicides and methods of weed control.

V. Theory

Weed biology, and ecology and classification, crop-weed competition including allelopathy; principles and methods of weed control and classification management; weed indices, weed shift in different eco-systems

Unit II

Herbicides introduction and history of their development; classification based on chemical, physiological application and selectivity; mode and mechanism of action of herbicides.

Unit III

Herbicide structure - activity relationship; factors affecting the efficiency of herbicides; herbicide formulations, herbicide mixtures, sequential application of herbicides, rotation; weed control through use ofnano-herbicides and bio-herbicides, myco-herbicides bio-agents, and allelochemicals; movement of herbicides in soil and plant, Degradation of herbicides in soil and plants; herbicide resistance, residue, persistence and management; development of herbicide resistance in weeds and crops and their management, herbicide combinationand rotation.

Unit IV

Weed management in major crops and cropping systems; alien, invasive and parasitic weeds and their management; weed shifts in cropping systems; aquatic and perennial weed control; weed control in non-crop area.

Unit V

Integrated weed management; recent development in weed management- robotics, use of drones and aeroplanes, organic etc., cost: benefit analysis of weed management.

VI. Practical

- Identification of important weeds of different crops, Preparation of a weed herbarium, Weed survey in crops and cropping systems, Crop-weed competition studies, Weed indices calculation and interpretation with data, Preparation of spray solutions of herbicides for high and low-volume sprayers, Use of various types of spray pumps and nozzles and calculation of swath width, Economics of weed control, Herbicide resistance analysis in plant and soil,
- Bioassay of herbicide resistance residues,
- Calculation of herbicidal herbicide requirement

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit to identify weeds.

VIII. Learning outcome

Basic knowledge on weed identification and control for crop production

IX. Suggested Reading

- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action*, *Targets*, *Genetic Engineering*, *Chemistry*. Springer.
- Chauhan B and Mahajan G. 2014. *Recent Advances in Weed Management*. Springer.
- Das TK. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi).
- Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Gupta OP. 2007. *Weed Management*: *Principles and Practices*, 2nd Ed.
- Jugulan, Mithila (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco TJ, Weller SC and Ashton FM. 2014. *Weed Science Principles and Practices*, Wiley
- Powles SB and Shaner DL. 2001. Herbicide Resistance and World Grains, CRC Press.
- Walia US. 2006. *Weed Management*, Kalyani.
- Zimdahl RL. (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub.*

I. Course Title : Principles and Practices of Water Management

II. Course Code : Agron 504

III. Credit Hours : 2+1

IV. Aim of the course

To teach the principles of water management and practices to enhance the water productivity

V. Theory

Unit I

Water and its role in plants; Irrigation: Definition and objectives, water resources and irrigation development in of India and concerned state, major irrigation projects, extent of area and crops irrigated in India and in different states.

Unit II

Field water cycle, water movement in soil and plants; transpiration; soil-water-plant relationships; water absorption by plants; plant response to water stress, crop plant adaptation to moisture stress condition. Water availability and its relationship with nutrient availability and loses.

Unit III

Soil, plant and meteorological factors determining water needs of crops, scheduling, depth and methods of irrigation; micro irrigation systems; deficit irrigation; fertigation; management of water in controlled environments and polyhouses. Irrigation efficiency and water use efficiency.

Unit IV

Water management of crop and cropping system, Quality of irrigation water and management of saline water for irrigation, water use efficiency, Crop water requirement- estimation of ET and effective rainfall; Water management of the major crops and cropping systems. Automated irrigation system.

Unit V

Excess of soil water and plant growth; water management in problem soils, drainage requirement of crops and methods of field drainage, their layout and spacing; rain water management and its utilization for crop production.

Unit VI

Quality of irrigation water and management of saline water for irrigation, water management in problem soils

Unit VII

Soil moisture conservation, water harvesting, rain water management and its utilization for crop production.

Unit VIII

Hydroponics,

Unit IX

Water management of crops under climate change scenario.

VI. Practical

- Determination of Field capacity by field method
- Determination of Permanent Wilting Point by sunflower pot culture technique
- Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus
- Determination of Hygroscopic Coefficient
- Determination of maximum water holding capacity of soil
- Measurement of matric potential using gauge and mercury type tensiometer
- Determination of soil-moisture characteristics curves
- Determination of saturated hydraulic conductivity by constant and falling head method
- Determination of hydraulic conductivity of saturated soil below the water table by auger hole method
- Measurement of soil water diffusivity
- Estimation of unsaturated hydraulic conductivity

- Estimation of upward flux of water using tensiometer and from depth ground water table
- Determination of irrigation requirement of crops (calculations)
- Determination of effective rainfall (calculations)
- Determination of ET of crops by soil moisture depletion method16. Determination of water requirements of crops
- Measurement of irrigation water by volume and velocity-area method
- Measurement of irrigation water by measuring devices and calculation of irrigation efficiency
- Determination of infiltration rate by double ring infiltrometer

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Basic knowledge on water management for optimization of crop yield

IX. Suggested Reading

- Majumdar DK. 2014. *Irrigation Water Management: Principles and Practice*. PHL Learning private publishers
- Mukund Joshi. 2013. *A Text Book of Irrigation and Water Management Hardcover*, Kalyani publishers
- Lenka D. 1999. *Irrigation and Drainage*. Kalyani.
- Michael AM. 1978. *Irrigation: Theory and Practice*. Vikas Publ.
- Paliwal KV. 1972. *Irrigation with Saline Water*. IARI Monograph, New Delhi.
- Panda SC. 2003. *Principles and Practices of Water Management*. Agrobios.
- Prihar SS and Sandhu BS. 1987. *Irrigation of Food Crops - Principles and Practices*. ICAR.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Singh Pratap and Maliwal PL. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Publ.

I. Course Title : Conservation Agriculture

II. Course Code : Agron 505

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge of conservation of agriculture for economic development.

V. Theory

Unit I

Conventional and conservation agriculture systems, sustainability concerns, conservation agriculture: Historical background and present concept, global experiences, present status in India.

Unit II

Nutrient management in CA, water management, weed management, energy use, insect-pest and disease management, farm machinery, crop residue management, cover crop management.

Unit III

Climate change mitigation and CA, C-sequestration, soil health management, soil microbes and CA.

Unit IV

CA in agroforestry systems, rainfed / dryland regions

Unit V

Economic considerations in CA, adoption and constraints, CA: The future of agriculture

VI. Practicals

- Study of long-term experiments on CA,
- Evaluation of soil health parameters,
- Estimation of C-sequestration,
- Machinery calibration for sowing different crops, weed seedbank estimation under CA, energy requirements, economic analysis of CA.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of various types of conservation of agriculture.

IX. Suggested Reading

- Arakeri HR and Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.
- Bisht JK, Meena VS, Mishra PK and Pattanayak A. 2016. Conservation Agriculture-An approach to combat climate change in Indian Himalaya. Publisher: Springer Nature. Doi: 10/1007/978-981-10-2558-7.
- Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.
- FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57.
- Gracia-Torres L, Benites J, Martinez-Vilela A and Holgado-Cabera A. 2003. Conservation Agriculture- Environment Farmers experiences, innovations Socio-economic policy.
- Muhammad F and Kamdambot HMS. 2014. Conservation Agriculture. Publisher: Springer Cham Heidelberg, New Yaork Dordrecht London. Doi: 10.1007/978-3-319-11620-4.
- Yellamanda Reddy T and Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani.

I. Course Title : Agronomy of Major Cereals and Pulses

II. Course Code : Agron 506

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of crop husbandry of cereals and pulse crops.

V. Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality components, handling and processing of the produce for maximum production of:

Unit I: *Rabi* cereals.

Unit II: *Kharif* cereals.

Unit III: *Rabi* pulses.

Unit IV: *Kharif* pulses.

VI. Practical

- Phenological studies at different growth stages of crop
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER etc)
- Estimation of protein content in pulses
- Planning and layout of field experiments
- Judging of physiological maturity in different crops
- Intercultural operations in different crops
- Determination of cost of cultivation of different crops
- Working out harvest index of various crops
- Study of seed production techniques in selected crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects
- Visit to nearby villages for identification of constraints in crop production

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on cereals and pulse growing in the country .

IX. Resources

- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Hunsigi G and Krishna KR. 1998. *Science of Field Crop Production*. Oxford & IBH.
- Jeswani LM and Baldev B. 1997. *Advances in Pulse Production Technology*.ICAR.
- Khare D and Bhale MS. 2000. *Seed Technology*. Scientific Publ.
- Kumar Ranjeet and Singh NP. 2003. *Maize Production in India: Golden Grain in Transition*. IARI, New Delhi.
- Pal M, Deka J and Rai RK. 1996. *Fundamentals of Cereal Crop Production*.Tata McGraw Hill.
- Prasad Rajendra. 2002. *Text Book of Field Crop Production*. ICAR.
- Singh C, Singh P and Singh R. 2003. *Modern Techniques of Raising FieldCrops*. Oxford & IBH.
- Singh SS. 1998. *Crop Management*. Kalyani.
- Yadav DS. 1992. *Pulse Crops*. Kalyani.

I. Course Title : Agronomy of Oilseed, Fibre and Sugar Crops

II. Course Code : Agron 507

III. Credit Hours : 2+1

IV. Aim of the course

To teach the crop husbandry of oilseed, fiber and sugar crops

V. Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality component, handling and processing of the produce for maximum production of:

Unit I

Rabi oilseeds – Rapeseed and mustard, Linseed and Niger

Unit II

Kharif oilseeds - Groundnut, Sesame, Castor, Sunflower, Soybean and Safflower

Unit III

Fiber crops - Cotton, Jute, Ramie and Mesta.

Unit IV

Sugar crops – Sugar-beet and Sugarcane.

VI. Practical

- Planning and layout of field experiments
- Cutting of sugarcane setts, its treatment and methods of sowing, tying and propping of sugarcane
- Determination of cane maturity and calculation on purity percentage, recovery percentage and sucrose content in cane juice phenological studies at different growth stages of crop
- Intercultural operations in different crops
- Cotton seed treatment
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER etc)
- Judging of physiological maturity in different crops and working out harvest index
- Working out cost of cultivation of different crops
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
- Determination of oil content in oilseeds and computation of oil yield
- Estimation of quality of fibre of different fibre crops
- Study of seed production techniques in various crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects
- Visit to nearby villages for identification of constraints in crop production

VIII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

IX. Learning outcome

Basic knowledge on production of oil seed, sugar and fibre crops.

X. Suggested Reading

- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Das PC. 1997. *Oilseed Crops of India*. Kalyani.
- Lakshmikantam N. 1983. *Technology in Sugarcane Growing*. 2nd Ed. Oxford & IBH.
- Prasad Rajendra. 2002. *Text Book of Field Crop Production*. ICAR.

- Singh C, Singh P & Singh R. 2003. *Modern Techniques of Raising FieldCrops*. Oxford & IBH.
- Singh SS. 1998. *Crop Management*. Kalyani.

I. Course Title : Agronomy of Medicinal, Aromatic and Under Utilized Crops

II. Course Code : Agron 508/PSMA 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about different medicinal, aromatic and underutilized field crops, their package of practices and processing.

V. Theory

Unit I

Importance of medicinal and aromatic plants in human health, national economy and related industries, classification of medicinal and aromatic plants according to botanical characteristics and their uses, export potential and indigenous technical knowledge.

Unit II

Climate and soil requirements; cultural practices; yield and important constituents of medicinal plants (Mulhati, Isabgol, Rauwolfia, Poppy, *Aloe vera*, Satavar, *Stevia*, Safed Musli, Kalmegh, Asaphoetida, *Nuxvomica*, Rosadle, etc).

Unit III

Climate and soil requirements; cultural practices; yield and important constituents of aromatic plants (Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, Patchouli, Geranium).

Unit IV

Climate and soil requirements; cultural practices; yield of under-utilized crops (Rice bean, Lathyrus, Sesbania, Clusterbean, French bean, Fenugreek, Grain Amaranth, Coffee, Tea and Tobacco).

Unit V

Post harvest handling –drawing, processing, grading, packing and storage, value addition and quality standards in herbal products.

VI. Practical

- Identification of crops based on morphological and seed characteristics
- Raising of herbarium of medicinal, aromatic and under-utilized plants
- Quality characters in medicinal and aromatic plants
- Methods of analysis of essential oil and other chemicals of importance in medicinal and aromatic plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Acquainted with various MAP and their commercial base for developing entrepreneurship.

IX. Suggested Reading

- Chadha KL and Gupta R. 1995. *Advances in Horticulture*. Vol. II. *Medicinal and Aromatic Plants*. Malhotra Publ.
- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Handa SS. 1984. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu.
- Hussain A. 1984. *Essential Oil Plants and their Cultivation*. CIMAP, Lucknow.
- Hussain A. 1993. *Medicinal Plants and their Cultivation*. CIMAP, Lucknow.
- ICAR 2006. *Hand Book of Agriculture*. ICAR, New Delhi.
- Kumar N, Khader Md. Abdul, Rangaswami JBM & Irulappan 1997. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants*. Oxford & IBH.
- Prajapati ND, Purohit SS, Sharma AK and Kumar T. 2003. *A Hand Book of Medicinal Plants: A Complete Source Book*. Agrobios.
- Sharma R. 2004. *Agro-Techniques of Medicinal Plants*. Daya Publ. House.

I. Course Title : Agronomy of Fodder and Forage Crops

II. Course Code : Agron 509

III. Credit Hours : 2+1

IV. Aim of the course

To teach the crop husbandry of different forage and fodder crops along with their processing.

V. Theory

Unit I

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important fodder crops like sorghum, maize, *bajra*, *guar*, cowpea, oats, barley, berseem, *senji*, lucerne, etc.

Unit II

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important forage crops/grasseslime, Napier grass, *Panicum, Lasiuras, Cenchrus,* etc.

Unit III

Year-round fodder production and management, preservation and utilization of forage and pasture crops.

Unit IV

Principles and methods of hay and silage making; chemical and biochemical changes, nutrient losses and factors affecting quality of hay and silage; use of physical and chemical enrichments and biological methods for improving nutrition; value addition of poorquality fodder. Fodder production through hydroponics. Azolla cultivation.

Unit V

Economics of forage cultivation uses and seed production techniques of important fodder crops.

VI. Practical

- Practical training of farm operations in raising fodder crops;
- Canopy measurement, yield, Leaf: Stem ratio and quality estimation, viz. crude protein, NDF, ADF, lignin, silica, cellulose and IVDMD, etc. of various fodder and forage crops

- Anti-quality components like HCN in sorghum and such factors in other crops
- Hay and silage making and economics of their preparation.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Acquainted with various fodder and forage crops and their commercial base for developing entrepreneurship.

IX. Suggested Reading

- Chatterjee BN. 1989. *Forage Crop Production - Principles and Practices*. Oxford & IBH.
- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Narayanan TR and Dabadghao PM. 1972. *Forage Crops of India*. ICAR.
- Singh P and Srivastava AK. 1990. *Forage Production Technology*. IGFRI, Jhansi.
- Singh C, Singh P and Singh R. 2003. *Modern Techniques of Raising Field Crops*. Oxford & IBH.
- Tejwani KG. 1994. *Agroforestry in India*. Oxford & IBH.

I. Course Title : Agrostology and Agro-forestry (To be taught jointly by Agronomy and Forestry)

II. Course Code : Agron 510

III. Credit Hours : 2+1

IV. Theory

V. Aim of the course

To teach crop husbandry of different forage, fodder and agroforestry crops/trees along with their processing.

Unit I

Agrostology: definition and importance; principles of grassland ecology: grassland ecology – community, climax, dominant species, succession, biotype, ecological status of grasslands in India, grass cover of India; problems and management of grasslands.

Unit II

Importance, classification (various criteria), scope, status and research needs of pastures; pasture establishment, their improvement and renovation-natural pastures, cultivated pastures; common pasture grasses.

Unit III

Agroforestry: definition and importance; agroforestory systems, agrisilviculture, silvipasture, agrisilvipasture, agrihorticulture, aquasilviculture, alley cropping and energy plantation.

Unit IV

Crop production technology in agro-forestory and agrostology system; silvipastoral system: meaning and importance for wasteland development; selection of species, planting methods and problems of seed germination in agro-forestry systems; irrigation and manuring in agro-forestry systems, associative influence in relation to above ground and underground interferences; lopping and coppicing in agro-forestry systems; social acceptability and economic viability, nutritive value of trees; tender operation; desirable tree characteristics.

VI. Practical

- Preparation of charts and maps of India showing different types of pastures and agro-forestry systems
- Identification of seeds and plants of common grasses, legumes and trees of economic importance with reference to agro-forestry
- Seed treatment for better germination of farm vegetation
- Methods of propagation/ planting of grasses and trees in silvipastoral system
- Fertilizer application in strip and silvipastroal systems
- After-care of plantation
- Estimation of protein content in loppings of important fodder trees
- Estimation of calorie value of wood of important fuel trees
- Estimation of total biomass and fuel wood
- Economics of agro-forestry
- Visit to important agro-forestry research stations

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Basic knowledge on agro forestry, forage crops and their utility

IX. Suggested Reading

- Chatterjee BN and Das PK. 1989. *Forage Crop Production. Principles and Practices*. Oxford & IBH.
- Dabadghao PM and Shankaranarayan KA. 1973. *The Grass Cover in India*. ICAR.
- Dwivedi AP. 1992. *Agroforestry- Principles and Practices*. Oxford & IBH.
- Indian Society of Agronomy. 1989. *Agroforestry System in India. Research and Development,* New Delhi.
- Narayan TR and Dabadghao PM. 1972. *Forage Crop of India*. ICAR, New Delhi.

I. Course Title : Cropping Systems and Sustainable Agriculture
II. Course Code : Agron 511
III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students about prevailing cropping systems in the country and practices to improve their productivity.

V. Theory

Unit I

Cropping systems: definition, indices and its importance; physical resources, soil and water management in cropping systems; assessment of land use.

Unit II

Concept of sustainability in cropping systems and farming systems, scope and objectives; production potential under monoculture cropping, multiple cropping, alley cropping, sequential cropping and intercropping, mechanism of yield advantage in intercropping systems.

Unit III

Above and below ground interactions and allelopathic effects; competition relations; multi-storied cropping and yield stability in intercropping, role of non-monetary inputs and low cost technologies; research need on sustainable agriculture.

Unit IV

Crop diversification for sustainability; role of organic matter in maintenance of soil fertility; crop residue management; fertilizer use efficiency and concept of fertilizer use in intensive cropping system. Advanced nutritional tools for big data analysis and interpretation.

Unit V

Plant ideotypes for drylands; plant growth regulators and their role in sustainability.

Unit VI

Artificial Intelligence- Concept and application.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment.

VIII. Learning outcome

Basic knowledge on cropping system for sustainable agriculture.

IX. Suggested Reading

- Panda SC. 2017. *Cropping Systems and Sustainable Agriculture*. Agrobios (India)
- Panda SC. 2018. *Cropping and Farming Systems*. Agrobios.
- Palaniappan SP and Sivaraman K. 1996. *Cropping Systems in the Tropics; Principles and Management*. New Age.
- Panda SC. 2003. *Cropping and Farming Systems*. Agrobios.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Sankaran S and Mudaliar TVS. 1997. *Principles of Agronomy*. The Bangalore Printing & Publ. Co.
- Singh SS. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1997. *Soil Fertility and Fertilizers*. Prentice Hall.

I. Course Title : Dryland Farming and Watershed Management

II. Course Code. : Agron 512

III. Credit Hours : 2+1

IV. Aim of the course

To teach the basic concepts and practices of dry land farming and soil moisture conservation.

V. Theory

Unit I

Definition, concept and characteristics of dry land farming; dry land versus rainfed farming; significance and dimensions of dry land farming in Indian agriculture.

Unit II

Soil and climatic parameters with special emphasis on rainfall characteristics; constraints limiting crop production in dry land areas; types of drought, characterization of environment for water availability; crop
planning for erratic and aberrant weather conditions.

Unit III

Stress physiology and resistance to drought, adaptation of crop plants to drought,

drought management strategies; preparation of appropriate crop plans for dry land areas; mid contingent plan for aberrant weather conditions.

Unit IV

Tillage, tilth, frequency and depth of cultivation, compaction in soil tillage; concept of conservation tillage; tillage in relation to weed control and moisture conservation; techniques and practices of soil moisture conservation (use of mulches, kinds, effectiveness and economics); antitranspirants; soil and crop management techniques, seeding and efficient fertilizer use.

Unit V

Concept of watershed resource management, problems, approach and components.

VI. Practical

- Method of Seed Priming
- Determination of moisture content of germination of important dryland crops
- Determination of Relative Water Content and Saturation Deficit of Leaf
- Moisture stress effects and recovery behaviour of important crops
- Estimation of Potential ET by Thornthwaite method
- Estimation of Reference ET ny Penman Monteith Method
- Classification of climate by Thornthwaite method (based on moisture index, humidity index and aridity index)
- Classification of climate by Koppen Method
- Estimation of water balance by Thornthwaite method
- Estimation of water balance by FAO method
- Assessment of drought
- Estimation of length of growing period
- Estimation of probability of rain and crop planning for different drought condition
- Spray of anti-transpirants and their effect on crops
- Water use efficiency
- Visit to dryland research stations and watershed projects

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment.

VIII. Learning outcome

Basic knowledge on dry land farming and soil moisture conservation.

IX. Suggested Reading

- Reddy TY. 2018. *Dryland Agriculture Principles and Practices*, Kalyani publishers
- Das NR. 2007. *Tillage and Crop Production*. Scientific Publ.
- Dhopte AM. 2002. *Agrotechnology for Dryland Farming*. Scientific Publ.
- Dhruv Narayan VV. 2002. *Soil and Water Conservation Research in India*. ICAR.
- Gupta US. (Ed.). 1995. *Production and Improvements of Crops forDrylands*. Oxford & IBH.
- Katyal JC and Farrington J. 1995. *Research for Rainfed Farming*. CRIDA.
- Rao SC and Ryan J. 2007. *Challenges and Strategies of Dryland Agriculture*. Scientific Publ.
- Singh P and Maliwal PL. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Publ. Company.
- Singh RP. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh RP. 2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Publ.
- Singh SD. 1998. *Arid Land Irrigation and Ecological Management*. Scientific Publ.
- Venkateshwarlu J. 2004. *Rainfed Agriculture in India. Research and Development Scenario*. ICAR.

I. Course Title : Principles and Practices of Organic Farming
II. Course Code : Agron 513
III. Credit Hours : 2+1

IV. Aim of the course

To study the principles and practices of organic farming for sustainable crop production.

V. Theory

Unit I

Organic farming - concept and definition, its relevance to India and global agriculture and future prospects; principles of organic agriculture; organics and farming standards; organic farming and sustainable agriculture; selection and conversion of land, soil and water management - land use, conservation tillage; shelter zones, hedges, pasture management, agro-forestry.

Unit II

Organic farming and water use efficiency; soil fertility, nutrient recycling, organic residues, organic manures, composting, soil biota and decomposition of organic residues, earthworms and vermicompost, green manures, bio-fertilizers and biogas technology.

Unit III

Farming systems, selection of crops andcrop rotations, multiple and relay cropping systems, intercropping in relation to maintenance of soil productivity.

Unit IV

Control of weeds, diseases and insect pest management, biological agents and pheromones, bio-pesticides.

Unit V

Socio-economic impacts; marketing and export potential: inspection, certification, labeling and accreditation procedures; organic farming and national economy.

VI. Practical

- Method of making compost by aerobic method
- Method of making compost by anaerobic method
- Method of making vermicompost
- Identification and nursery raising of important agro-forestry tress and tress for shelter belts
- Efficient use of biofertilizers, technique of treating legume seeds with *Rhizobium* cultures, use of *Azotobacter*, *Azospirillum*, and PSB cultures in field
- Visit to a biogas plant
- Visit to an organic farm
- Quality standards, inspection, certification and labeling and accreditation procedures for farm produce from organic farms

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment. exposure visit

VIII. Learning outcome

Basic knowledge on organic farming for sustainable agriculture and development of entrepreneurship on organic inputs.

IX. Suggested Reading

- Ananthakrishnan TN. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford & IBH.
- Gaur AC. 1982. *A Manual of Rural Composting*, FAO/UNDP Regional Project Document, FAO.
- Joshi M. 2016. *New Vistas of Organic Farming*. Scientific Publishers
- Lampin N. 1990. *Organic Farming*. Press Books, lpswitch, UK.
- Palaniappan SP and Anandurai K. 1999. *Organic Farming – Theory and Practice*. Scientific Publ.
- Rao BV Venkata. 1995. *Small Farmer Focused Integrated Rural Development: Socio-economic Environment and Legal Perspective*: Publ.3, ParisaraprajnaParishtana, Bangalore.
- Reddy MV. (Ed.). 1995. *Soil Organisms and Litter Decomposition in the Tropics*. Oxford & IBH.
- Sharma A. 2002. *Hand Book of Organic Farming*. Agrobios.
- Singh SP. (Ed.). 1994. *Technology for Production of Natural Enemies*. PDBC, Bangalore.
- Subba Rao NS. 2002. *Soil Microbiology*. Oxford & IBH.
- Trivedi RN. 1993. *A Text Book of Environmental Sciences*, Anmol Publ.
- Veeresh GK, Shivashankar K and Suiglachar MA. 1997. *Organic Farming and Sustainable Agriculture*. Association for Promotion of Organic Farming, Bangalore.
- WHO. 1990. *Public Health Impact of Pesticides Used in Agriculture*. WHO.
- Woolmer PL and Swift MJ. 1994. *The Biological Management of Tropical Soil Fertility*. TSBF & Wiley.

Course Title with Credit Load
Ph.D. in Agronomy

Course Code	Course Title	Credit Hours
Agron 601*	Current trends in Agronomy	3+0
Agron 602	Recent trends in crop growth and productivity	2+1
Agron 603	Irrigation management	2+1
Agron 604	Recent trends in weed management	2+0
Agron 605	Integrated farming systems for sustainable Agriculture	2+0
Agron 606	Soil Conservation and Watershed Management	2+1
Agron 607	Stress Crop Production	2+1
Agron 608*	Research and Publication ethics	2+0
Agron-691	Doctoral Seminar	1+0
Agron 692	Doctoral Seminar	1+0
Agron 699	Doctoral Research	75

*Indicates Core course for Ph.D.

Course Contents
Ph.D. in Agronomy

I. Course Title : Current Trends in Agronomy
II. Course Code : Agron 601
III. Credit Hours : 3+0

IV. Aim of the course

To acquaint the students about recent advances in agricultural production.

V. Theory

Unit I

Agro-physiological basis of variation in yield, recent advances in soilplant-water relationship.

Unit II

Globalization of agriculture and WTO, precision agriculture, contract farming, organic farming, marketing and export potential of organic products, certification, labeling and accreditation procedures and ITK in organic farming.

Unit III

Crop residue management in multiple cropping systems; latest developments in plant managementMechanizationin crop production: modern agricultural precision tools and technilogies, weed management, cropping systems, grassland management, agro-forestry, allelopathy.

Unit IV

GIS, GPS and remote sensing for crop management, global warming, GM crops, seed production technology; seed certification, seed multiplication, hybrid seed production etc.

Unit V

Concepts of system agriculture; holistic approach of farming systems, dryland farming, sustainable agriculture and research methodology in Agronomy. Conservation agriculture, principles, prospects and importance, potential benefits of CA under climate change scenario, policy issues.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Recent advances in agricultural production

VIII. Suggested Reading

- Agarwal RL. 1995. *Seed Technology*. Oxford & IBH.
- Dahiya BS and Rai KN. 1997. *Seed Technology*. Kalyani.
- Govardhan V. 2000. *Remote Sensing and Water Management in Command Areas: Agroecological Prospectives*. IBDC.

- ICAR. 2006. *Hand Book of Agriculture*. ICAR.
- Narasaiah ML. 2004. *World Trade Organization and Agriculture*. Sonali Publ.
- Palaniappan SP and Annadurai K. 2006. *Organic Farming - Theory and Practice*. Scientific Publ.
- Sen S and Ghosh N. 1999. *Seed Science and Technology*. Kalyani.
- Tarafdar JC, Tripathi KP and Kumar M. 2007. *Organic Agriculture* Scientific Publ.
- Kumar, R, Swarnkar KS, Singh KS and Narayan S. 2016. *A Text Book of Seed Technology*. Kalyani Publication.
- Reddy SR and Prabhakara G. 2015. *Dryland Agriculture*. Kalyani Publishers.
- Gururajan B, Balasubhramanian R and Swaminath V. 2013. *Recent Strategies on Crop Production*. Kalyani Publishers.
- Venkateswarlu B and Shanker Arun K. 2009. *Climate change and agriculture: Adaptation and mitigation strategies*. *Indian Journal of Agronomy* **54**(2): 226-230.

I. Course Title : Recent Trends in Crop Growth and Productivity

II. Course Code : Agron 602

III. Credit Hours : 2+1

IV. Aim of the course

To study the physiology of vegetative and reproductive growth in relation to productivity of different crops in various environments.

V. Theory

Unit I

Plant density and crop productivity; plant and environmental factors, yield, plant distribution, strategies for maximizing solar energy utilization; leaf area; interception of solar radiation and crop growth; photosynthesis: the photosynthetic apparatus, factors essential for photosynthesis; difference in photosynthetic rates among and within species; physiological limitations to crop yield; solar radiation concept and agro-techniques for harvesting solar radiation.

Unit II

Growth analysis: concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and Limitations in interpreting crop growth and development; growth curves: sigmoid, polynomial and asymptotic; root systems; root-shoot relationship; principles involved in inter and mixed cropping systems under rainfed and irrigated conditions; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages.

Unit III

Competitive relationship and competition functions; biological and agronomic basis of yield advantage under intercropping; physiological principles of dry land crop production, constraints and remedial measures; heat unit concept of crop maturity: concept and types of heat units.

Unit IV

Concept of plant ideotypes: crop physiological and new ideotypes; characteristics of ideotype for wheat, rice, maize, etc.; concept and types of growth hormones; their role in field crop production; efficient use of resources.

VI. Practical

- Field measurement of root-shoot relationship in crops at different growth stages
- Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at

different stages of crop growth
- Computation of harvest index of various crops
- Assessment of crop yield on the basis of yield attributing characters
- Construction of crop growth curves based on growth analysis data
- Computation of competition functions, viz. LER, IER aggressivity competition index etc in intercropping
- Senescence and abscission indices
- Analysis of productivity trend in un-irrigated areas
- Analysis of productivity trend in irrigated areas

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of crop growth for agricultural production

IX. Suggested Reading

- Chopra VL and Paroda RS. 1984. *Approaches for Incorporation of Drought and Salinity Resistance in Crop Plants*. Oxford & IBH.
- Delvin RM and Vitham FH. 1986. *Plant Physiology*. CBS Publ.
- Evans LT. 1975. *Crop Physiology*. Cambridge Univ. Press.
- Evans LT. 1996. *Crop Evolution, Adaptation and Yield*. Cambridge Univ. Press.
- Gupta US. (Ed.). 1995. *Production and Improvement of Crops for Drylands*. Oxford & IBH.
- Gupta US. 1988. *Progress in Crop Physiology*. Oxford & IBH.
- Kramer PJ and Boyer JS. 1995. *Water Relations of Plant and Soils*. Academic Press.
- Mukherjee S and Ghosh AK. 1996. *Plant Physiology*. Tata McGraw Hill.
- Narwal SS, Politycka B and Goswami CL. 2007. *Plant Physiology: Research Methods*. Scientific Pub.
- Tiaz L. and Zeiger E. 2006. Plant Physiology. Sinauer Associates, Inc.

I. Course Title : Irrigation Management

II. Course Code : Agron 603

III. Credit Hours : 2+1

IV. Aim of the course

To teach students about optimization of irrigation in different crops under variable agro climatic conditions.

V. Theory

Unit I

Global water resources; Water resources of India, irrigation projects during pre and post independence period and their significance in crop production; irrigation needs, atmospheric, soil, agronomic, plant and water factors affecting irrigation need; water deficits and crop growth.

Unit II

Movement of water in soil-water movement under saturated and unsaturated conditions, Poiseulle's and Darcy's law, general equation of saturated and unsaturated flow of water in soil.
Soil-plant-water relationships, evaporation, transpiration and evapotranspiration, significance of transpiration, energy utilization in transpiration, physiological processes and crop productivity.

Unit III

Water requirement, irrigation needs, factors affecting irrigation need; water use efficiency, Infiltration; water movement under saturated and unsaturated conditions; management practices for improving water use efficiency of crops.

Unit IV

Soil and plant water potential, SPAC, transpiration and evapotranspiration, significance of transpiration, energy utilization in transpiration, factors affecting ET, control of ET by mulching and use of anti-transpirents; fertilizer use in relation to irrigation.

Unit V

Crop water stress – water deficits and crop growth, adoptability to the crops. Water availability with relation to nutrient availability.

Unit VI

Application of irrigation water, conveyance and distribution system, irrigation efficiency; agronomic considerations in the design and operation of irrigation projects; characteristics of irrigation and farming systems affecting irrigation management.

Unit VII

Strategies of using limited water supply; factors affecting ET, control of ET by mulching and use of anti-transpirants; fertilizer use in relation to irrigation; optimizing the use of given irrigation supplies.

Unit VIII

Land suitability for irrigation, land irrigability classification; integrated water management in command areas, institution of water management in commands, farmer's participation in command areas; irrigation legislation.

Unit IX

Economic analysis of irrigation and cop planning for optimum use of irrigation water

Unit X

Crop water production function

VI. Practical

- Determination of water infiltration characteristics and water holding capacity of soil profiles.
- Determination Moisture extraction pattern of crops
- Determination of water balance component of transplanted rice by drum culture technique
- Determination of consumptive use and water requirement of a given cropping pattern
- Determination of crop efficient of one important crop
- Planning, designing and installation of drip irrigation system
- Planning, designing and installation of sprinkler irrigation system
- Designing of drainage channel
- Measurement of irrigation efficiencies
- Determination of irrigation timing under different methods of irrigation
- Visit to irrigation command area

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Management of irrigation water for sustainable agriculture

IX. Suggested Reading

- MP. Singh 2017. Recent advances in Irrigation water management. Kalyani Publishers
- FAO. 1984. *Irrigation Practice and Water Management*. Oxford & IBH.
- Michael AM. 1978. *Irrigation: Theory and Practice*. Vikas Publ.
- Mishra RR and Ahmad M. 1987. *Manual on Irrigation and Agronomy*. Oxford & IBH.
- Panda SC. 2003. *Principles and Practices of Water Management*. Agrobios.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Sankara Reddy GH and Yellamananda Reddy. 1995. Efficient Use of Irrigation Water. In: Gupta US. (Ed.). *Production and Improvement of Crops for Drylands*. Oxford & IBH.
- Singh SS. 2006. Principles and Practices of Agronomy. In: Gupta US.(Ed.). *Production and Improvement of Crops for Drylands*. Oxford & IBH

I. Course Title : Recent Trends in Weed Management

II. Course Code : Agron 604

III. Credit Hours : 2+0

IV. Aim of the course

To teach about the changing weed flora, new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

V. Theory

Unit I

Crop-weed competition in different cropping situations; changes in weed flora, various causes and effects; different methods of weed management. Migration, introduction, adaptation of weeds, Invasive weeds – biology and management. Different mechanisms of invasion – present status and factors influencing weed invasion.

Unit II

Physiological and biological aspects of herbicides, their absorption, translocation, metabolism and mode of action; selectivity of herbicides and factors affecting them.

Unit III

Climatic factors and phytotoxicity of herbicides; fate of herbicides in soil and factors affecting them, Degradation of herbicides in soil and plants- factors affecting it, primary and secondary metabolites, residue management of herbicides, adjuvants.

Unit IV

Advances in herbicide products and application techniques and methods; herbicide resistance; antidotes and crop protection compatibility of herbicides of different groups; compatibility of herbicides with other pesticides; herbicide rotation and herbicide mixtures.

Unit V

Development of transgenic herbicide resistant crops; herbicide development, registration procedures.

Unit VI

Relationship of herbicides with tillage, fertilizer, and irrigation, cropping system; bioherbicides, allelochemical and alleloherbicides, herbicide bioassays. Recent advances in nonchemical weed management including deleterious rhizobacteria, robotics, biodegradable film, etc.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

VIII. Suggested Reading

- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action, Targets, Genetic Engineering, Chemistry*. Springer.
- Das TK. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi)
- Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Gupta OP. 2007. *Weed Management: Principles and Practices*, 2nd Ed.
- Jugulan M, (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco TJ, Weller SC and Ashton FM. 2014. *Weed Science Principles and Practices*, Wiley
- Powles SB and Shaner DL. 2001. *Herbicide Resistance and World Grains*, CRC Press.
- Walia US. 2006. *Weed Management*, Kalyani.
- Zimdahl RL. (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub*

I. Course Title : Integrated Farming Systems and Sustainable Agriculture

II. Course Code : Agron 605

III. Credit Hours : 2+0

IV. Aim of the course

To apprise about different enterprises suitable for different agroclimatic conditions for sustainable agriculture.

V. Theory

Unit I

Integrated Farming systems (IFS): definition, scope and importance; classification of IFS based on enterprises as well as under rainfed/irrigated condition in different land situation. farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply, enterprises.

Unit II

Concept of sustainability in of Integrated farming systems; efficient Integrated farming systems based on economic viability and natural resources - identification and management.

Unit III

Production potential of different components of Integrated farming systems; interaction and mechanism of different production factors; stability of Integrated Farming system based on research/long term information. in different systems through research; eco-physiological approaches to intercropping. Integration of components and adaptability of different farming system based on land situations and climatic condition of a region; evaluation of IFS.

Unit IV

Simulation models for intercropping; soil nutrient in intercropping; preparation of different farming system models; evaluation of different farming systems. Formation of different Integrated Farming system Models; evaluation of different Integrated Farming system models. Recycling of organic waste in farming system, in IFS.

Unit V

New concepts and approaches of farming system and organic farming; value addition, waste recycling, quantification and mitigation of Green House gases; case studies/ success stories of different Integrated Farming systems. cropping systems and organic farming; case studies on different farming systems. Possible use of ITK in Integrated farming system.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of enterprises suitable for different agroclimatic conditions for sustainable agriculture and their proper utilization .

VIII. Suggested Reading

- Ananthakrishnan TN. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford & IBH.
- Baishya A, Borah M, Das AK, Hazarika J, Gogoi B and Borah AS 2017. *Waste Recycling Through Integrated Farming systems. An Assam Agriculture Experience*. Omni Scriptum Gmbh & Co. KG, Germany.
- Balasubramanian P and Palaniappan SP. 2006. *Principles and Practices of Agronomy*. Agrobios.
- Edens T. 1984. *Sustainable agriculture and integrated farming system*. Michigan State Univ. press.
- Jayanthi C. 2006. *Integrated Farming systems-A way to sustainable Agriculture*. Tamil Nadu Agricultural University, Coimbatore
- Joshi M and Parbhakarasetty TK. 2005. *Sustainability through Organic Farming*. Kalyani.
- Kolhapure A and Madhukar D. *A text book of farming system and sustainable agriculture*.
- Palaniappan SP and Anandurai K. 1999. *Organic Farming - Theory and Practice*. Scientific Publ.
- Panda SC. 2004. *Cropping systems and Farming Systems*. Agribios.
- Lampin N. 1990. *Organic Farming*. Farming Press Books.
- Ravisankar D and Jayanthi C. 2015. *Farming systems: concepts and approaches*. Agrobios,

I. Course Title : Soil Conservation and Watershed Management

II. Course Code : Agron 606

III. Credit Hours : 2+1

IV. Aim of the course

To teach about different soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach watershed management.

V. Theory

Unit I

Soil erosion: definition, nature and extent of erosion; types of erosion, factors affecting erosion.

Unit II

Soil conservation: definition, methods of soil conservation; agronomic measures - contour cultivation, strip cropping, cover crops; mulching, tillage, cropping system vegetative barriers; improved dry farming practices; mechanical measures - bunding, gully control, bench terracing; role of grasses and pastures in soil conservation; wind breaks and shelter belts.

Unit III

Watershed management: definition, objectives, concepts, approach, components, steps in implementation of watershed; development of cropping systems for watershed areas.

Unit IV

Land use capability classification, alternate land use systems; agro-forestry; ley farming; *jhum* management - basic concepts, socio-ethnic aspects, its layout.

Unit V

Drainage, methods of drainage, Drainage considerations and agronomic management; rehabilitation of abandoned *jhum* lands and measures to prevent soil erosion.

VI. Practical

- Study of different types of erosion
- Determination of dispersion ratio
- Estimation of soil loss by Universal Soil Loss Equation
- Estimation of soil loss by wind erosion
- Measurement of runoff and soil loss
- Field studies of different soil conservation measures
- Laying out run-off plot and deciding treatments
- Identification of different grasses and trees for soil conservation
- Visit to watershed areas
- Visit to a soil conservation research centre, demonstration and training centre

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach watershed management.

IX. Suggested Reading

- Arakeri HR and Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.
- Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.
- FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57.
- Frederick RT, Hobbs J, Arthur D and Roy L. 1999. *Soil and Water Conservation: Productivity and Environment Protection.* 3rd Ed. Prentice Hall.

- Gurmel Singh, Venkataraman CG, Sastry B and Joshi P. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.
- Murthy VVN. 1995. *Land and Water Management Engineering*. Kalyani.
- Tripathi RP and Singh HP. 1993. *Soil Erosion and Conservation*. Wiley Eastern.
- Yellamanda Reddy T and Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani.

I. Course Title : Stress Crop Production

II. Course Code : Agron 607

III. Credit Hours : 2+1

IV. Aim of the course

To study various types of stresses in crop production and strategies to overcome them.

V. Theory

Unit I

Stress and strain terminology; nature and stress injury and resistance; causes of stress.

Unit II

Low temperature stress: freezing injury and resistance in plants, measurement of freezing tolerance, chilling injury and resistance in plants, practical ways to overcome the effect of low temperature tress through, soil and crop manipulations.

Unit III

High temperature or heat stress: meaning of heat stress, heat injury and resistance in plants, practical ways to overcome the effect of heat stress through soil and crop manipulations.

Unit IV

Water deficit stress: meaning of plant water deficient stress and its effect on growth and development, water deficit injury and resistance, practical ways to overcome effect of water deficit stress through soil and crop, manipulations.

Unit V

Excess water or flooding stress: meaning of excess water stress, its kinds and effects on crop plants, excess water stress injury and resistance, practical ways to overcome excess water stress through soil and crop manipulations.

Unit VI

Salt stress: meaning of salt stress and its effect on crop growth, salt stress injury and resistance in plants, practical ways to overcome the effect of salt stress through soil and crop manipulations.

Unit VII

Mechanical impedance of soil and its impact on plant growth; measures to overcome soil mechanical impedance.

Unit VIII

Environmental pollution: air, soil and water pollution, and their effect on crop growth and quality of produce; ways and means to prevent environmental pollution.

VI. Practical

- Determination of electrical conductivity of plant cell sap
- Determination of osmotic potential and tissue water potential
- Measurement of transpiration rate
- Measurement of stomatal frequency
- Measurement of Relative Water Content of leaf
- Measurement of electrolytic leakage
- Growing of plants in sand culture under salt stress for biochemical and physiological studies
- Studies on effect of osmotic and ionic stress on seed germination and seedling growth
- Measurement of low temperature injury under field conditions
- Studies on plant responses to excess water.

VIII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

IX. Learning outcome

Experience on the knowledge of various types of stresses in cropproduction and strategies to overcome these.

X. Suggested Reading

- Baker FWG.1989. *Drought Resistance in Cereals*. Oxon, UK.
- Gupta US. (Ed.). 1988. *Physiological Aspects of Dryland Farming*. Oxford & IBH.
- Kramer PJ.1983. *Water Relations of Plants*. Academic Press.
- Levitt J. 1980. *Response of Plants to Environmental Stresses*. Vols. I, II. Academic Press.
- Mavi HS.1978. *Introduction to Agro-meteorology*. Oxford & IBH.
- Michael AM and Ojha TP.1981. *Principles of Agricultural Engineering*. Vol II. Jain Bros.
- Nilsen ET and Orcut DM. 1996. *Physiology of Plants under Stress – Abiotic Factors*. John Wiley & Sons.
- Singh K. 2000. *Plant Productivity under Environmental Stress*. Agribios.
- Singh KN and Singh RP. 1990. *Agronomic Research Towards Sustainable Agriculture*. Indian Society of Agronomy, New Delhi.
- Somani LL and Totawat KL. 1992. *Management of Salt-affected Soils and Waters*. Agrotech Publ.
- Virmani SM, Katyal JC, Eswaran H and Abrol IP. 1994. *Stressed Ecosystem and Sustainable Agriculture*. Oxford & IBH.

I. Title : Research and Publication Ethics

II. Course Code : Agron 608

III. Credit Hours : 0+2

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatorypublishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to checkpublisher copy right and selfarchivingpolicies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools viz., JANE, Elsevier Journal Finder, Springer Journal Suggesteretc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open sourcesoftware tools

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index altmetrics.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field practicals and laboratory visit.

VI. Learning outcome

Developed skill for research management, quality publication.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Soil Science

Preamble

Soils comprise a multiple phase system consisting of numerous solid phases (about 50%), a liquid phase (about 25%) and a gas phase (about 25%). The solids include rock consisting of many different primary and secondary minerals. Superimposed on this inorganic matrix is what Truog (1951) described as the 'living phase' which includes bacteria, fungi, actinomycetes, algae, protozoa, nematodes and other forms of life. These living organisms are continuously breaking down organic residues and synthesizing many of the products into body tissues while others are released to the surroundings Many physical, chemical and biological changes continually take place in soils. Physical processes such as wetting, drying, freezing, thawing changing temperatures and leaching modify the surface areas of soil particles. Primary minerals change to secondary minerals as ionic species in solution seek lower free energy levels. In addition, plants capture energy from sun and store in the form of organic compounds. Because of dynamic nature of soils, various changes take place regularly in soils and therefore, it is very essential to know the behaviour of soil solution, matrix potential so that proper technology can be achieved through research works.

Our knowledge has increased rapidly during the last decade concerning the role of macro and micro nutrients in soils, plants, animal nutrition and in food for man. The skills of several scientific disciplines, combined with sophisticated instruments, have extended our knowledge about nutrients in plants and soils to molecular level and to microenvironments of roots in soil. One of the cherished objectives of the salient feature of the revised syllabi is to foster high standard in education system of soil science. A paradigm shift is necessary in education prioritization to meet the challenges of the present and future in soil science.

Students, therefore have to be acquainted with the modern concepts of different processes, concepts and development so as to develop competencies on the area of specialization of the subject. For the purpose, it is proposed to revise the course syllabus of Soil Science in the light of the present days need incorporating the basic concepts, developments of the discipline.

The existing M.Sc. (Ag) courses of soil science have been modified taking into account of present day need by incorporating the necessary and important topics in the respective courses such as basic principle of physics applied to soils, fertility status of major soil groups of India, Long term effect of manures and fertilizers on soil fertility and crop productivity, Soil health quality in relation to human health, Speciality fertilizers, Concept of quantity/ intensity relationship, Soil mapping, Interaction of clay with humus, pesticides and heavy metals, Soil enzyme, Humus formation, Root rhizosphere and Biodegradation of pesticide. The new topics are covered in Ph.D courses as Soil-plant-atmospheric continuum (SPAC), Kinetics studies of nutrients in soils, Climate change on soil properties and Carbon sequestration. Major changes have been made in some of the existing courses like soil fertility and fertilizer uses, soil biology and biochemistry and Analytical technique and instrumental methods in soil and plant analysis under MSc programme and Biochemistry of soil organic matter under PhD programme. As a part of course curriculum, M. Sc.(Ag) soil science was restructured to equip students to tackle emerging issues by inclusion of two new courses on (i) Soil survey and land use planning (ii) Introduction to nanotechnology. The Ph.D. courses of soil science was revised by adding four important new courses (i) Recent trend in soil microbial diversity (ii) Soil resource management (ii) Modelling of soil plant system (iv) Clay mineralogy.

Course Title with Credit Load
M.Sc. in Soil Science

Course Code	Course Title	Credit Hours
*Soil 501	Soil physics	(2+1)
*Soil 502	Soil fertility and fertilizer use	(2+1)
*Soil 503	Soil chemistry	(2+1)
*Soil 504	Soil mineralogy, genesis and classification	(2+1)
Soil 505	Soil erosion and conservation	(2+1)
Soil 506	Soil Biology and Biochemistry	(2+1)
Soil 507	Radioisotopes in soil and plant studies	(1+1)
Soil 508	Soil, water and air pollution	(2+1)
Soil 509	Remote sensing and GIS technique for soil and crop studies	(2+1)
Soil 510	Analytical technique and instrumental methods in soil and plant analysis	(0+2)
Soil 511	Management of problematic soils and water	(1+1)
Soil 512	Land degradation and restoration	(1+0)
Soil 513	Soil Survey and Land use Planning	(2+0)
Soil 514	Introduction to nanotechnology	(2+1)
Soil 591	Master's Seminar	(1+0)
Soil 599	Master's Research	-30

*Indicates Core Courses which are Compulsory for Master Programme

Course contents
M.Sc. in Soil Science

I. Course Title : Soil Physics
II. Course Code : Soil 501
III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about soil physical properties and processes in relation to plant growth.

V. Theory

Unit I

Basic principles of physics applied to soils, soil as a three phase system.

Unit II

Soil texture, textural classes, mechanical analysis, specific surface.

Unit III

Soil consistence; dispersion and workability of soils; soil compaction and consolidation; soil strength; swelling and shrinkage - basic concepts.Alleviation of soil physical constraints for crop production. Soil erosion and edibility

Unit IV

Soil structure - genesis, types, characterization and management soil structure; soil
aggregation, aggregate stability; soil tilth, characteristics of good soil tilth; soil crusting -mechanism, factors affecting and evaluation; soil conditioners; puddling, its effect on soil physical properties; clod formation.

Unit V

Soil water: content and potential, soil water retention, soil-water constants, measurement of soil water content, energy state of soil water, soil water potential, soil-moisture characteristic curve; hysteresis, measurement of soil-moisture potential.

Unit VI

Water flow in saturated and unsaturated soils, Poiseuille's law, Darcy's law; hydraulic conductivity, permeability and fluidity, hydraulic diffusivity; measurement ofhydraulic conductivity in saturated and unsaturated soils.

Unit VII

Infiltration; internal drainage and redistribution; evaporation; hydrologic cycle, field water balance; soil-plant-atmosphere continuum.

Unit VIII

Composition of soil air; renewal of soil air - convective flow and diffusion; measurement of soil aeration; aeration requirement for plant growth; soil air management.

Unit IX

Modes of energy transfer in soils; energy balance; thermal properties of soil; measurement of soil temperature; soil temperature in relation to plant growth; soiltemperature management.

VI. Practical

- Determination of B.D, P.D and mass volume relationship of soil, Mechanical analysis by hydrometer and international pipette method,
- Measurement of Atterberg limits, Aggregate analysis - dry and wet, Measurement of soil-water content by different methods, Measurement of soil-water potential by using tensiometer and gypsum Blocks, Determination of soil-moisture characteristics curve and computation of pore-size, distribution, Determination of hydraulic conductivity under saturated and unsaturated conditions, Determination of infiltration rate of soil, Determination of aeration porosity and oxygen diffusion rate, Soil temperature measurements by different methods, Estimation of water balance components in bare and cropped fields.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Ghildyal BP and Tripathi RP. 2001. *Soil Physics*. New Age International.
- Hanks JR and Ashcroft GL. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1972. *Optimizing the Soil Physical Environment toward Greater Crop Yields*. Academic Press.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Fundamentals of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physic*s. Academic Press.
- Hillel D. 2003. *Introduction to Environmental Soil Physics*. Academic Press.
- Indian Society of Soil Science. 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley-Interscience.
- Kohnke H. 1968. *Soil Physics*. McGraw Hill.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Soil Fertility and Fertilizer Use

II. Course Code : Soil 502

III. Credit Hours : 3+1

IV. Aim of the course

To impart knowledge about soil fertility and its control, and to understand the role of fertilizers and manures in supplying nutrients to plants so as to achieve high fertilizer use efficiency.

V. Theory

Unit I

Soil fertility and soil productivity; fertility status of major soils group of India;

nutrient sources – fertilizers and manures; Criteria of essentiality, classification, law of minimum and maximum, essential plant nutrients - functions and deficiency symptoms, Nutrient uptake, nutrient interactions in soils and plants; long term effect of manures and fertilizers on soil fertility and crop productivity.

Unit II

Soil and fertilizer nitrogen – sources, forms, immobilization and mineralization, nitrification, denitrification; biological nitrogen fixation -types, mechanism, microorganisms and factors affecting; nitrogenous fertilizers and their fate in soils; management of fertilizer nitrogen in lowland and upland conditions for high fertilizer use efficiency.

Unit III

Soil and fertilizer phosphorus - forms, immobilization, mineralization, reactions in acid andalkali soils; factors affecting phosphorus availability in soils; phosphatic fertilizers - behavior in soilsand management under field conditions. Potassium - forms, equilibrium in soils and its agriculturalsignificance; mechanism of potassium fixation; management of potassium fertilizers under fieldconditions.

Unit V

Sulphur - source, forms, fertilizers and their behavior in soils; roleincropsandhuman health; calcium and magnesium– factors affecting their availability in soils; management of sulphur, calcium and magnesium fertilizers.

Unit VI

Micronutrients – critical limits in soils and plants; factors affecting their availability and correction of their deficiencies in plants; role of chelates in nutrient availability.

Unit VII

Common soil test methods for fertilizer recommendations; quantity–intensityrelationships; soil test crop response correlations and response functions.

Unit VIII

Fertilizer use efficiency; site-specific nutrient management; plant need based nutrient management; integrated nutrient management; specialityfertilizersconcept, needand category.CurrentstatusofspecialityfertilizersuseinsoilsandcropsofIndia;

Unit IX

Soil fertility evaluation - biological methods, soil, plant and tissue tests; soilquality in relation to sustainable agriculture, Determination of critical limit, DRIS

Unit X

Definition and concepts of soil health and soil quality; Longterm effects of fertilizers and soil quality.

VI. Practical

- Soil and plant sampling and processing for chemical analysis
- Determination of soil pH, total and organic carbon in soil
- Chemical analysis of soil for total and available nutrients(major and micro)
- Analysis of plants for essential elements(major and micro)

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Kabata-Pendias A and Pendias H. 1992. *Trace Elements in Soils and Plants*. CRC Press.
- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technology*. Scientific Publ.
- Leigh J G. 2002. *Nitrogen Fixation at the Millennium*. Elsevier.
- Mengel K and Kirkby EA. 1982. *Principles of Plant Nutrition*. International Potash Institute, Switzerland.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. 1991. *Micronutrients in Agriculture*. 2nd Ed. SSSA, Madison.
- Pierzinsky GM, Sims TJ and Vance JF. 2002. *Soils and Environmental Quality*. 2nd Ed. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.
- Tisdale SL, Nelson SL, Beaton JD and Havlin JL. 1999. *Soil Fertility and Fertilizers*. 5th Ed. Prentice Hall of India.
- Troeh FR and Thompson LM. 2005. *Soils and Soil Fertility*. Blackwell.

I. Course Title : Soil Chemistry

II. Course Code : Soil 503

III. Credit Hours : 2+1

IV. Suggested Reading

To introduce the classical concepts of soil chemistry and to familiarize students with modern developments in chemistry of soils in relation to using soils as a medium for plant growth.

V. Theory

Unit I

Chemical (elemental) composition of the earth’s crust, soils, rocks and minerals

Unit II

Elements of equilibrium thermodynamics, chemical equilibria, electrochemistry and chemical kinetics.

Unit III

Soil colloids: inorganic and organic colloids - origin of charge, concept of point of zero-charge (PZC) and its dependence on variable-charge soil components, surface charge characteristics of soils; diffuse double layer theories of soil colloids, zeta potential, stability, coagulation/flocculation and peptization of soil colloids; electrometric properties of soil colloids; sorption properties of soil colloids; soil organic matter - fractionation of soil organic matter and different fractions, Characterization of OM; clay-organic interactions.

Unit IV

Ion exchange processes in soil; cation exchange- theories based on law of massaction (Kerr-Vanselow, Gapon equations, hysteresis, Jenny’s concept), adsorptionisotherms, Donnan-membrane equilibrium concept, clay-membrane electrodes and ionicactivity measurement, thermodynamics, statistical mechanics; anion and ligand exchange–

innersphere and outer-sphere surface complex formation, fixation of oxyanions, hysteresisin sorption-desorption of oxy-anions and anions, shift of PZC on ligand exchange, AEC, CEC; experimental methods to study ion exchange phenomena and practical implications in plant nutrition.

Unit V

Potassium, phosphate and ammonium fixation in soils covering specificand non-specific sorption; precipitation-dissolution equilibria; Conceptof quantity/intensity(Q/I)relationship; step and constant-rate K; managementaspects.

Unit VI

Chemistry of acid soils; active and potential acidity; lime potential, chemistry of acid soils; sub-soil acidity.

Unit VII

Chemistry of salt-affected soils and amendments; soil pH, ECe, ESP, SAR and important relations; soil management and amendments.

Unit VIII

Chemistry and electrochemistry of submerged soils, geochemistry of micronutrients, environmental soil chemistry

VI. Practical

Preparation of saturation extract, measurement of pH, EC, CO, HCO, Ca, Mg, K and Na, Determination of CEC and AEC of soils, Analysis of equilibrium soil solution for pH, EC, Eh by the use of Eh-pH meter andconductivity meter, Determination of point of zero-charge and associated surface charge characteristics by the serial potentiometric titration method, Extraction of humic substances, Potentiometric and conductometric titration of soil humic and fulvic acids, (E4/E6) ratio of soil humic and fulvic acids by visible spectrophotometric studies and the D (E4/E6) values at two pH values, Adsorption-desorption of phosphate/sulphate by soil using simple adsorption isotherm, Construction of adsorption envelope of soils by using phosphate/fluoride/sulphate and ascertaining the mechanism of the ligand exchange process involved, Determination of titratable acidity of an acid soil by BaCl2-TEA method, Determination of Q/I relationship of potassium, Determination of lime requirement of an acid soil by buffer method, Determination of gypsum requirement of an alkali soil.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of chemical behaviour of soil and their utility in research for solving field problem.

IX. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil*. Oxford and IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. *Chemistry of Soil Constituents*. John Wiley & Sons.
- McBride MB. 1994. *Environmental Chemistry of Soils*. Oxford University Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.

- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley & Sons.
- Van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. Course Title : Soil Mineralogy, Genesis and Classification

II. Course Code : Soil 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with basic structure of alumino-silicate minerals and genesis of clay minerals; soil genesis interms of factors and processes of soil formation, and to enable students conduct soil survey and interpret soil survey reports in terms of land use planning.

V. Theory

Unit I

Fundamentals of crystallography, space lattice, coordination theory, isomorphism and polymorphism.

Unit II

Classification, structure, chemical composition and properties of clay minerals; genesis and transformation of crystal line and non-crystal line clay minerals; identification techniques; amorphous soil constituents and other non-crystalline silicate minerals and their identification; clay minerals in Indian soils, role of clay minerals in plant nutrition, interaction of clay with humus, pesticides and heavy metals.

Unit III

Factors of soil formation, soil formation models; soil forming processes; weathering of rocks and mineral transformations; soil profile; weathering sequences of minerals with special reference to Indian soils.

Unit IV

Concept of soil individual; soil classification systems – historical developments and modern systems of soil classification with special emphasis on soil taxonomy; soil classification, soil mineralogy and soil maps – usefulness.

VI. Practical

- Separation of sand, silt and clay fraction from soil
- Determination of specific surface area and CEC of clay
- Identification and quantification of minerals in soil fractions
- Morphological properties of soil profile in different land forms
- Classification of soils using soil taxonomy
- Calculation of weathering indices and its application in soil formation
- Grouping soil susing available database in terms of soil quality

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil taxonomy and genesis and and their utility in research for solving field problem.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu. Buol EW, Hole ED, MacCracken RJ and Southard RJ. 1997. *Soil Genesis*
- *and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.
- USDA. 1999. *Soil Taxonomy*. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy*: II. *The Soil Orders*. Elsevier.
- Wilding NE and Holl GF. (Eds.). 1983. *Pedogenesis and Soil Taxonomy*. I.

I. Course Title : Soil Erosion and Conservation

II. Course Code : Soil 505

III. Credit Hours : 2+1

IV. Aim of the course

To enable students to understand various types of soil erosion and measures to betaken for controlling soil erosion to conserve soil and water.

V. Theory

Unit I

History, distribution, identification and description of soil erosionproblems in India.

Unit II

Forms of soil erosion; effects of soil erosion and factors affecting soilerosion; types and mechanisms of water erosion; raindrops and soil erosion; rainfall erosivity - estimation as EI30 index and kinetic energy; factors affectingwater erosion; empirical and quantitative estimation of water erosion; methods of measurement and prediction of runoff; soil losses in relation to soil properties andprecipitation.

Unit III

Wind erosion- types, mechanism and factors affecting wind erosion; extent of problem in the country.

Unit IV

Principles of erosion control; erosion control measures – agronomical and engineering; erosion control structures - their design and layout.

Unit V

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wet lands.

Unit VI

Watershed management - concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socioeconomic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds; use of remote sensing in assessment and planning of watersheds, sediment measurement

VI. Practical

- Determination of different soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index
- Computation of kinetic energy of falling rain drops
- Computation of rainfall erosivity index (EI30) using rain gauge data
- Land capability classification of a watershed
- Visits to a watersheds

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil conservation and their utility in research for solving field problem.

IX. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.) 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Society of Soil Science No. 17.
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Spl Publ. No. 49, Madison, USA.
- Gurmal Singh, Venkataramanan C, Sastry G and Joshi BP. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.
- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Soil Biology and Biochemistry

II. Course Code : Soil 506

III. Credit Hours : 2+1

IV. Aim of the course

To teach students the basics of soil biology and biochemistry, including biogeochemical cycles, plant growth promoting rhizobacteria, microbial interactions in soil and other soil activities.

V. Theory

Unit I

Soilbiota, soil microbialecology, types of organisms indifferent soils; soil microbial biomass; microbial interactions; un-culturable soilbiota.

Unit II

Microbiology and biochemistry of root-soil interface; phyllosphere; soil enzymes, origin, activities and importance; soil characteristics influencing growth and activity of microflora; Root rhizosphere and PGPR.

Unit III

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil; biochemical composition and biodegradation of soil organic matter and crop residues, microbiology and biochemistry of decomposition of carbonaceous and protenaceous materials, cycles of important organic nutrients.

Unit IV

organic wastes and their use for production of biogas and manures; biotic factors in soil development; microbial toxins in the soil.

Unit V

Preparation and preservation of farmyard manure, animal manures, rural and urban composts and vermicompost.

Unit VI

Biofertilizers–definition, classification, specifications, method of production and role in crop production; FCO specifications and quality control of biofertilizers.

Unit VII

Biological indicators of soil quality; bioremediation of contaminated soils; microbial transformations of heavy metals in soil; role of soil organisms inpedogenesis – important mechanisms and controlling factors; soil genomics and bioprospecting; soil sickness due to biological agents; xenobiotics; antibiotic production in soil.

VI. Practical

- Determination of soil microbial population
- Soil microbial biomass carbon
- Elemental composition, fractionation of organic matter and functional groups
- Decomposition of organic matter in soil
- Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification, N_2 fixation, S oxidation, P solubilization and mineralization of other micronutrients

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil microbes and their utility in research for solving field problem.

IX. Suggested Reading

- Paul EA and Clark FE. *Soil Microbiology and Biochemistry.*
- Lynch JM. *Soil Biotechnology*
- Willey JM, Linda M. Sherwood and Woolverton CJ. *Prescott's Microbiology.*
- Subba Rao NS. *Advances In Agricultural Microbiology.*

I. Course Title : Radioisotopes in Soil and Plant Studies

II. Course Code : Soil 507

III. Credit Hours : 1+1

IV. Aim of the course

To train students in the use of radio isotopes in soil and plant research.

V. **Theory**

Unit I

Atomic structure, radio activity and units; radio isotopes-properties and decay principles; nature and properties of nuclear radiations; interaction of nuclear radiations with matter, artificial radioactivity

Unit II

Principles and use of radiation monitoring instruments-proportional, Geiger Muller counter, solid and liquids cintillation counters; neutron moisture meter, mass spectrometry, autoradiography

Unit III

Isotopic dilution techniques used in soil and plant research; use of stable isotopes; application of isotopes in studies on organic matter, nutrient transformations, ion transport, rooting pattern and fertilizer use efficiency; carbon dating

Unit IV

Doses of radiation exposure, radiation safety aspects regulatory aspects, collection, storage and disposal of radioactive wastes

VI. **Practical**

- Storage and handling of radioactive materials
- Determination of half-life and decay constant
- Preparation of soil and plant samples for radioactive measurements
- Settingup of experiment on fertilizer use efficiency and cation exchange equilibria using radio isotopes
- Determination of A, E and L values of soil using 32P/65Zn
- Use of neutron probe for moisture determination
- Sample preparation and measurement of 15N enrichment by mass spectro photometery/ emission spectrometry

VII. **Teaching methods/ activities**

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. **Learning outcome**

Experience on the knowledge of radio activity and their utility in research for solving field problems.

IX. **Suggested Reading**

- Comer CL. 1955. *Radioisotopes in Biology and Agriculture: Principles and Practice*. Tata McGraw Hill.
- Glasstone S. 1967. *Source Book on Atomic Energy*. East West Press.
- Michael FL and Annunziata. 2003. *Handbook of Radioactivity Analysis*. Academic Press.

I. **Course Title : Soil, Water and Air Pollution**

II. **Course Code : Soil 508**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To make the student saw are of the problems of soil, water and air pollution associated with use of soils for crop production.

V. Theory

Unit I

Soil, water and air pollution problems associated with agriculture, nature and extent.

Unit II

Nature and sources of pollutants – agricultural, industrial, urban wastes, fertilizers and pesticides, acid rains, oil spills etc.; air, water and soil pollutants- their CPC standards and effect on plants, animals and human beings.

Unit III

Sewage and industrial effluents–their composition and effecton soil properties/ health, and plant growth and humanbeings; soil as sink for waste disposal.

Unit IV

Pesticides–their classification, behaviour in soil and effecton soil microorganisms.

Unit V

Toxic elements–their sources, behaviour in soils, effect on nutrients availability, effect on plant and human health.

Unit VI

Pollution of water resources due to leaching of nutrients and pesticides from soil; emission of green house gases–carbondioxide, methane and nitrous oxide.

Unit VII

Risk assessment of polluted soil, Remediation/ amelioration of contaminated soil and water; remote sensing applications in monitoring and management of soil and water pollution.

VI. Practical

Sampling of sewage waters, sewage sludge, solid/ liquid industrial wastes, polluted soils and plants and their processing, Estimation of dissolved and suspended solids, chemical oxygen demand (COD), biological demand (BOD), measurement of coliform (MPN), nitrate and ammoniacal nitrogen and phosphorus, heavy metal content in effluents, Heavy metals in contaminated soils and plants, Management of contaminants in soil and plants to safe guard food safety, Air sampling and determination of particulate matter and oxides of sulphur, NO_2 and O_2 conc**.** Visit to various industrial sites to study the impact of pollutants on soil and plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Management of soil and water pollution

IX. Suggested Reading

- Lal R, Kimble J, Levine E and Stewart BA. 1995. *Soil Management and Greenhouse Effect*. CRC Press.
- Middlebrooks EJ. 1979. *Industrial Pollution Control*. Vol. I. *Agro-Industries*. John Wiley Interscience.
- Ross SM. *Toxic Metals in Soil Plant Systems*. John Wiley & Sons.
- Vesilund PA and Pierce 1983. *Environmental Pollution and Control*. Ann Arbor Science Publ.

I. Course Title : **Remote Sensing and GIS Technique for Soil, Water and Crop Studies**

II. Course Code : **Soil 509**

III. Credit Hours : **2+1**

IV. Aim of the course

To impart knowledge about the basic concepts of remote sensing, aerial photographs and imageries, and their interpretation; application of remote sensing in general and with special reference to soil, plants and yield forecasting; to impart knowledge about geo-statistical techniques with special reference to krigging, and GIS and applications in agriculture.

V. Theory

Unit I

Introduction and history of remote sensing; sources, propagation of radiations in atmosphere; interactions with matter, basic concepts and principles; hardware and software requirements; common terminologies of geographic information system (GIS)

Unit II

Sensor systems-camera, microwave radio meters and scanners; fundamentals of aerial photographs and multispectral imaging, hyperspectral imaging, thermal imaging; image processing and interpretations.

Unit III

Application of remote sensing techniques-landuse soil surveys, crop stress and yield forecasting, prioritization in watershed and drought management, waste land identification and management.

Unit IV

Significance and sources of the spatial and temporal variability in soils; variability in relation to size of sampling; classical and geo-statistical techniques of evolution of soil variability.

Unit V

Applications of GIS for water resources, agriculture, precision farming, disaster management, e-governance, Agricultural Research Information System (ARIS).

VI. Practical

Familiarization with different remote sensing equipments and data products, Interpretation of aerial photo graphs and satellite data for mapping of land resources, Analysis of variability of different soil properties with classical and geostatistical techniques, Creation of datafiles in a database programme, Use of GIS for soil spatial simulation and analysis, To enable the students to conduct soil survey and interpret soil survey reports in terms of land use planning.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and their utility in research for solving field problem.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Elangovan K. 2006. *GIS Fundamentals, Applications and Implementations*. New India Publ. Agency.
- Lillesand TM and Kiefer RW. 1994. *Remote Sensing and Image Interpretation*. 3rd Ed. Wiley.
- Nielsen DR and Wendroth O. 2003. *Spatial and Temporal Statis*tics. Catena Verloggmbh.
- Star J and Esles J. 1990. *Geographic Information System: An Introduction*. Prentice Hall.

I. Course Title	:	**Analytical Technique and Instrumental Methods in Soil and Plant Analysis**
II. Course Code	:	**Soil 510**
III. Credit Hours	:	**0+2**

IV. Aim of the course

To familiarize the students with commonly used instruments – their working, preparations of common analytical reagents for qualitative and quantitative analysis of both soil as well as plant samples.

V. Practical

Unit I

Preparation of solutions for standard curves, indicators and standard solutions for acid-base, oxidation reduction and complexometric titration; soil, water and plant sampling techniques, their processing and handling.

Unit II

Determination of nutrient potentials and potential buffering capacities of soils for phosphorus and potassium; estimation of phosphorus, ammonium and potassium fixation capacities of soils.

Unit III

Principles of visible, ultra violet and infrared spectrophotometery, atomic absorption, flame-photometry, inductively coupled plasma spectrometry; chromatographic techniques, mass spectrometry and X-ray defractrometery; identification of minerals by X-ray by different methods, CHNS analyzer.

Unit IV

Electrochemical titration of clays; estimation of exchangeable cations (Na, Ca, Mg, K); estimation of root cation exchange capacity.

Unit V

Wet digestion/fusion/extraction of soil with aquaregia with soil for elemental analysis; triacid/di-acid digestion of plant samples; determination of available and total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in soils; determination of total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in plants

Unit VI

Drawing normalized exchange isotherms; measurement of redox potential.

VI. Teaching methods/activities

Classroom teaching and laboratory practicals

VII. Learning outcome

Development of confidence for setting soil testing laboratory.

VIII. Suggested Reading

- Hesse P. 971. *Textbook of Soil Chemical Analysis*. William Clowes & Sons.
- Jackson ML. 1967. *Soil Chemical Analysis*. Prentice Hall of India.
- Keith A Smith 1991. *Soil Analysis; Modern Instrumental Techniques*. Marcel Dekker.
- Kenneth Helrich 1990. *Official Methods of Analysis*. Association of Official Analytical Chemists.
- Page AL, Miller RH and Keeney DR. 1982. *Methods of Soil Analysis*. Part II. SSSA, Madison.
- Piper CE. *Soil and Plant Analysis*. Hans Publ.
- Singh D, Chhonkar PK and Pandey RN. 1999. *Soil Plant Water Analysis - A Methods Manual*. IARI, New Delhi.
- Tan KH. 2003. *Soil Sampling, Preparation and Analysis*. CRC Press/Taylor & Francis.
- Tandon HLS. 1993. *Methods of Analysis of Soils, Fertilizers and Wat*ers. FDCO, New Delhi.
- Vogel AL. 1979. *A Textbook of Quantitative Inorganic Analysis*. ELBS Longman.

I. Course Title : Management of Problem Soils and Water

II. Course Code : Soil 511

III. Credit Hours : 2+1

IV. Aim of the course

To educate students about basic concepts of problem soils and brackish water, and their management. Attention will be on management of problem soils and safe use of brackish water in relation to crop production.

V. Theory

Unit I

Area and distribution of problem soils–acidic, saline, sodic and physically degraded soils; origin and basic concept of problematic soils, and factors responsible.

Unit II

Morphological features of saline, sodic and saline-sodic soils; characterization of salt-affected soils-soluble salts, ESP, pH; physical, chemical and microbiological properties.

Unit III

Management of salt-affected soils; salt tolerance of crops- mechanism and ratings; salt stress meaning and its effect on crop growth, monitoring of soils alinity in the field; management principles for sandy, clayey, red lateritic and dryland soils.

Unit IV

Acid soils-nature of soil acidity, sources of soil acidity; effect on plant growth, lime requirement of acid soils; management of acid soils; biological sickness of soils and its management.

Unit V

Quality of irrigation water; management of brackish water for irrigation; salt balance under irrigation; characterization of brackish waters, area and extent; relationship in water use and quality.

Unit VI

Agronomic practices in relation to problematic soils; cropping pattern for utilizing poor quality groundwaters.

VI. Practical

Characterization of acid, acid sulfate, salt-affected and calcareous soils, Determination of cations (Na+, K+, Ca++ and Mg++) in groundwater and soil samples, Determination of an ions (Cl^-, SO_4^-, CO_3^- and HCO_{3-}) in ground waters and soil samples, Lime and gypsum requirements of acid and sodic soils.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on solving field problem of problem soil and waters.

IX. Resources

- Bear FE. 1964. *Chemistry of the Soil*. Oxford & IBH.
- Jurinak JJ. 1978. *Salt-affected Soils*. Department of Soil Science & Biometeorology. Utah State University
- USDA Handbook No. 60. 1954. *Diagnosis and improvement of Saline and Alkali Soils*. Oxford & IBH.

I. Course Title : Land Degradation and Restoration

II. Course Code : Soil 512

III. Credit Hours : 1+0

IV. Aim of the course

To impart knowledge related to various factors and processes of land degradation and their restoration techniques.

V. Theory

Unit I

Type, factors and processes of soil/land degradation and its impact on soil productivity including soil fauna, biodegradation and environment.

Unit II

Land restoration and conservation techniques-erosion control, reclamation of salt-affectedsoils; minelandreclamation, afforestation, organic products.

Unit III

Extent, diagnosis and mapping of land degradation by conventional and modern RS-GIS tools; monitoring land degradation by fast assessment, modern tools, land use policy, incentives and participatory approach for reversing land degradation; global issues for twenty first century.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on restoration of degraded soil for optimization of crop yield.

VIII. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.). 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Soc. Soil Sci. 17, New Delhi.
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Madison.
- Greenland DJ and Szabolcs I. 1994. *Soil Resilience and Sustainable Land Use*. CABI.
- Lal R, Blum WEH, Vailentine C and Stewart BA. 1997. *Methods for Assessment of Soil Degradation*. CRC Press.
- Sehgal J and Abrol IP. 1994. *Soil Degradation in India - Status and Impact*. Oxford & IBH.

I. Course Title : Soil Survey and Land Use Planning

II. Course Code : Soil 513

III. Credit Hours : 2+0

IV. Aim of the course

To teach the better utilization of land for agricultural purposes, and better management of run-off or surplus/ excessive rain-water in the catchment area for agricultural purposes in a watershed.

V. Theory

Unit I

Soil survey and its types; soil survey techniques- conventional and modern; soil series–characterization and procedure for establishing soil series; benchmark soils and soil correlations; soil survey interpretations; thematic soil maps, cartography, mapping units, techniques for gene ration of soil maps, application of remote sensing and GIS in soil survey and mapping of major soil group of India

Unit II

Landform–soil relationship; major soil groups of India with special reference to respective states; land capability classification and land irrigability classification; land evaluation and land use type (LUT)–concept and application; approaches for managing soils and landscapes in the framework of agro-ecosystem.

Unit III

Concept and techniques of land use planning; factors governing present land use; Land evaluation method sand soil-site suitability evaluation for different crops; land capability classification and constraints in application.

Unit IV

Agro-ecological regions/sub-regions of India and their characteristics in relation to crop production. Status of LUP in India.

VI. Practical

- Aerial photo and satellite data interpretation for soil and land use
- Cartographic techniques for preparation of base maps and thematic maps, processing of field sheets, compilation and obstruction of maps in differentscales
- Land use planning exercises using conventional and RS tools

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit and exposure visit

VIII. Learning outcome

Planning for land use in proper way for higher crop productivity.

IX. Suggested Reading

- Boul SW, Hole ED, MacCraken RJ and Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Brewer R. 1976. *Fabric and Mineral Analysis of Soils*. John Wiley & Sons.

I. Course Title : Introduction to Nanotechnology

II. Course Code : Soil 514

III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about nanoscience, properties of nanoparticles and their applications in biology

V. Theory

Unit I

General introduction: Basics of quantum mechanics, harmonic oscillator, magnetic phenomena, band structure in solids, Mössbauer effect and spectroscopy, optical phenomena, bond in solids, an isotropy.

Unit II

Nanostructures: growth of compound semiconductors, super lattices, self-assembled quantum dots, nano-particles, nano tubes and nanowires, fullerenes (buckballs, graphene). Nanofabrication and nano-patterning: Optical, X-ray, and electron beam lithography, self-assembled organic layers, process of synthesis of nanopowders, electrode position, important nanomaterials.

Unit III

Mechanical properties, magnetic properties, electrical properties, electronic conduction with nanoparticles, investigating and manipulating materials in the nanoscale: Electron microscopy

Unit IV

Nano-biology: Interaction between biomolecules and nano-particle surface, different types of in organic materials used for the synthesis of hybrid nano-bioassemblies, application of nano-inagriculture, current status of nano-biotechnology, future perspectives of nano-biology, nano-sensors.

VI. Practical

- Sources of nanoparticles and its preparation by different approaches
- Electrospinning and its use in agriculture and allied sector.
- Equipments used in Nanotechnology: its principle and uses
- Acquaintances with different equipments used in nanotechnology.
- Synthesis and characterization of Ag and ZnO nanoparticles.
- Mode of action of ZnO nanoparticles against soil borne diseases
- Study on efficacy of ZnO nanoparticles as seed treating agent on plant growth parameters.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of nano science and their utility in research for solving field problem.

IX. Suggested Reading

- Balandin AA and Wang KL. 2006. *Handbook of semiconductor nano structures and nano devices.* California: American Scientific Publishers.
- Timp G. 1999. *Nanotechnology*. New York: Springer Verlag.
- Challa Kumar SSR. 2006. *Nanotechnologies for the life sciences*. Weinheim: Wiley-VCHGmbH.
- Kohler M and Frintzsche W. 2007. *Nanotechnology: Introduction to nanostructuring techniques* W Weinheim: Wiley-VCH Verlag GmbH.
- Kosal ME. 2009. *Nanotechnology for chemicao and biological defense*. Dordrecht: Stringer.

Course Title with Credit Load
Ph.D. in Soil Science

Course Code	Course Title	Credit Hours
Soil 601	Recent trends in soil physics	2+0
Soil 602	Modern concept in soil fertility	2+0
Soil 603*	Physical chemistry of soil	2+0
Soil 604*	Soil genesis and micromorphology	2+0
Soil 605	Bio-chemistry of soil organic matter	2+0
Soil 606	Soil resource management	3+0
Soil 607	Modelling of soil plant system	2+0
Soil 608	Clay Mineralogy	2+1
Soil 609	Recent trends in soil microbial biodiversity	2+1
Soil 691	Doctoral seminar	1+0
Soil 692	Doctoral seminar	1+0
Soil 699	Doctoral Research	-75

*Indicates Core Courses which are Compulsory for PhD Programme

Course Contents
Ph.D. in Soil Science

I. Course Title : Recent Trends in Soil Physics
II. Course Code : Soil 601
III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge of modern concept sin soil physics.

V. Theory

Unit I

Soil-water interactions, soil water potential, free energy and thermodynamic basis of potential concept, chemical potential of soil water and entropy of the system, soil-plant-atmospheric continuum (SPAC).

Unit II

Fundamentals of fluid flow, Poiseuilles law, Laplace's equation, Darcy's law in saturated and unsaturated flows; development of differential equations in saturated and unsaturated waterflow, capillary conductivity and diffusivity; limitations of Darcy's law; numerical solution for one dimensional waterflow.

Unit III

Theories of horizontal and vertical infiltration under different boundary conditions.

Unit IV

Movement of salts in soils, models formiscible-immiscible displacement, diffusion, mass flow and dispersion of solutes and their solutions through differential equations; break-through curves.

Unit V

Soil air and aeration, mass flow and diffusion processes; thermal properties of soil, heat transfer in soils, differential equation of heatflow, measurement of thermal conductivity of soil; Soil, Plant, Water relations- Plant uptake of soil moisture, Water balance and energy balance in the field; irrigation and water use efficiency.

Unit VI

Soil crust and clod formation; structural management of puddled rice soils; soil conditioning-concept, soils conditioners-types, characteristics, working principles, significance in agriculture.

Unit VII

Solar and terrestrial radiation measurement, dissipation and distribution in soil-crop systems; prediction of evapotranspiration using aerodynamic and canopy temperature-based models; canopy temperature and leaf diffusion resistance in relation to plant water deficit; evaluation of soil and plant water status using infra-red thermometer.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

VIII. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Hanks and Ascheroft. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Environmental Soil Physic*s. Academic Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley Interscience.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Modern Concept in Soil Fertility

II. Course Code : Soil 602

III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge of modern concepts of soil fertility and nutrient use in crop production.

V. Theory

Unit I

Nutrient availability-concept and relationships, modern concepts of nutrient s availability; soil colloids and nutrient availability; soil amendments and availability maintenance of nutrients, soil solution and plant growth; nutrient response functions and availability indices.

Unit II

Nutrient movement in soils; nutrient absorption by plants; mechanistic approach to nutrient supply and uptake by plants; models for transformation and movement of major micronutrients in soils.

Unit III

Chemical equilibria (including solid-solution equilbria) involving nutrientions in soils, particularly in submerged soils; Kinetic studies of nutrients in soils.

Unit IV

Modern concepts of fertilizer evaluation, nutrient use efficiency and nutrient budgeting.

Unit V

Modernconcepts in fertilizer application; soil fertility evaluation techniques; role of soil tests in fertilizer use recommendations; site-specific nutrient management for precision agriculture.

Unit VI

Monitoring physical, chemical and biological changes in soils; permanent manurial trials and long-term fertilizer experiments; soil productivity under long-term intensive cropping; direct, residual and cumulative effect of fertilizer use.

Unit VII

Carbon– a nutrient central to soil fertility; carbon cycle in nature, stocks, pools and fluxes; greenhouse effect and climate change; carbon sequestration vis-à-vis sustenance of soil quality and crop productivity.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

VIII. Suggested Reading

- Barber SA. 1995. *Soil Nutrient Bioavailability*. John Wiley & Sons.
- Barker V Allen and Pilbeam David J. 2007. *Handbook of Plant Nutrition*. CRC / Taylor & Francis.
- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Educ.
- Cooke GW. 1979. *The Control of Soil Fertility*. Crossby Lockwood & Sons.
- Epstein E. 1987. *Mineral Nutrition of Plants - Principles and Perspectives*. International Potash Institute, Switzerland.
- Kabata- Pendias Alina 2001. *Trace Elements in Soils and Plants*. CRC / Taylor & Francis.
- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technolog*y. Scientific Publ.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. (Eds.). 1991. *Micronutrients in Agriculture*. 2nd Ed. Soil Science Society of America, Madison.
- Prasad R and Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture*. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.
- Stevenson FJ. (Ed.). 1982. *Nitrogen in Agricultural Soils*. Soil Science Society of America, Madison.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1990. *Soil Fertility and Fertilizers*. 5th Ed. Macmillan Publ.
- Wild A. (Ed.). 1988. *Russell's Soil Conditions and Plant Growth*. 11th Ed. Longman.

I. Course Title : Physical Chemistry of Soil

II. Course Code : Soil 603

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about modern concepts of physical chemistry of soils and clays, with emphasis on understanding the processes involved with practical significance.

V. Theory

Unit I

Colloidal chemistry of in organic and organic components of soils–their formation, clay organic interaction.

Unit II

Predictive approaches for cation exchange equilibria- thermodynamics, empirical and diffuse double layer theory (DDL)- relationships among different selectivity coefficients; structure and properties of diffuse double layer.

Unit III

Thermodynamics of nutrient transformations in soils; Climate change effects on minerology and surface properties of variable charge; cationic and anionic exchange and their models, molecular interaction.

Unit IV

Adsorption/desorption isotherms-Langmuir adsorption isotherm, Freundlich adsorption isotherm, normalized exchange isotherm, BET equation; selective and non-selective adsorption of ions on in organic surfaces and organic surfaces of soil materials (citation of utility in agricultural system).

Unit V

Common solubility equilibria-carbonates, ironoxide and hydroxides, aluminum silicate, aluminum phosphate; electrochemical properties of clays (citation of examples from agricultural use).

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil chemical behaviour on research for solving field problems.

VIII. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil*. Oxford & IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Fried M and Broeshart H. 1967. *Soil Plant System in Relation to Inorganic Nutrition*. Academic Press.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. 1978. *Chemistry of Soil Constituents*. John Wiley & Sons.
- Jurinak JJ. 1978. *Chemistry of Aquatic Systems*. Department of Soil Science and Biometeorology, Utah State University
- McBride MB. 1994. *Environmental Chemistry of Soils*. Oxford University Press.
- Sparks DL. 1999. *Soil Physical Chemistry*. 2nd Ed. CRC Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.
- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley.
- van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. Course Title : Soil Genesis and Micromorphology

II. Course Code : Soil 604

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about the pedogenic processes in soils and to acquaint with the micro-pedological study of soil profile.

V. Theory

Unit I

Pedogenic evolution of soils; soil composition and characterization.

Unit II

Weathering and soil formation–factors and pedogenic processes; stability and weathering sequences of minerals.

Unit III

Assessment of soil profile development by mineralogical and chemical analysis.

Unit IV

Micro-pedological features of soils–their structure, fabric analysis, role in genesis and classification.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil micro pedology and soil taxonomy on research for solving field problems.

VIII. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.
- USDA. 1999. *Soil Taxonomy*. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.

I. Course Title : Biochemistry of Soil Organic Matter

II. Course Code : Soil 605

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge related to chemistry and reactions of organic substances and their significance in soils.

V. Theory

Unit I

Organic matter in soils and its maintenance Role of organic matter in soil productivity; humus levels in soils; current thinking on the maintenance of organic matter in the soils. Carbon retention and sequestration.

Unit II

Biochemistry of the humus formation; different pathways for humus synthesis in soil; soil carbohydrates and lipids.

Unit III

Nutrient transformation–N, P, S; tracemetal interaction with humic substances, significance of chelation reactions in soils.

Unit IV

Reactive functional groups of humic substances, adsorption of organic compounds by clay and role of organic substances in pedogenic soil aggregation processes; clay-organic matter complexes.

Unit V

Humus-pesticide interactions in soil, mechanisms.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil biochemistry on research for solving field problems.

VIII. Reading Materials

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*
- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*

I. Course Title : Soil Resource Management

II. Course Code : Soil 606

III. Credit Hours : 3+0

IV. Aim of the course

To impart the students basic holistic knowledge on soil resource and latest developments in its sustainable use.

Unit I

Relevance of soil management to sustainable agriculture; soil as a natural resource for biomass production, filtering, buffering, transportation of solutes, genereserves, and geogenic source of raw materials; soil as a source and sink of greenhouse gases.

Unit II

Concept of sustainable land management (SLM); spatial variability of soils; soil quality and food security; soil quality indices, conservation agriculture in relation to soil quality; soil resilience and resistance.

Unit III

Types, factors and causes of land degradation and desertification; GLASOD classification; application of GIS and remote sensing in monitoring, diagnosis and mapping land degradation; history, distribution, identification and description of soil erosion problems in India; forms of soil erosion; impact of soil erosion-on-site and off-site effects; strategies for erosion control and conservation; soil conservation in hilly, arid, semiarid, coastal and diaralands. Management of forest, peat and muck soils.

Unit IV

Soil conservation planning; land capability classification; soil conservation in special problem are as such as hilly, arid and semi-arid regions, waterlogged and wetlands; land restoration and conservation techniques–erosion control, reclamation of salt affected soils; mine land reclamation, afforestation, organic products, soil fauna and biodegradation.

Unit V

Watershed management-concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socio-economic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds.

Unit VI

Agro-ecological regions of India; potentials and constraints of soils of different regions; land evaluation and rationalizing land use, decision support system with relation to land management; national and international soil policy considerations.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VI. Learning outcome

Experience on the knowledge of soil resources on research for solving field problems.

VII. Suggested Reading

- Abrol IP and Dhruvanarayana VV. 1990. *Technology for Wasteland Development*. ICAR, New Delhi.
- Andriesse JP. 1988. *Nature and Management of Tropical Peat Soils*, Soil Resources, FAO Soils Bulletin 59, Management and Conservation Service, Land and Water Development Division, FAO, Rome
- Blackwell, Dent D and Young A. 1981. *Soil Survey and Land Evaluation*. George Allen and Unwin, London.
- Burrough A and McDonnell RK. 1998.*Principles of Geographical Information System*. Oxford University Press.
- Dan Binkley D and Fisher R. 2012. *Ecology and Management of Forest Soils*,4th Edition, Wiley.
- FAO. 1996. *Land Quality Indicators and their Use in Sustainable Agriculture and Rural Development*. FAO Land and Water Bulletin.5. FAO, Rome.
- Faroq M and Siddique K. (Ed.). 2015. *Conservation Agriculture*, Springer Nature, Chennai, India.
- FESL. 1993. *An International Framework for Evaluating Sustainable Land Management, FAO World Soil Resources Report No. 73*, Land Development Division, FAO, Rome.
- ISSS. 1994. *Management of Land and Water Resources for Sustainable Agriculture and Environment*. Diamond Jubilee Symposium Publication, Indian Society of Soil Science, New Delhi.
- Lal R, Blum WEH, Valentine C and Stewart BA. (Editors). 1988. *Methods for Assessment of Soil Degradation*. CRC Press, Boca Raton.
- Mulders MA. 1987. *Remote Sensing in Soil Science*. Elsevier Science Publishers, Amsterdam.
- Sehgal J. 2014. *A Text Book of Pedology Concepts and Application*. Kalyani publishers, New Delhi.
- SSSA 1996. *Methods for Assessing Soil Quality*. SSSA Publication Number 49, Madison, Wisconsin, USA.

I. Course Title : Modelling of Soil Plant System

II. Course Code : Soil 607

III. Credit Hours : 2+0

IV. Aim of the course

To train the students in concepts, methodology, technology and use of systems simulation in soil and crop studies

V. Theory

Unit I

Introduction, terms and definitions; classification of models; Taylor series; numerical methods of differentiation and integration.

Unit II

High level computer language: FORTRAN-its commands and usage; testing and evaluation of model.

Unit III

Description of spatially homogeneous models; K transformation model; nitrogen and phosphorus dynamics in soil.

Unit IV

Spatially heterogeneous models; equation of continuity; Simulation of water flow through soil; Explicit and Explicit-Implicit method; simulation of solute movement through soil with variable moisture flux by explicit-implicit method.

Unit V

Nutrient uptake model: Integration of nutrient movement in soil (mass flow and diffusion) and uptake by plants (Michaelis-Menten kinetics); Nutrient uptake model: Solubility and free ion activity model.

IV. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil modelling concept for forecasting productivity

VIII. Suggested Reading

- Datta SC. 2008. *Theory and Principles of Simulation Modeling in Soil-Plant System*. Capital Publishing Company, New Delhi.
- Frame J and Thornley JHM. 1984. *Mathematical Models in Agriculture—A Quantitative approach to problems in agriculture and related science*. Butterworth and Co. Ltd.
- Freud PJ and Minton PD. 1979. *Regression Methods—A tool for data Analysis*. Marcel Dekker Inc., New York.
- Frissel MJ and Reinger P. 1974. *Simulation of Accumulation and Leaching in Sils*. Oxford and IBM Pub. Co., New Delhi.
- Hanks J and Richie JT. (Eds.). 1991. *Modeling Plant and Soil System*. Agronomy Bulletin No. 31, ASA, SSSA Madison, Wisconsin, USA.
- Lipschutz S and Poe A. 1978. *Schaum's Outline Series–Theory and Problems of programming with Fortran*. McGraw-Hill Book Co., Singapore.
- Penning de Vries FWT, Jansen DM, Ten Berge HFM and Baker A. 1989. *Simulation of ecophysiological processes of growth in several annual crops*. PUDOC, Wageningen.
- Shaffer MJ, Ma L and Hansen S. 2001. *Modeling Carbon and Nitrogen Dynamics for Soil Management*. Lewis Publishers, Boca Raton.

I. Course Title : Clay Mineralogy
II. Course Code : Soil 608
III. Credit Hours : 2+1

IV. Theory

Unit I

Definition and concepts of clays and clay minerals, Fundamentals of crystallography – unit cell, external characteristics of crystals, crystallographic notations, crystal systems.

Unit II

Structures and classification of silicate minerals, basics of phyllosilicates, laws governing structural characteristics of phyllosilicates, Goldschmitdt's laws – Laws I and Law II, Classification of Phyllosilicates.

Unit III

Kaolonite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins.

Unit IV

Smectites; properties of smectites, Reference models of structure, principal types based on Hofmann-Marshal-Hendricks (H-M-H) models, occurrence of smectites, transformation and formation in soils.

Unit V

Micas: occurrence and origin in soils, polytypes of micas, structure and formation of muscovites and illite.

Unit VI

Vermicullites: structure, occurrence in soils, formation, relation between vermiculites and montmorillonite.

Unit VII

Chlorite: occurrence and structure of chlorites, "swelling chlorites", formation of chlorite.

Unit VIII

Non-crystalline clays (amorphous materials), subgroups and chemical composition, morphology and structure, physico-chemical properties, influence of non-crystalline clays on soil properties.

Unit IX

Interstratified clay minerals, occurrence and formation in soils, regularly interstratified and partially random interstratified minerals.

Unit X

Genesis and transformation of clay minerals, Generalized conditions for formation and persistence of common clay-size minerals in soils.

Unit XI

Surface chemistry of clay minerals, clay-organic complexes, nanoclay mineralogy.

Unit XII

Clay minerals in different soil orders, role of clay minerals in soil fertility management.

V. Practicals

- Separation of clay for mineralogical study
- X-ray diffraction analysis of clay
- Selective dissolution of clay minerals
- IR, DTA and SEM of clay minerals
- Identification and quantification of clay minerals
- Determination of surface charge of clay minerals
- Potentiometric titration of clay minerals.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil clays and utility in soil research.

VIII. Suggested Reading

- Dixon JB and Weed SB (Co-editors). *Minerals in Soil Environment.*
- Gieseking JE (Ed). *Soil Component*, Vol. 2. Inorganic Components.
- Grim RE. *Clay Mineralogy*.
- Mukherjee SK and Biswas TD (Editors). *Mineralogy of Soil Clays and Clay Minerals.*
- Read HH. *Rutley's Elements of Mineralogy.*
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy Part II – Soil Orders.*

I. Course Title : Recent Trends in Soil Microbial Biodiversity

II. Course Code : Soil 609

III. Credit Hours : 2+1

IV. Theory

Unit I

Microbial evaluation and biodiversity, Microbial communities in ecosystems, New insights in below ground diverse of plant performance.

Unit II

Qualitative ecology of microorganisms; Biomass and activities.

Unit III

Nitrogen fixing organisms, Trends in diversity of N fixing organisms. Molecular approaches in characterising N fixing microorganisms.

Unit IV

Serology and molecular characterization, ecological aspects of bio determination, soil waste and water management

Unit V

Biodegradability, testing and monitoring of the bioremediation of xerobiotic pollutants and bacterial fertilizers.

V. Practicals

- Determination of soil microbes using classical techniques.
- Determination of soil microbial diversity using molecular techniques.
- Estimation of soil microbial biomass carbon, nitrogen and phosphorus.
- Estimation of key soil enzyme activities.
- Community level physiological profiling of microbial diversity.

VI. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, field visit

VII. Learning outcome

Experience on soil microbial diversity and planning for proper utilization.

VIII. Suggested Reading

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*.
- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*.

I. Course Title : Research and Publication Ethics

II. Course Code : Soil 610

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, *etc*., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, *etc*. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g index, i10 index altmetrics

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field, laboratory and library visit

VI. Learning outcome

Quality research output and outstanding research publication with excellent impact factor.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agricultural Physics

Preamble

Agricultural Physics is the discipline dealing with the application of the Principles and laws of Physics in agriculture to study soil, plant and atmosphere for eco-friendly and sustainable exploitation of agricultural resources. Considering the recent advancement of knowledge and the need to make our students to be well aware of the recent developments in Science the syllabi for the discipline of Agricultural Physics was modified. Agricultural Physics is gaining importance in view of its potential to serve as a tool to solve the challenges of feeding a growing population, providing a livelihood for farmers, and protecting the environment. The need for Agricultural Physics as a discipline in M.Sc. and Ph.D. program is emphasized due to the recent applications in crop modelling as a decision tool, satellite remote sensing based near real time crop condition monitoring, drone-based crop disease, pest surveillance, digital soil mapping, artificial intelligence based crop status characterization through image processing, nano biosensors for quick and effective detection and management of crop requirement, etc. This could be possible in future, by starting the M.Sc. and Ph.D. programs in the discipline of Agricultural Physics in all the state agricultural universities and research institutions of ICAR.

In the present syllabus emphasis on knowledge enrichment through field-based studies in the discipline of Agricultural Physics is made by introducing new courses on Satellite Meteorology, Nanotechnology, Image processing and development of sensors for Soil, Crop and Environment Monitoring in agriculture. In view of the various national program like Fasal Bhima Yojana the new modified syllabus for the Agricultural Physics include course content on Remote sensing for crop status monitoring, biomass burning, crop acreage and harvest etc. Similarly, in view of the various Government scheme like Soil Health Card, more crop per drop, etc. Our modified syllabus includes topics on Digital soil mapping, Farmers' participatory GIS, Nanobiosensors for monitoring crop irrigation, fertigation, etc. As per the under New Education Policy 2020, the present syllabus will ensure the students of Agricultural Physics discipline to become holistic individuals with identified set of skillsand values.

The modified syllabus with courses on Physics of Soil and Water Conservation, Fundamentals of Meteorology, General Climatology, Sensors for Soil, Crop and Environment Monitoring and Weather Hazards and its Management are related to the global developments to meet the triple challenges of feeding the growing global population, providing a livelihood for farmers, and protecting the environment. With the rise in the requirement for Biophysics, Remote sensing, nanotechnology, crop simulation modelling, biosensors, big data analytics artificial intelligence, etc. students of the discipline of Agricultural Physics will be a skilled work force as they will have the blend of multidisciplinary ability across the different disciplines of agricultural sciences.

Course Title with Credit Load
M.Sc. in Agricultural Physics

Course Code	Course Title	Credit Hours
AP 501*	Basic Concepts of Agricultural Physics -I	2+1
AP 502*	Basic Concepts of Agricultural Physics -II	3+0
AP 503	Fundamentals of Soil Physics	2+1
AP 504*	Mathematics in Agriculture	3+0
AP 505	Fundamentals of Meteorology	2+1
AP 506*	Principles of Biophysics	2+1
AP 507	Principles of Remote Sensing	2+1
AP 508	Physics of Soil and Water Conservation	2+1
AP 509	General Climatology	2+1
AP 510	Soil Physical Environment and Plant growth	2+1
AP 511	Simulation of Soil, Plant and Atmospheric Processes	2+1
AP 512	Principles of Physical techniques in agriculture	2+1
AP 513	Principles and Applications of GIS and GPS	2+1
AP 514	Nanoscience and Technology for Agriculture	2+0
AP 515	Remote Sensing in Agriculture	2+1
AP 591	Master's Seminar	1+0
AP 599	Master's Research	30

*the core courses compulsorily to be taken

Course Contents
M.Sc. in Agricultural Physics

I. Course Title : Basic Concepts of Agricultural Physics-I

II. Course Code : AP 501*

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the concepts of Agricultural Physics and physics laws.

V. Theory

Unit I

Relevance of Linear, circular, relative motions, conservation of mass, energy and momentum, forces in nature, range of their operation, action at a distance, gravitational field, potential, in agriculture.

Unit II

Concepts of Elasticity, stress-strain relations – moduli of elasticity, Hooke's law, molecular and structural basis of strengths of materials, hydrostatic pressure; surface tension, capillary rise, contact angle, hydrodynamics – laminar and streamline flow, Poiseuille's equation, Stoke's law and their application in agriculture.

Unit III

Principles of Thermometry, measurement of heat, specific heat, transfer of heat - conduction, convection and radiation, Change of phase, equation of state, vapour pressure and relative humidity, laws of thermodynamics, free energy, chemical potential along with their importance in agriculture.

Unit IV

Concepts of Kinetic theory of gases, Brownian motion, mean free path, simple harmonic motion, concepts of phase, phase difference, interference and reflection of sound waves, ultrasonic, along with their relevance in agriculture.

Unit V

Agricultural significance of Wave theory of light, Huygen's principle, reflection, refraction, diffraction, polarization, interference and scattering of light waves; electromagnetic theory of light, geometrical optics, aberrations, resolving power, principles of optical instruments, illuminated and luminous objects and light sources; luminescence, incandescence, fluorescence, auto-fluorescence, phosphorescence, bioluminescence, qualitative and quantitative measurement of light, colour, optical spectrometry.

Unit VI

Principles of Electric charges, potential, field, intensity and strength of electric field, current, Coulomb's law, dielectrics, capacitance, electrostatic units, resistance, resistivity, Ohm's law, steady currents in conductors, insulators and semi-conductors, magnetic materials, induced magnetism, electromagnetism, measurement of magnetic field, geomagnetism, effects of the earth's magnetic field on life, electromagnetic inductions and applications in agriculture

VI. Practical

Use of the instruments in agriculture: Vernier/ Screw Gauge/ Spherometer, Sextant, Surface Tension, Viscosity, Interference Phenomenon, Optical Instruments (diffraction grating), Resistivity measurement (Potentiometer/ Wheatstone bridge), Young's Modulus.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge ofprinciples and loaws of Physics and their application in agriculture

IX. Suggested Reading

- Rose CW, Ashhurst W, Flint HT. (Eds). 1966 *Agricultural Physics*. ISBN: 9781483139258, p. 248.
- Halliday D, Resnick R, Walker J. *Fundamentals of Physics*.
- Young HD, Freedman RA. *University Physics with Modern Physics*.
- Feynman RP, Leighton RB and Sands M. *The Feynman Lectures on Physics*
- Kittel C, Knight W and Ruderman MA. *Berkeley physics course: Mechanics* Vol. 1.
- Purcell EM. *Berkeley physics course: Electricity and Magnetism*, Vol. II.
- Crawford FS, Jr. *Berkeley physics course: Waves*. Vol. III
- Krishna R. 1960. *General Properties of Matter*, Kitab Mahal, Allahabad.
- Mathur DS. 1956. *Elements of Properties of Matter*, S Chand & Co, New Delhi.
- Sengupta PC and Kohli BS. 1967. *Text Book of Physics*, Vol I, II, Kitab Ghar, New Delhi.

I. Course Title : Basic Concepts of Agricultural Physics-II

II. Course Code : AP 502*

III. Credit Hours : 3+0

IV. Aim of the course

To impart knowledge on the concepts of Agricultural Physics and physics laws.

V. Theory

Unit I

Agricultural relevance of Maxwell's theory of electromagnetism, Atomic structure, Avogadro hypothesis and molecules, Atomic and molecular weights, atomic sizes, Quantum mechanics: uncertainty principle, De-Broglie hypothesis, Wave function, Eigen state, Schrodinger equation.

Unit II

Principles of Spectroscopy: atomic and molecular spectra, Spectroscopy: atomic and molecular spectra, Cathode rays; positive rays; Radio activity; alpha-, beta-, and gamma-rays; Rutherford's theory of the scattering of alpha particles; X-rays, nature and properties; scattering of X-rays by atoms; Diffraction of X-rays and Bragg's law; characteristic X-ray spectra.

Unit III

Principles of Quantum theory in agriculture: Planck's quantum theory of thermal radiation; Quantum theory and Photo-electric effect; Elements of special theory of relativity, Atomic Nucleus and its constitution, Angular momentum of the nucleus; Nuclear transmutation of elements; proton-neutron hypothesis; Cosmic rays; elementary particles.

Unit IV

Radioactivity in agriculture: Natural radioactivity, types of radiations Interaction of radiation with matter and decay; Isotopes; isotopic masses and abundances; mass spectrograph; Stable isotopes; atomic masses, packing fractions & binding energy, Theory of radioactive disintegration; half-life and mean life; Mass spectrometers

Unit V

Application of radioactivity in agriculture: Nuclear fission, fusion, Nuclear reactions, neutron moderation, Nuclear energy, atomic power; Production of artificial isotope. Physical principles of Radiation detection; Types of radiation detectors; efficiency of detectors; Uses of radiation detectors, Elements of radioactive sources, handling, Radiation protection and cardinal principles of radiation safety.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge ofphysics and its application in soil, plant and atmospheric continuum.

VIII. Suggested Reading

- Chandrasekharan H and Gupta N. 2006. *Fundamentals of Nuclear Science: Application in Agriculture*, Northern Book Centre, New Delhi.
- David H, Robert R, Jearl W. *Fundamentals of Physics*
- Young HD, Freedman RA. *University Physics with Modern Physics*
- Feynman RP, Leighton RB and Sands M. *The Feynman Lectures on Physics*
- Wichmann EH. *Berkeley physics course: Quantum physics.* Vol IV
- Slater John C. 1960. *Quantum Theory of Atomic Structure*, Vol.1, McGraw Hill, New York.
- Burcham E. 1995. *Nuclear Physics*, ELBS/Longman.
- Kapoor SS and Ramamurthy VS. 1986. *Nuclear Radiation Detectors*, Wiley Eastern Ltd, New Delhi.
- Pochin E. 1983. *Nuclear Radiation: Risks and Benefits*, Clarendon Press, Oxford.
- Rajam JB. 2000. *Atomic Physics*, S Chand and Co, New Delhi.
- Any Graduate level Text book of Physics, Lecture notes/hand-outs given in selected classes

I. Course Title : Fundamentals of Soil Physics

II. Course Code : AP 503

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge (both theoretical and practical) of the physical aspects of the soil and explains the processes of retention and transport of water, solute, heat and air in soil and their role for its proper management.

V. Theory

Unit I

Soil as a disperse polyphase system; mass-volume relationships of soil constituents; sample problems.

Unit II

Soil texture; nature and behaviour of soil particles; textural classes; particle-size analysis.

Unit III

Soil structure- genesis, classification and evaluation; soil aggregation and dispersion; soil conditioners; soil tilth.

Unit IV

Consistency; consistency limits; soil strength and its measurement; swelling and shrinkage; soil compaction; soil crusting; phenomenon and implications.

Unit V

Soil water retention; soil water constants; energy concept of soil water; different components of soil water potential; measurement of soil water content and potential; soil moisture characteristics; hysteresis.

Unit VI

Flow of water in soils; saturated and unsaturated flow; hydraulic conductivity of soils; soil-water diffusivity; measurement of saturated and unsaturated hydraulic conductivity.

Unit VII

Infiltration, redistribution and evaporation of water; soil water balance; permeability; drainage.

Unit VIII

Soil aeration and its characterization; measurement of soil aeration; gaseous diffusion; factors affecting.

Unit IX

Soil temperature and significance; thermal properties of soils; energy balance and mode of heat transfer in soils; factors affecting soil temperature; measurement of soil temperature; management of extreme soil temperatures.

VI. Practical

- Particle-size analysis by hydrometer method and international pipette method
- Determination of particle density and bulk density of soils
- Soil water content determination
- Measurement of soil water potential by using tensiometer
- Soil-moisture characteristics
- Aggregate analysis by wet and dry sieving methods
- Measurement of Atterberg limits
- Measurement of soil strength
- Determination of saturated and unsaturated hydraulic conductivity
- Determination of infiltration rates

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Baruah TC and Barthakur HP. 2001. *Textbook of Soil Analysis*. Vikas Publishing House Pvt. Ltd, New Delhi.
- Ghildyal BP and Tripathi RP. 1987. *Soil Physics*. Wiley Eastern and New Age International, New Delhi.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press, New York.
- Hillel D. 1998. *Environmental Physics*, Academic Press, New York.
- Jury WA, Gardner W and Horton R. 2004. *Soil Physics*. John Wiley and Sons, New York.
- Klute A. (Ed). 2006. *Methods of Soil Analysis*. Part 1. *Physical and Minerological Methods* (SSSA Book Series No. 5), ASA and SSSA, Madison, Wisconsin.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*, Marcel Dekker, New York.
- Warrick AW. (Ed). 2002. *Soil Physics Companion*, CRC Press, Boca Raton.

I. Course Title : Mathematics in Agriculture

II. Course Code : AP 504*

III. Credit Hours : 3+0

IV. Aim of the course

To impart the theoretical and practical knowledge of mathematical concept in agriculture.

V. Theory

Unit I

Vectors, matrices and determinants, inversion of matrices, Eigen values and Eigen vectors, Orthogonality, Grahm-Schmidt processes, least square problems.

Unit II

Trigonometric functions and relations.

Unit III

Differentiation, Integration, Integration, applications, linear equations, Non-linear equations, Polynomials, Partial differential equations.

Unit IV

System of coordinates, Cartesian, cylindrical, spherical and polar coordinates, Three-dimensional geometry, Relative motion of frame of reference.

Unit V

Probability, probability distributions and applications, Curve fitting, Regression, Correlation, Linear and non-linear.

Unit VI

Geo-statistics, Averaging and scaling methods, Fourier analysis, Numerical approximation, Numerical analysis, finite element method, Monte carlo analysis, Stochastic methods, Iterative and optimal techniques.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of mathematics in developing models in relation to plant growth, soil dynamics and atmospheric processes.

VIII. Suggested Reading

- Pal SK. *Statistics for Geoscientist-Techniques and application*
- Reddick HW. *Advanced Mathematics for Engineers*
- Ray M and Sharma HS. *Mathematical statistics*
- Wylie CR. *Advanced Engineering Mathematics*

I. Course Title : Fundamentals of Meteorology

II. Course Code : AP 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge about basic physical processes in the atmosphere which have direct and indirect relevance to agriculture.

V. Theory

Unit I

Atmosphere and its constituents, weather and climate; meteorology- meaning and scope; historical development; meteorological elements, instruments for measurement of meteorological elements; different branches of meteorology.

Unit II

Meteorological observatory and its classes; theory and working principles of surface meteorological instruments; automatic weather station; meteorological organizations – IMD, NCMRWF, IITM, WMO.

Unit III

Sun and earth; solar radiation and Laws of radiations-Plancks law, Stefan-Boltzman Law, Wiens displacement law, Kirchoffs law, solar constant; radiation receipt on earth surface; atmospheric and astronomical factors affecting solar radiation; ozone hole; albedo and net radiation sensible and latent heat, direct and diffuse radiation; radiation balance of the earth and atmosphere.

Unit IV

Thermal profile of the atmosphere; variation of pressure with height; hydrostatic equation and its application in atmosphere; geopotential, standard atmosphere, altimetry; concept of specific heat at constant volume and pressure; First and second law of thermodynamics, gas laws.

Unit V

Atmospheric moisture, vapour pressure, relative humidity, absolute humidity, specific humidity, mixing ratio, dew point temperature, vapour pressure deficit, psychromatric equations, T-phi diagram; lapse rates; Vertical stability of atmosphere, Virtual and potential temperature, moist and dry adiabatic process; tropical convection.

Unit VI

Atmospheric motion; balancing forces- pressure gradient and Coriolis forces; isobar; pressure systems; geostrophic, cyclostrophic, thermal and gradient winds; trough, ridge and col; Divergence and vertical motion Rossby, Richardson, Reynolds and Froude numbers.

Unit VII

Cyclonic and anticyclonic motions, tropical and extra-tropical cyclones and their structure, cyclone tracks over Indian regions; Air masses and fronts; Land and sea breeze; Mountain and valley winds.

Unit VIII

Clouds and their classification, theories of cloud formation, condensation nuclei, precipitation processes; artificial rain making, thunderstorms and dust storms; haze, mist, fog and dew, hail, hail suppression, fog and cloud – dissipation.

Unit IX

Weather charts and its reading, weather forecasting – now-cast, short, medium and long-range forecasting, numerical weather prediction; synoptic charts and synoptic approach to weather forecasting. Meteorological satellites for weather forecasts; forecast of Indian monsoon rainfall.

VI. Practical

- Visit to meteorological observatory; meteorological instruments, Recording of weather parameters;
- Calculation of daily, weekly and monthly statistics;
- Exploration of meteorological websites – IMD, NCMRWF, IITM and WMO;
- Calculation of standard meteorological weeks and Julian days;
- Visual classification of clouds;
- Understanding synoptic weather charts;
- Climatic normal, climatic chart and identification of low and high pressure systems.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

X. Suggested Reading

- Barry RG and Chorley RJ. 1982. *Atmosphere Weather and Climate*. ELBS (UK).
- Byers HR. 1959. *General Meteorology*. McGraw Hill (New York).
- Ghadekar SR. 2001. *Meteorology*. Agromet Publishers (Nagpur)
- Ghadekar SR. 2002. *Practical Meteorology*. Agromet Publishers (Nagpur).
- Menon PA. 1989. *Our Weather*. NBT (New Delhi).
- Petterssen S. 1958. *Introduction to Meteorology*. McGraw Hill (New York).
- Trewartha GT. 1954. *An Introduction to Climate*. McGraw Hill (New York).

I. Course Title : Principles of Biophysics

II. Course Code : AP 506*

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of interactive effects of various physical forces on life processes and their applications.

V. Theory

Unit I

Introduction and scope of biophysics, Weak and strong interactions in biological systems, Structure and property of water, Physical, chemical and biological origin of life

Unit II

Experimental techniques used for separation and characterization of bio-molecules: sedimentation, ultra-centrifugation, diffusion, osmosis, viscosity, polarization and electrophoresis, chromatography, amino acid and nucleotide sequence analysis.

Unit III

Spectroscopic techniques for bio-molecular characterization: UV-Visible, IR, NMR, EPR spectroscopy, X-ray diffraction & its application in biology

Unit IV

Physics of photosynthesis, transpiration, chlorophyll fluorescence, principles of thermal and fluorescence imaging and its application in agriculture

Unit V

Principles of magnetic seed treatment and its application in agriculture, Transport phenomena in biological systems, active and passive transport; absorption and germination kinetics of seeds, tissue water status and its characterization by NMR, principles of NIR and its application in non-destructive characterization of grain quality

Unit VI

Fiber physics; strength, physical properties, micronaire, elastic properties, tensile strength, thermal resistance, water absorption, breaking, elongation, crystallinity

Unit VII

Bio-energetic- First and second laws of thermodynamics- Heat, work, entropy and free energy, Concept of negative entropy & its application in living systems; Information theory.

VI. Practical

- Spectroscopy-Verification of Beer-Lambert's law;
- Spectroscopy-Absorption spectrum of chlorophyll a & b;
- Viscometer-Measurement of intrinsic viscosity and molecular mass;
- Polarimeter-Measurement of molar rotation;
- Measurement of leaf water potential;
- Measurement of Osmotic potential of seed;
- NMR spectroscopy- Relaxation time measurements, NMR Spectroscopy oil content measurement;
- Leaf Photosynthesis, Measurement of LAI.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on biological parameters in relation to crop development and yield

IX. Suggested Reading

- Cotterill RMJ. 2002. *Biophysics- An Introduction*, John Wiley & Sons, Ltd.
- Daniel M. 2005. Agrobios. *Basic Biophysics for Biologists.*
- Narayanan P. 2003. *Essentials of Biophysics* New Age International Publishers.
- van Holde KE, Johnson WC and P Shing Ho. 2006. *Principles of Physical Biochemistry*. Printice-Hall International, Inc.
- Wilson K and Walker J. *Practical Biochemistry-Principles and Techniques* Cambridge University Press.

I. Course Title : **Principles of Remote Sensing**
II. Course Code : **AP 507**
III. Credit Hours : **2+1**

IV. Aim of the course

To teach about basic principles and techniques of remote sensing and introduce its applications.

V. Theory

Unit I

Introduction, electromagnetic radiation, electromagnetic spectrum, physics of remote sensing, radiation interactions with the atmosphere and target, radiometric quantities, BRDF/BRF, remote sensing systems, characteristics of images

Unit II

Platforms, orbits, classification of sensors, satellite characteristics, pixel size, and scale, spectral, radiometric and temporal resolution

Unit III

Spectral signatures of natural targets in optical and thermal regions, physical basis of signatures, spectral indices.

Unit IV

Imaging and nonimaging systems, multispectral imaging, hyperspectral imaging, thermal imaging, microwave and LIDAR, Fluorescence imaging, aerial remote sensing

Unit V

Weather, land, ocean and other observation satellites, Indian remote sensing satellites, data reception, data products

Unit VI

Thermal remote sensing: Principles, signature, measurements, IR detection and imaging technology

Unit VI

Microwave remote sensing: principles, signatures, interferometry, radar basics, viewing geometry and spatial resolution, image distortion, target interaction, image properties.

Unit VII

Image analysis: Visual interpretation, digital image processing, pre-processing, enhancement, transformations, classification, accuracy, integration, processing of multispectral, hyperspectral, thermal and microwave images.

Unit VIII

Overview of remote sensing applications in earth resource management: agriculture, meteorology, forestry, land cover/land use, water resources

VI. Practical

- Use of Spectroradiometer, Use of FTIR, Spectral signatures of different materials; Derivation and analysis of vegetation indices;
- Analysis of emissivity spectra;
- Familiarization with satellite imagery (FCC);

- Visual Image Interpretation;
- Satellite data acquisition and satellite Data Receiving Station;
- Digital Image processing – Introduction to software, GPS and Ground truth Collection;
- Digital image processing: Pre-processing, Enhancement and training site collection, classification and Post Classification Accuracy Assessment.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and their utility in research for solving field problem.

IX. Suggested Reading

- Campbell JB. 1996. *Introduction to Remote Sensing*, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.) 1983. *Manual of Remote Sensing*, Vol.I, American Society of Photogrammetry, Falls Church, Va.
- Curran PJ. 1985. *Principles of Remote Sensing*, Longman, London.
- David L Verbyla. 1995. *Satellite Remote Sensing of Natural Resources*, Lewis Pub.
- George Joseph. 2005. *Fundamentals of Remote Sensing*, 2nd ed., University Press.
- Jansen JR. 2004. *Introductory Digital Image Processing: A Remote Sensing Perspective*, 3rd ed., Prentice Hall.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. *Remote Sensing and Image Interpretation*, 5th ed., John Wiley & Sons, Inc., New York.
- Panda BC. 2008. *Principles and Applications of Remote Sensing*, Viva Publications.
- Sabins FF. 1996. *Remote Sensing: Principles and Interpretations*, 3rd ed., W.H. Freeman.

I. Course Title : Physics of Soil and Water Conservation

II. Course Code : AP 508

III. Credit Hours : 2+1

IV. Aim of the course

To teach about extent and significance of different forms of soil erosion and their control measures.

V. Theory

Unit I

History of soil erosion; geological and accelerated erosion; agents of soil erosion; acceptable limits of soil erosion.

Unit II

Physics of soil erosion by water; types of water erosion - sheet erosion, splash erosion, rill erosion, gully erosion; specialized forms of soil erosion- pedestal erosion, pinnacle erosion, piping, slumping.

Unit III

Soil erodibility; factors affecting soil erodibility - soil physical characteristics, land management, crop management; soil erodibility indices; empirical constants.

Unit IV

Rainfall erosivity; estimation of rainfall erosivity - EI_{30}index and kinetic energy, and their calculations; erosivity indices.

Unit V

Runoff measurements – current meters, flumes, weirs and orifice, stage level recorder, hydrographs; runoff estimation - quantities and rates of runoff, Rational formula, Cook's method.

Unit VI

Sediment measurement - multiplot divisor, Coshocton wheel sampler, point and depth integrated sediment samplers; universal soil loss equation; estimation of soil loss and its prediction.

Unit VII

Physics of wind erosion - wind velocity, initiation and movement of soil particles; saltation, suspension and surface creep; soil physical properties affecting wind erosion.

Unit VIII

Overview of soil and water conservation in India; soil and water conservation research; techniques for soil and water conservation for agricultural and non-agricultural land - use of mechanical structures and biological methods; wind erosion control.

Unit IX

Concept of watershed development and management - size and shape of watershed; characterization and management of watersheds using remote sensing and GIS; understanding concept of integrated watershed management through case studies.

VI. Practical

- Determination of soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index; computation of kinetic energy of falling rain drops
- Measurement of land slope using Abney's level
- Computation of rainfall erosivity index (EI_{30}) using rain gauge data
- Estimation of surface runoff/water flow using different techniques
- Estimation of soil losses
- Visit to a watershed

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil water environment and their utilization in crop growth

IX. Suggested Reading

- Fangmeier DD, Elliot WF, Wookman SR, Huffman RL and Schwab GO. 2006. *Soil and Water Conservation Engineering*. Delmer Learning.
- Flanagan DC. (Ed.). 1990. *WEPP* Second Edition, USDA-Water Erosion Prediction Project; Hill Slope Profile Model Documentation Corrections and Additions. NSERL Rpt. No. 4. National Soil Erosion Res. Services, USDA.
- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Pierce FJ and Frge WW. 1998. *Advances in Soil and Water Conservation*. CRC Press.
- Renald KG, Foster GR, Weesies GA, Cool DK and Yoder DC. 2000. *Predictory Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. Agricultural Handbook AH 703. USDA.

- Singh G, Babu R and Chandra S. 1981. *Soil Loss Prediction Research in India*. Central Soil and Water Conservation Research and Training Institute, Dehradun. Bull. No. T12/D9.

I. Course Title : General Climatology
II. Course Course : AP 509
III. Credit Hours : 2+1

IV. Aim of the course

To learn about the climatic controls, climatic classifications, and their relevance in agriculture

V. Theory

Unit I

Sun and earth, solar system, solar constant; latitudes and longitudes of the earth, seasons, rotation and revolution, solstices and equinoxes, radiation receipt on earth surface, radiation balance of the earth and atmosphere.

Unit II

Earth's environment- atmosphere, hydrosphere, lithosphere and biosphere: Atmospheric constituents: Weather and climate- weather and climatic elements.

Unit III

Climatic controls, latitudinal and seasonal variation of insolation, temperature, pressure belts & wind system, precipitation.

Unit IV

Climatic classification: Koppen and Thornthwaite systems, Hargreaves, Troll, Trewartha and Papadakis systems. Climatic types- continental, maritime and monsoon climate; climatic indices, climatic zones.

Unit V

Climatology of India; monsoons -origin, branches onset, progress and withdrawal of south-west monsoon monsoon breaks, rainfall variability; El Nino, La Nina, QBO (quasi-biennial oscillation) and ENSO and their impacts on Indian economy. North-east monsoon. North- western disturbances and nor 'wester shower.

Unit VI

Climate change and global warming, disastrous weather and climatic events in different regions and their frequencies. Heat & cold wave, frost, dust storm, lightning & thunderstorm, cyclone, cloud burst, drought and flood - their impacts on public life and agriculture.

Unit VII

Drought climatology- Concept, definition, types of drought and their causes; rainfall and its variability, intensity, duration, beginning and end of drought and wet spells; moisture availability indices; Monitoring of drought; drought indices, crop water stress index, crop stress detection;

VI. Practical

- Calculations of climatic normal;
- Determination of climate type of particular station using different climate classification systems;

- Rainfall probability analysis;
- Computation of drought indices;
- Indices for extreme weather events;
- Climatic water balance for climate classification.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

Books

- Barry RG and Chorley RJ. 1982. *Atmosphere Weather and Climate*. ELBS (UK)
- Critchfield HJ. 1982. *General Climatology*. Prentice Hall of India (New Delhi).
- Das PK. 1995. *The Monsoon*. NBT (New Delhi).
- Haurwitz B and Austin JM. 1944. *Climatology*. McGraw-Hill.
- Lal DS. 2011. *Climatology* Sharda Pustak Bhavan, (Allahabad).

Journals

- *Journal of Climate*
- *International Journal of Climatology*
- *Climate and Development*
- *Climate Change*
- *Nature- Climate Change*

I. Course Title : Soil Physical Environment and Plant Growth

II. Course Code : AP 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about characterization and management of soil physical environment in relation to plant growth and yield.

V. Theory

Unit I

Introduction: Effect of soil physical properties on plant growth - soil water, soil air, soil temperature, mechanical impedance and tillage practices.

Unit II

Soil water: Soil moisture – plant water relations, available water, newer concepts of water availability, least limiting water range, soil-plant-atmosphere system as a physical continuum, plant uptake of soil moisture, evaporation, transpiration and evapotranspiration, dynamics of water in the soil-plant-atmosphere continuum.

Unit III

Root growth – germination and seedling emergence, hydraulic properties of roots, characterization of root growth parameters, water balance of the root zone, soil physical properties and root growth, flow of water to roots.

Unit IV

Soil Temperature – effect of soil temperature on plant growth, soil temperature management, thermal regimes, mulching, radiation – heat budget and energy balance in the field, radiation use efficiency, radiation exchange in the field, exchange of heat and vapour to the atmosphere.

Unit V

Aeration – critical oxygen concentration and factors affecting.

Unit VI

Field water balance – field water balance, irrigation and water use efficiency, consumptive use, plant uptake of soil moisture

Unit VII

Nutrient uptake and use by plants, managing soil physical condition for improved nutrient use efficiency, integrated nutrient management in relation to soil physical condition.

Unit VIII

Resource conservation technologies- bed planting & zero-tillage - types, suitability and effect on soil physical properties, other resource conservation technologies and the impact (short and long term) on soil health.

Unit IX

Modelling: Interactions of soil, management and climatic factors on plant growth, development of sustainability indices.

VI. Practical

- Measurement of penetration resistance and LLWR, Plant water potential;
- Field saturated hydraulic conductivity, transpiration using Porometer;
- Root Length Density, Root Diameter, Root weight using Root Scanner, plant N content;
- Germination percentage as affected by temperature;
- Estimation of evapotranspiration losses, estimation of consumptive water use, production functions, field water balance components, water uptake by plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on soil physical environment to solve field problem

IX. Suggested Reading

- Doorenbos J and Pruitt WO. 1975. *Crop Water Requirements*. FAO Irrigation and Drainage Paper 24. Rome.
- Hanks and Ascheroft. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1971. *Soil and Water: Physical Principles and Processes*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press. Slatyer RO. 1967. P*lant- Water Relations*. Academic Press.

I. Course Title : Simulation of Soil, Plant and Atmospheric Processes

II. Course Code : AP 511

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of using simulation models for crop-environment interactions

V. Theory

Unit I

Fundamentals of dynamic simulation, systems, models and simulation.

Unit II

Descriptive and explanatory models, modelling techniques steps, states, rates and driving variables, feedbacks and relational diagrams.

Unit III

Numerical integration, introduction to FST language.

Unit IV

Modelling crop environment and crop pest interactions, soil water, nitrogen and balance, introduction to a simple crop ecological model, applications of simulation modelling in environmental impact assessment and greenhouse gas emission.

Unit V

Data requirements and limitations of modelling; modelling crop-environment and pest interaction, soil, water, nitrogen and C balance; assessing crop growth, scheduling and management practices and water use planning through simulation tools.

VI. Practical

- Scheduling planting and harvesting of crops;
- Drawing relational diagrams;
- Applying numerical integration techniques;
- Fitting probability distribution functions;
- Hands on model validation through statistical indices;
- FST programming language;
- Hands on to InfoCrop model;
- Assessing crop growth through InfoCrop model;
- Hands on to USAR model, Crop rotation & water use planning through USAR model.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on simulation model for solving problems in field.

IX. Suggested Reading

- Cox GW, Atkins MD. 1979. *Agriculture Ecology*. Freeman & Co.
- Etherington JR. *Environmental and Plant Ecology*. John Wiley Sons.
- Mitchell R. *The analysis of Indian agro-ecosystem*.
- Odum OP. *Ecology*. Oxford & IBM Publishing Co.
- Sinclair TR and Gardener FP (Eds). *Principle of ecology in plant production*. CABI, UK.

I. Course Title : Principles of Physical Techniques in Agriculture

II. Course Code : AP 512

III. Credit Hours : 2+1

IV. Aim of the course

To educate about different optical, electrical, colorimetric and nuclear techniques used in agriculture.

V. Theory

Unit I

Principles of measurements; laboratory, field and regional scales.

Unit II

Principles of optical and polarized microscopes; reflection, transmission and absorption in relation to properties of object; colorimetric techniques; single and double beam instruments; spectrophotometry; Beer and Lambert law; fluorescence; Raman spectra.

Unit III

Sensors and transducers; principles of leaf area meter, canopy analyser, quantum sensor, Spectro-radiometer, laser land leveller; photosynthetic system analyser for determination of plant water and photosynthetic parameters.

Unit IV

Principles of infrared thermometry; thermal imaging, emissivity laws; characteristics of agricultural materials.

Unit V

Principles of X-ray and its applications in clay mineralogy; small angle scattering.

Unit VI

Principles and applications of electron microscopes; transmission and scanning electron microscopes; confocal microscope and its applications.

Unit VII

Atomic absorption spectroscopy - principles, detection limits and sensitivity.

Unit VIII

Nuclear techniques - detection and measurements of charged particles, radiation monitoring instruments, radiation hazards evaluation and protection. Tracer methodology - isotopes and their applications in agriculture, gamma irradiation for genetic variability

Unit IX

Concepts of Nano Science and technology and their applications in agriculture

Unit X

NMR, NIR, mass spectrometer - principles and applications.

V. Practical

- Discharge of electricity through gases
- Ionization current measurements
- Photoelectric effect and measurements
- Geiger Muller counter- quenching time
- Thickness measurement of thin films/ foils/ paper sheets
- Half-life determination
- Tracer applications of artificial radionuclides
- Multi-channel analyser
- Neutron moisture meter
- Use of NMR spectrometer
- Seed irradiation with gamma rays
- Radiocarbon dating.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Basic knowledge on, electrical, colorimetric and nuclear techniques used in agriculture.

VIII. Suggested Reading

- Arnikar HJ. 1989. *Isotopes in the Atomic Age*. Wiley Eastern.
- Bhaskaran S, Ghosh SK and Sethi GR. 1973. *Proceedings of the International Symposium on Use of Isotopes and Radiation in Agriculture and Animal Husbandry Research,* Nuclear Research Laboratory, IARI, New Delhi.
- Broetjes C. 1965. *The Use of Induced Mutations in Plant Breeding*. Pergamon Press.
- Burcham E. 1995. *Nuclear Physics*. ELBS/Longman.
- Glasstone S. 1967. *Source Book of Atomic Energy*. Affiliated East West Press.
- Kapoor SS and Ramamurthy VS. 1986. *Nuclear Radiation Detectors*. Wiley Eastern.
- Pochin E. 1983. *Nuclear Radiation: Risks and Benefits*. Clarendon Press.
- Rajan JB. 2000. *Atomic Physics*. S Chand & Co.
- Tiwari PN. 1985. *Nuclear Techniques in Agriculture*. Wiley Eastern. Wolf G. 1964. *Isotopes in Biology*. Academic Press.

I. Course Title : Principles and Applications of GIS and GPS

II. Course Code : AP 513

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on dealing with spatial data and its applications in natural resource management.

V. Theory

Unit I

Introduction; History of cartography and maps.

Unit II

Basic concepts and principles; hardware and software requirements; common terminologies of geographic information system (GIS).

Unit III

Geographical data structures; relational database management system; overview of MS Access.

Unit IV

Maps and projections: principles of cartography; Basic geodesy: Geoid/ Datum/ Ellipsoid; cartographic projections, coordinate systems, types and scales; accuracy of maps.

Unit IV

GIS data collection, linking spatial and non-spatial data; Errors and quality control, data output.

Unit V

Raster based GIS: spatial referencing, definition and representation, data structure, advantages and disadvantages; Vector based GIS: Definition, concept, data structure, capture and Vector and raster formats, vector to raster and raster to vector conversion, advantages and disadvantages

Unit VI

Principles of graph theory, topology and geometry; spatial analysis: statistical analysis, measurement, proximity (buffering), overlay analysis, classification, network analysis, multicriteria analysis, site suitability analysis, nearest neighbour analysis.

Unit VII

Surface modelling: Thiessen polygon, interpolation, DEM; Geostatistical analyses, spatial and non-spatial query.

Unit VII

Software and hardware requirements of GIS; Integrated image analysis and GIS; GIS for modelling.

Unit VIII

Web GIS/ Geoportal, 3D GIS, object-oriented GIS, mobile GIS, knowledge-based GIS; data warehousing, data mining; metadata, data interoperability, open GIS consortium, GIS customization, DSS and SDSS.

Unit IX

Applications of GIS for water resources, agriculture, precision farming, disaster management, e-governance, Agricultural Research Information System (ARIS).

Unit X

Basic Concepts, segments, working principles; Measuring distance and timing, errors in GPS data and correction; Differential GPS; Integration of GPS data with GIS data, use of GPS in remote sensing analysis; Past, present and future status of GPS; Applications of GPS in agriculture and natural resource management.

VI. Practical

- Overview of current GIS software: ArcMap/ArcGIS/QGIS;
- Introduction to MS Access;
- Data input (spatial data); digitization and scanning;
- Data input: editing, Data input: non-spatial attributes and linking with spatial data;
- Database creation and map registration;
- Spatial analysis: Surface modelling, overlaying, buffering, neighbourhood analysis, Coordinate data collection through GPS and its integration with GIS.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and GPS and their utility in research for solving field problem.

IX. Suggested Reading

- Burroughs PA. 1986. *Geographical information systems for land resources assessment*. Oxford University Press
- Chakraborty D and Sahoo RN. *Fundamentals of Geographic Information System*, Viva Books Pvt. Ltd, New Delhi.

- Laurini R and Thompson D. 1992. *Fundamentals of Spatial Information Systems*. London, Academic Press, New York.
- Longley PA, Goodchild MF, Maguire DJ and Rhind DW. 1997. *Geographical Informatics Systems*. II Edition, New York, John Wiley. Online useful materials

Websites

http://www.gisdevelopment.net/tutorials/tuman006.htm
- http://www.colorado.edu/geography/gcraft/notes/datacon/datacon_f.html
- http://egsc.usgs.gov/isb/pubs/gis_poster/ http://www.quantdec.com/SYSEN597/
- http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Tutorials (especially for ArcGIS user)

I. Course Title : Nanoscience and Technology for Agriculture

II. Course Code : AP 514

III. Credit Hours : 2+0

IV. Aim of the course

To impart basic knowledge about nanoscience, properties of nanoparticles and their applications in biology.

V. Theory

Unit I

Outline of the course; Nanostructure: growth of compound semiconductors, super lattices, self-assembled quantum dots, Nano-particles, nano tubes and Nano wires, fullerenes (buck balls, grapheme), Nanofabrication and nano-patterning; Optical, X-ray, and electron beam lithography, self-assembled organic layers, Process of synthesis of nano powders, Electro-deposition, Important nano materials.

Unit II

Mechanical properties, Magnetic properties, Electrical properties, Electronic conduction with nano particles, Investigating and manipulating materials in the nanoscale; Electron microscopy, scanning probe microscopy, optical microscopy for nano science and technology, X-ray diffraction, scanning tunnelling microscopy, atomic force microscopy.

Unit III

Nano-biology: Interaction between biomolecules and nano-particle surface, Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies. Applications of nano in agriculture, current status of nano biotechnology, Future perspectives of Nanobiology, Nano sensors.

Unit IV

Types of nanomaterial hazard their identification, toxicity and exposure assessment, threshold limit, characterization, health risk assessment.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VI. Learning outcome

Experience on the knowledge of nano science and their utility in agricultural research.

VII. Suggested Reading

- Balndin AA and Wang KL. (Ed.) 2006. *Handbook of semiconductor nanostructure and nanodevices*. American Scientific Publishers, California.
- Challa Kumar (Ed.). 2006. *Nanotechnologies for the life sciences*. Willey-VCH GmbH, Weinheim.
- Gregory Timp. 1999. *Nanotechnology*. Springer Verlag, New York.
- Margaret E Kosal. 2009. *Nanotechnology for chemical and biological defence*. Springer, Dordrecht.
- Michael Kohler and Wolfgang Frintzsche. 2007. *Nanotechnology: Introduction to nano structuring techniques*. Wiley-VCH Verlag GmbH, Weinheim.

I. Course Title : Remote Sensing in Agriculture (Pre-requisite AP 507 Principles of Remote Sensing)

II. Course Code : AP 515

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about the remote Sensing techniques and their applications in agriculture.

V. Theory

Unit I

Scope of remote sensing in agriculture, sensors platforms and data availability for agricultural remote sensing and recent developments.

Unit II

Remote Sensing of soil spectroscopy of soils, differentiation and identification of soils, soil parameters by hyperspectral remote sensing, soil survey and resource mapping, soil health.

Unit III

Crop identification and discrimination, crop acreage estimation, monitoring of crop growth and phenology, yield modelling and forecasting.

Unit IV

Retrieval of crop biophysical parameters – empirical and radiative transfer approaches, assessing crop abiotic and biotic stresses, monitoring agricultural drought and early warning, crop loss assessment and insurance using remote sensing.

Unit V

Land use/ land cover mapping and change detection analysis, land use modelling, cropping system analysis land planning with reference to different agro eco-regions, land degradation process (Salinity, waterlogging, etc) and their evaluation by remote sensing.

Unit VI

Role of remote sensing in water resource development and management, identification of ground water potential zones, generation of different thematic maps for integrated watershed management; Microwave remote sensing for crop and soil studies, soil moisture mapping, flood assessment and management by remote sensing.

Unit VII

Precision farming principles - VRT, Modern techniques and machines. Remote sensing for plant phenotyping, post-harvest quality assessment.

VI. Practical

- Use of Infrared thermometry and spectral data for crop stress monitoring;
- Hyperspectral data for soil and crop characterization;
- Computation of Spectral Indices for Soil and Vegetation;
- BRDFs and Radiative transfer modelling, processing of microwave remote sensing data;
- Salinity mapping from remote sensing data; Pre-processing of time series satellite data;
- Crop discrimination and acreage estimation;
- Crop yield modelling from satellite data;
- Land use land cover classification and change detection;
- Drought and crop condition monitoring, processing of image data for plant phenotyping.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and GPS and their utility in research for solving field problem.

IX. Suggested Reading

- Barret EC and Curtis LF. 1982. *Introduction to Environmental Remote Sensing*, Chapman & Hall, London.
- Colwell RN. (Ed.) 1983. *Manual of Remote Sensing*, Vol. II, American Society of Photogrammetry, Falls Church, Va.
- Jensen JR. 2006. *Remote Sensing of the Environment: An Earth Resource Perspective*, 2nd ed., Prentice Hall.
- Narayan LRA. 1999. *Remote Sensing and its Applications,* Oscar Publ.
- Patel AN and Singh S. 2004. *Remote Sensing: Principles and Applications*. Scientific Publ.
- Thenkabail P, Turral H, Biradar C and Lyon JG. (Eds) 2009. *Remote Sensing of Global Croplands for Food Security,* CRC Press.
- Ustin S. 2004. *Remote Sensing for Natural Resource Management and Environmental Monitoring*, 3rd ed., Wiley.

Course Title with Credit Load
Ph.D. in Agricultural Physics

Course Code	Course Title	Credit Hours
AP 601*	Principles of Soil Physics	2+1
AP 602	Applied Soil Physics	2+1
AP 603	Crop Micrometeorology and Evapotranspiration	2+1
AP 604*	Digital Image Processing	1+1
AP 605	Satellite Agrometeorology	2+1
AP 606	Sensors for Soil, Crop and Environment Monitoring	2+1
AP 607	Weather Hazards and its Management	2+0
AP 691	Doctoral Seminar I	1+0
AP 692	Doctoral Seminar II	1+0
AP 699	Doctoral Research	75

*the core courses compulsorily to be taken

Course Contents
Ph.D. in Agricultural Physics

I. Course Title : Advanced Soil Physics (Pre-requisite AP 503 Fundamentals of Soil Physics)

II. Course Code : AP 601

III. Credit Hours : 2+1

IV. Aim of the course

To study the physical processes for transport of water, solute, heat and air in soil using advanced mathematical tools and techniques.

V. Theory

Unit I: Mathematical tools

Vector calculus: gradient, divergence and curl of a vector. Fourier series, Laplace and inverse Laplace transforms and their applications for solving flow and transport equations in soil analytically; Numerical approximations: finite difference methods for solving transport equations. Iterative procedures for solving linear and nonlinear equations, Monte Carlo simulation.

Unit II: Soil water transport

Saturated flow equations: Poiseuille's and Darcy's equations, Laplace equation of steady flow and Poisson equation for unsteady flow, three-dimensional saturated hydraulic conductivity and fluxes, Specific Storage Coefficient, Aquifer Transmissivity, conductance coefficient, Effective hydraulic conductivity for layered soils.

Unsaturated flow equations of Vadose zone: Buckinghum-Darcy equation, Richards equation; Unsaturated flow parameters: Unsaturated Hydraulic conductivity: Models for estimation – Gardener's model, van Genucheten model, Brooks and Corey model and Kosugi model; Capillary Length Scales: Macroscopic and microscopic capillary lengths; Woodings equation for steady infiltration from a shallow ponded ring. Preferential flow: Macropore Flow, fingering and Funnel flow; Measurement of saturated and unsaturated hydraulic conductivity: Lab methods- constant head and falling head methods, Field methods- infiltrometers and permeameters, instantaneous profile and field inverse methods; Numerical models of water flow - finite difference method.

Infiltration models: Empirical models-Kostikov model, Horton model, Physical models - Green-Ampt and Philip models both for horizontal and vertical infiltration, Boltzmann transformation of wetting front for solving water flow during horizontal and vertical infiltration, computation of profile controlled and supply controlled infiltration along with time of ponding, homogeneous and layered soil infiltration, curve number method, preferential flow.

Solute transport: solute transport mechanisms: mass flow, diffusion, hydrodynamic dispersion, miscible and immiscible displacement, hypothetical and experimental breakthrough curves, Convective-Diffusive equation (CDE), linear and non-linear adsorption, solution of CDE, analytical solution by Laplace transformation, numerical solutions by finite difference and finite element methods, applications, methods of determination of dispersion and diffusion coefficients.

Unit III: Soil heat flow

Equation of heat transport by conduction and its sine wave solution, damping depth and its significance. Measurement of soil thermal conductivity by single and dual probe and thermal diffusivity by time lag and amplitude-based methods. Computation of volumetric heat capacity by de Vries method. Soil heat flux measurement by heat flux plates. Estimation of thermal diffusivity by finite difference method.

Unit IV: Movement and exchange of gases in soils

Darcy's law for advective transport (non-isobaric system) of gases, deviation from Darcy's law, gas transport by diffusion in isobaric system (Fick's law). Multi component gas transport- Dusty Gas model, Stefan Maxwell equation. Gas permeability: laboratory and field measurement of gas permeability.

VI. Practical

- Guelph Permeameter for field saturated hydraulic conductivity;
- Hydraulic conductivity by instantaneous profile method;
- Computation of dispersion and diffusion coefficients of CDE;
- Calibration of parameters of Green and Ampt and Philip models and calculation of time of ponding, measuring thermal properties in field;
- Bruce and Klute method for computing hydraulic diffusivity under horizontal infiltration, Modelling water and heat transport in soil.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Daniel Hillel. *Advanced Soil Physics*.
- Kirkham and Powers. *Advanced Soil physics*.
- Warrick AW. *Soil Physics Companion*.

I. Course Title : Applied Soil Physics
(Pre-requisite AP 503 Fundamentals of Soil Physics)

II. Course Code : AP 602

III. Credit Hours : 2+1

IV. Aim of the course

To map soil properties for precision farming, assessment of soil quality, structural problems of different soils and their amelioration through appropriate conservation tillage, soil conditioning.

V. Theory

Unit I: Techniques for mapping soil properties and their use

Classical methods of interpolation: IDW, spline, global polynomial; Geostatistics:

Spatial variability of soil properties: spatial dependence and spatial structure studies – empirical semi variogram and semi variogram models, kriging for interpolation – type of kriging, Geostistical analyst, 3D analyst and spatial analyst tools of GIS for mapping soil properties, Use of soil maps for soil health assessment and reducing input use in precision farming.

Unit II: Assessment of Soil quality

Definitions of soil quality, selection of minimum data set of physical, chemical and biological characteristics for quality assessment, indices of soil quality: Physical rating of soils, least limiting water range (LLWR) as an indicator of structural quality, Proctor compaction test, soil erodibility indices.

Unit III: Soil structural problems of major soil types and their amelioration

Management of highly permeable soils, slow permeable black soils, hardening of redchalka soils, shallow soils, soils with subsurface hardpan, tal lands, paddy soils, soil crusting

Unit IV: Soil tillage

Role of tillage for modification of soil structure, Assessment of site-specific tillage requirement based on soil and climatic properties, conservation tillage, effect of tillage on water and solute transport in soil.

Unit V: Soil conditioners

Water soluble conditioners and soil hydrogels – mode and rate of their application and modification in soil water retention curve of different soil types. Influence of atmospheric demand on hydrothermal regimes of soils with conditioners.

Unit VI: Applications of remote sensing in surface soil moisture estimation:

Estimation of surface soil moisture by thermal and passive microwave techniques

VI. Practical

- Empirical semi variogram and fitting appropriate semi variogram model;
- Preparation of prediction map of a soil property by kriging;
- Soil physical health assessment of a farm;
- Comparison of soil water retention curves of a soil with variable rates of applied conditioner;
- Computation of LLWR under different soil management practices.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Daniel Hillel. *Advanced Soil Physics*.
- Gupta RP and Ghildyal BP. *Soil Structure*.
- Warrick AW. *Soil Physics Companion*.
- ARC GIS manual.

I. Course Title : Crop Micrometeorology and Evapotranspiration (Pre-requisite AP 505 Fundamentals of Meteorology)

II. Course Code : AP 603

III. Credit Hours : 2+1

IV. Aim of the course

To impart advanced theoretical and practical knowledge about the physical processes in the atmosphere near the ground for growing crop plants with special emphasis of evapotranspiration process.

V. Theory

Unit I

Micro-, meso- and macro-climates and their importance, Atmosphere near the ground – bare soil and crop surfaces, exchange of mass, momentum and energy between surface and overlaying atmosphere, exchange coefficients, Richardson number & Reynold's analogy, Mixing length theory, boundary layer equations, surface layer, Ekman layer, frictional affects, eddy diffusion, forced & free convection. Wind profile near the ground; roughness and zero plane displacement.

Unit II

Micrometeorology of plant canopies: Radiation, temperature, wind, humidity and carbon dioxide profiles in crops; Influence of topography on microclimate; variation in microclimate under irrigated and rainfed conditions; Micrometeorology of field crops rice and wheat, forest and orchards etc.

Unit III

Hydrological cycle and concept of water balance, concepts of evaporation. evapotranspiration, potential, reference and actual evapotranspiration, consumptive use, different approaches of ET determination by empirical methods, energy balance and Bowen's ratio methods, water balance single and multi-layered soil methods, aerodynamic, eddy correlation and combination approaches, field lysimetric approaches and canopy temperature-based methods; Advantages and limitations of different methods.

Unit IV

Measurement of water use efficiency/water productivity, irrigation scheduling and yield functions; Advective energy determination and its effect on water use by crops; Physiological variation in relation to crop growth and development.

VI. Practical

- Micromet sensors and automatic weather station;
- Global and net radiation diurnal variations;
- Temperature profile, Humidity profile and Wind profile in the crops at different stages;
- Energy balance components for IARI station;
- PET by Thornthwaite's method, Blaney Criddle method, Radiation (Makkink's) method;
- Bowen's Ratio, Aerodynamic method, Combination (FAO-56) method, Pan Evaporation, Lysimeter, Eddy Covariance.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

Books

- *Disaster Management in India*, Ministry of Home Affairs, Govt. of India, 2011.
- *Manual of Drought Management*, Ministry of Agriculture, Govt. of India, 2016.
- *Textbook of Disaster Management*, by Nitesh Kumar, Satish Serial Publishing House.

Journals

- *Natural Hazards*
- *Disasters*
- *Agriculture & Forest Meteorology*

I. Course Title : Digital Image Processing (Pre-requisite: AP 507 Principles of Remote Sensing)

II. Course Code : AP 604

III. Credit Hours : 1+1

IV. Aim of the course

To impart advanced technical and practical knowledge about the image processing procedures with emphasis on their applications in agriculture

V. Theory

Unit I

Introduction - Image processing display systems. Initial statistical extraction - univariate and multivariate image statistics, histogram and its significance in remote sensing data. Pre-processing - Introduction, missing scan lies, desk tripping methods, geometric correction and registration, atmospheric corrections, illumination and view angle effects.

Unit II

Image reduction, image magnification, contrast enhancement; linear, non-linear, ratioing, edge enhancement; linear, non-linear; low pass filters, high pass filters, edge detection, point and neighbourhood operation Image transform - Arithmetic operations'-based image transforms, principle component analysis, discriminate analysis. Fourier transforms, Fast Fourier frequency domain filters and vegetation indices.

Unit III

Image compression fundamentals: Coding, interpixel and Psyco-visual redundancy, and fidelity criteria. Image compression models: Source encoder and decoder, channel encoder décor, Elements of information theory: Measuring information, entropy, the information channel fundamental coding theorems and using information theory, Image Fusion.

Unit IV

Image segmentation: Detection of points, lines and edge detection and combined detection Edge linking and boundary detection: Local processing, Global processes via Hough transform; Thresholding: foundation, role of illumination, simple global thresholding, optimal thresholding. Split and merge and Texture based Segmentation.

Unit V

Classification: Geometrical basis, unsupervised & supervised techniques; Advance classification techniques: Use of external data, contextual information, feature - sub-feature study, classification accuracy; Change detection - the nature of change detection, change detection algorithms, image differencing, and image rationing and classification comparisons; Imaging Spectroscopy, Data Processing techniques, data mining techniques, Spectral angle mapping, Spectral unmixing, Construction digital terrain models, Application of DTMs – contour generation, fill, fly though; slope and aspect; viewshed analysis; watershed and drainage extraction; volumetric analysis; preparation of orthoimages

VI. Practical

- Digital Image processing –Introduction to software, MATLAB and R software, Image acquisition;
- Digital image processing: Pre-processing, Enhancement and training site collection, classification;
- Post Classification, Accuracy Assessment;
- Processing of microwave image;
- Processing of thermal image;
- Processing of Hyperspectral image: Pre-processing and classification, Multi-resolution image Fusion.

V. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VI. Learning outcome

Basic knowledge on image processing procedures with emphasis on their applications in agriculture

VII. Suggested Reading

Books

- Gonzalez RC and Woods RE. 2014. *Digital Image Processing*. Pearson.
- Jensen JR. 1986. *Introductory Digital Image Processing: A Remote Sensing Perspective*. Prentice Hall.
- Qihao Weng 2011. *Advances in Environmental Remote Sensing: Sensors, Algorithms and Applications*, CRC Press.

Journal

- *IEEE Trans. Geoscience and Remote Sensing*
- *IEEE Transactions on Image Processing*
- *International Journal of Image Processing - IJIP - CSC Journals*
- *Signal Processing: Image Communication - Journal - Elsevier*

I. Course Title : Satellite Agrometeorology
(Pre-requisite: AP 505 Fundamental of Meteorology)

II. Course Code : AP 605

III. Credit Hours : 2+1

IV. Aim of the course

To learn the use of satellite images for retrieval agro-meteorological parameters and their applications in agriculture.

V. Theory

Unit I

Scope and importance of agrometeorology from space, types of meteorological satellites – Geostationary and Polar orbiting.

Unit II

International satellite systems and their payloads – NOAA, S-NPP, TERRA and AQUA, DMSP, METEOSAT, GOES, TRMM, etc., National satellite systems and their payloads – INSAT, IRS/RESOURCESAT, MEGHA-TROPIQUES, RISAT, OCEANSAT, etc., Agromet parameter's requirements and satellite data products available.

Unit III

Retrieval of cloud type and structure in visible and infrared regions, estimation of rainfall by visible, infrared and passive and active microwave techniques.

Unit IV

Retrieval of land surface emissivity and temperature – single channel and split window algorithms, components of surface radiation balance – global radiation, surface albedo and outgoing long wave radiation, estimation of latent heat flux (ET), sensible heat and roughness parameter.

Unit V

Retrieval of surface soil moisture by thermal and passive microwave, retrieval of crop biophysical parameters by empirical and physical techniques.

Unit VI

Vegetation phenology and dynamics, crop yield modelling, linking Simulation models and remote sensing, crop growth monitoring system

Unit VII

Drought monitoring, assessment and management, modelling net primary productivity of agroecosystems, agroecological zoning using remote sensing and GIS, remote sensing of air pollutants and greenhouse gases.

VI. Practical

- Handling MODIS image products (Reflectance, LAI, fAPAR, LST);
- Handling SPOT VGT Products, PROSAIL MODEL, Retrieval of: LST, Albedo, Radiation, Estimation of Crop Phenology from multi-temporal satellite images, Spectral yield model, Remote sensing-based Drought indices and Drought assessment and Spatial Net Primary Productivity modelling.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on satellite remote sensing in meteorology.

IX. Suggested Reading

- Lecture Notes Module II: *RS & GIS Applications in Agriculture & Soil Science*, CCSTEAP, Indian Institute of Remote Sensing, Dehradun, India
- Lecture Notes on *Satellite Meteorology & Global Change*, Vol 1, 2 & 3, CSSTEAP, Space Applications Centre, ISRO, Ahmedabad, India
- Molly E. Brown. 2008. *Famine Early Warning Systems and Remote Sensing Data*, Springer. Okamoto K. (Ed.). 2001. *Global Environment Remote Sensing*, IOS Press.
- Shivkumar MVK, Roy PS, Harmsen K and Saha SK. 2004. *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology*, WMO, Geneva.
- Special Issue on Remote Sensing Applications in Meteorology, *Mausam*, Vol 54, No. 1, Jan 2003. Toselli F. (Ed.). 1989. *Applications of Remote Sensing to Agrometeorology*, Kluwer Academic Publishers, London.
- Ustin S. 2004. *Remote Sensing for Natural Resource Management and Environmental Monitoring*, 3rd ed., Wiley.
- Vaughan RA. 1987. *Remote Sensing Applications in Meteorology and Climatology*, NATO Science Series C.

I. Course Title : Sensors for Soil, Crop and Environment monitoring

II. Course Code : AP 606

III. Credit Hours : 2+1

IV. Aim of the course

To teach the applications of sensors for soil, crop and environment monitoring

V. Theory

Unit I

Sensing strategies: Traditional field scouting and sampling –laborious and time consuming, Sampling approaches.

Unit II

Sensor platforms and location of sensors: Remote airborne - Satellite, Airplane, UAV (1 m to 100 m); Proximal mobile, earthbound: Continuous moving, Stop - and - go, Proximal & in - situ, stationary Towers Probes in soil and on crop.

Unit III

Criteria for selecting sensors: Spatial sampling: Extend, coverage, sample area/volume Temporal: Turnaround time, temporal resolution Data processing: post processing / real - time Use in management: Predictive / reactive approach Costs Robustness Accuracy Handling: User - friendliness and safety, off - line, on-line, and on-line with map overlay.

Unit IV

Sensors for Environmental Monitoring: 1 Weather radar, 2 Satellite, 3 Aircraft, 4 UAV, 5 Atmospheric, Lidar, 6 Sensor network, 7 Radiometer, 8 Deposition sampler, 9 Atmospheric profiler, 10 Weather station & eddy - covariance 11 Groundwater level monitor, 12 Surface water level monitor, 13 Automatic water sampler, 14 Gas exchange sensor.

Unit V

Soil sensors: Plant nutrients (pools): Macro and Micro nutrients, Water content and water potential, Acidity (pH), Buffering, CEC, AEC, Redox Potential, Toxic substances like U, Cd, Pb, Physical properties: Soil strength, Permeability, Porosity Soil biota: Biological activity, pathogens, Organic matter, penetrometers, Geo-electrical sensors, Gamma ray soil sensing, potentiometric sensors, sensors for soil mapping, multi sensors, Visible and near - infrared diffuse reflectance spectroscopy (Vis - NIRS), sensor fusion, handheld XRF.

Unit VI

Plant sensors: Target parameters: Water Potential, Yield quality, Nutrients- macro and micro, Morphology: Biomass, Leaf area, Distribution of plants and organs, Biological threats: disease, pest and weeds, Principles of measurement: (a) mechanical, (b) optical (spectral, spatial resolution, geometry) (c) Acoustics.

Unit VII

Applications in agriculture: Principle of N application based on chlorophyll sensing with spot sensors, On - line application with map - overlay, weedSeeker, CropCircle & OptRXWEEDit Ag, CropSpec, Fluorescence sensor for agriculture, Laser: Crop morphology - leaf area, Imaging and Non-imaging crop sensors, site specific weed management, hyperspectral video cameras, 3D imaging, stereo vision, sensor based VRT, Thermal imaging, multi reflection ultra-sonic sensor, smart phone based sensors.

Unit VIII

Challenges of sensor technology in agriculture: Direct assessment of relevant properties/ better distinction between various factors, Robustness & user - friendliness, Costs, Data processing and interpretation.

VI. Practical

- Demonstration of various soil sensors, moisture pH, EC monitoring systems, crop sensors - Green seeker, SPAD meters, Leaf area meters, line quantum sensors, sensors for environment monitoring - humidity, temperature, radiation recorders, comparison of different sensors, optical, mechanical.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on sensors for soil, crop and environment monitoring.

IX. Suggested Reading

- Raphael A. Viscarra Rossel, Alex B. McBratney and Budiman Minasny. 2010. *Proximal Soil Sensing*. Springer Netherlands. ISBN 904818858X, 9789048188581, 448 pages.
- Subhas Chandra Mukhopadhyay. 2012. *Smart Sensing Technology for Agriculture and Environmental Monitoring*. Springer. 486 pages.
- Vanden Berg E. 2011. *Agricultural sensors*. ASAE publication. ISBN: 0916150984, 9780916150983, 81 pages.

I. Course Title : Weather Hazards and its Management

II. Course Code : AP 607

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about natural hazards, their management and best practices

V. Theory

Unit I

Importance & scope of subject in the context of agriculture and developing countries; Concepts, definitions & fundamentals of Hazard, Disaster, Vulnerability, Resilience and Risk

Unit II

Classification of hazards: Natural & Human Induced, Geological – Hydrometeorological – Environmental – Biological, Sudden & creeping, Global and regional trends in hazards; Cycle and Steps in Disaster Management: Risk Management vs crisis management, Activities before, during and after disasters

Unit III

International treaties and mechanisms of disaster management, National institutional mechanisms

Unit IV

Early Warning and Communication system: Characteristics and Components of Early Warning System (formulation, issuance, reception and response), Disaster Specific National and International Early Warning Systems (Drought, Flood, Cyclone, Tsunami), Types of Communication Networks for Disaster Management (Terrestrial, Satellite, Wireless, Mobile), National Disaster Communication System

Unit V

Natural Disasters (Drought, Flood, Cyclone, Heat Wave / Cold Wave): their preparedness, Early warning & dissemination, response, recovery, mitigation

Unit VI

Biological Disasters (Epidemics, Pest attack of crops and livestock): their preparedness, Early warning & dissemination, response, recovery, mitigation

Unit VII

Risk Transfer and Insurance; Climate Change & Disaster Management

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Basic knowledge on natural hazards, their management and best practices

VIII. Suggested Reading

Books

- *Disaster Management in India*, Ministry of Home Affairs, Govt. of India, 2011.
- *Manual of Drought Management*, Ministry of Agriculture, Govt. of India, 2016.
- *Textbook of Disaster Management*, by Nitesh Kumar, Satish Serial Publishing House.

Journals

- *Natural Hazards*
- *Disasters*
- *Agriculture and Forest Meteorology*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Organic Farming

Preamble

Although, India had been traditionally organic and its farmers are 40 century farmers with large pool of traditional wisdom on best practices in organic agriculture, the modern standards based organic agriculture started only recently with the growing demand for organic food and fiber in the western world. Movement got major push when civil society organizations and farmer association brought in the focus on sustainability and food safety in the wake of deteriorating soil health and fertility, depleting natural resources, diminishing returns to the farmers and growing chemical residues in food. Growing demand for organic food nationally and internationally with the increased awareness for safe and healthy food further added to the strength of organic farming and attracted the attention of agricultural scientists and planners to look for alternative environment friendly ways which are not only productive enough to meet our growing demands but are also resource conserving and continuously contributing to the improvement of soil health and fertility. Organic agriculture emerged as the viable alternative to all such concerns. Ardent promoters of organic farming consider that present day organic agriculture, which is a mix of traditional wisdom and modern science and technology, can meet all these demands and become the mean for complete development of rural areas, especially in the developing countries like India where large chunk of farmers are small, with limited resources and with limited access to water, mainly through seasonal rains.

Institutional development such as National Programme for Organic production (NPOP) launched during 2001, followed by setting up of National Centre of Organic Farming (NCOF) under Ministry of Agriculture and Farmers Welfare and initiation of Network Project on Organic Farming (NPOF) Research by ICAR during 2004 laid the foundation for systematic development of the sector in the country. Started with just 42,000 ha during 2003-04, it has now grown almost 39-fold, touching a figure of 1.64 million ha during 2017-18. India is now the ninth largest in terms of total arable land under organic farming and largest in terms of total number of organic producers. Market started with exports is also catching up domestically and is now a 5000 crore industry. Dedicated stores and retail chains catering to the demand of organic food can be seen in almost all tier I and tier II cities in the country.

But this growth story has also many shortcomings and weaknesses. In the absence of technology and continuous research support, farmers are struggling to maintain yields. Availability of organic seeds and quality inputs for nutrient and pest management is one of the major bottlenecks. Absence of knowledge for diversified cropping systems (a pre-requisite for organic farming) keeps farmers relying on mono-crops which often yields poorly. Absence of trained manpower for extension, certification management and value chain management is also widely experienced and industry make do with less competent experts and personals. To take the organic farming fast forward it is necessary that efforts are made in value chain mode with an aim to transform farmers into entrepreneurs and create an infrastructure that cater to the ever evolving technology needs through research, extension and education. Although a National Organic Farming Research Institute (NOFRI) at Sikkim and some Institutes of Organic Farming in SAUs has started functioning but still there is lacking of institutions that can cater to the need of trained manpower. ICARs proposal to launch postgraduate programme in organic farming is the first of the efforts to bridge that gap. This report summarizes the recommendations of the committee constituted by the ICAR for drafting the course curriculum for M.Sc. Agriculture in Organic farming:

By the end of March 2017, India has brought more than 3.42 million ha area under organic certification, comprising of 1.64 million ha (47.95%) under cultivation and 1.780 million ha (52.05%) under wild harvest collection. India is producing wide range of crops under organic management with oilseeds, sugar crops, fiber crops, cereals and millets and pulses occupy the large chunk of the basket.

With mainstreaming of organic farming there is growing requirement for first generation extension personals trained in organic farming. Similarly, for research the country requires first generation scientists with actual organic farming background and passionate-will to work for the sector. As on March 2018 there are more than 3500 grower groups comprising of about 1 million farmers. These groups are known as ICS units and each group comprising of an average of 250-350 farmers and are managed by not less than 5-7 technical persons for documentation management, internal inspections, certification, collective input purchases and sales. Besides third-party certification another farmer group centric certification under PGS-India programme is also certifying farmers. To manage the certification of PGS there are more than 400 Regional Councils and all these require technical manpower, not only in organic crop and livestock management, but also in certification and quality assurance. As on March 2018, there are 28 certification bodies and another 10 are in the pipeline. Each certification body requires an average of 20-150 technical persons. Similarly, for PGS management there are more than 400 Regional Councils requiring more than 4000 technical staff. There are more than 950 organic food processors in the country. As organic system requires complete integrity, therefore processing needs to be dedicated, away from conventional processing units. This is a fast-growing sector and may require large number of organic food professionals in the years to come.Therefore, to feed to the existing and future requirement of technical manpower it is essential that a postgraduate course in organic farming is launched and state Agricultural Universities be encouraged to offer such course.

Minimum Requirements for starting postgraduate course in the University:

1. **Faculty**

University having Centre of Excellence in Organic farming or having dedicated Institutes for Organic farming are ideal for launching such programme. In cases, if there is no such existing infrastructure then the university must aim to start such Department with multidisciplinary faculty or must be in a position to spare competent faculty for undertaking such course. Initially it may be possible that the institute do not have faculty for each subject, then in such cases faculty may be contracted as visiting faculty for specific course content.

2. **Land**

As organic farming is a farming system approach, therefore, there is a needfor a dedicated organic farmof not less than 5 ha. This farm must be kept organic for long term as frequent switching of land under conventional and organic is not allowed and may not be advisable.

3. Laboratory

There must be fully equipped laboratory for the following:

(i) Soil testing laboratory having facilities for micronutrient analysis along with the usual soil test parameters. Facilities should also be available for estimation of soil microbial carbon, soil enzymatic analysis and soil respiration studies.

(ii) General microbiological laboratory

(iii) General entomology and plant pathology laboratory

(iv) Access to plant analysis equipment and residue analysis laboratories.

Course Title with Credit Load
M.Sc. (Ag) in Organic Farming

Course Code.	Course Title	Credit Hours
OF 501	Concepts and Principles of organic farming	2+0
OF 502	Soil fertility, Crop Nutrition and Nutrients input	3+1
OF 503	Organic Crop Production Systems	2+1
OF 504	Plant Health Management	2+1
OF 505	Post harvest handling of organic produce	1+1
OF 506	Farming systems suitable for organic managements	2+1
OF 507	Organic certification Standards and regulation	2+1
OF 508	Value Chain Management	2+2
OF 509	Marketing	2+0
OF 510	Research Methodology and Biostatistics	2+1
OF 511	Organic Input Management and Production Technologies	2+1
Soil 591	Masters Seminar	1+0
Soil 599	Masters Research/ Thesis	0+30

Course Contents
M.Sc. (Ag) in Organic Farming

I. Course Title : Concepts and Principles of Organic Farming
II. Course Code : OF 501
III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge on the basic concept of organic farming

V. Theory

Unit I: Concepts and principles of organic farming

History and evolution of organic farming in the world and India. Scenario of organic farming in India and world, global market for organic products, IFOAM's Guiding principles of organic farming, conversion to organic agriculture, advantages and limitations.

Unit II: Definitions and types of organic farming

Definitions of organic farming, types of organic farming such as natural farming, zero chemical natural farming, bio dynamic farming, biological farming, compost farming, Natueco culture, integrated farming, homa farming, permaculture etc, traditional farming systems in India and evolving indigenous knowledge systems

Unit III: Conventional *vs* Organic farming

Philosophy of two farming systems, fundamental differences, productivity issues, management protocols, food quality, nutritional differences and impact of conventional practices on soil fertility, natural resources, environment and overall social perception. Myths and realities about organic farming in addressing nutritional security and food safety need *vis-à-vis* national food security.

Unit IV: Advocacy, Ethics, health and social issues in organic farming

Advocacy for organic farming with sustainability, resource conservation and food safety issues. Advocacy through overall farm productivity under diversified cropping systems. Spirituality values and ethics in organic farming. Socio economic importance of organic farming: concept measurements and issues. Need for ethical practices and values across the organic agriculture value chain including trading and reaching to consumers.

Unit V: Organic farming for sustainability, resource conservation, climate change issues and safe and healthy food

General concerns on sustainability, climate change issues threatening sustainability, potential of organic farming practices in addressing sustainability and climate change. Resource conservation through organic farming, rainwater conservation and preservation of native seeds and germplasm an essential component of organic farming, Consumers concerns on food quality and safety, organic farming for safe and healthy food, ITKs potential and role in sustainability of modern organic farming practices

Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

Learning outcome

Basic knowledge on organic farming so as to be an organic trainer, promoter and grower.

Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition.
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Published by Jain Brothers
- *Basics of Organic Farming:* Deshpande, WR, 2009, All India Biodynamic and Organic Farming Association, Indore, MP, India P-306.
- Eyhorn, F, Heeb M and Weidmann, Gilles IFOAM *Training Manual for Organic Agriculture in the Tropics*, FiBL and IFOAM.

I. Course Title : Soil Fertility, Crop Nutrition and Nutrient Inputs

II. Course Code : OF 502

III. Credit Hours : 3+1

IV. Aim of the course

To provide knowledge on fertility of soil and also different organic inputs to be used in organic farming

V. Theory

Unit I: Soil – Source of Infinite Life

Soil as source of life, fundamentals of soil structure and quality, soil fertility, physico-chemical parameters and soil as living entity in organic farming.

Unit II: Soil fertility and productivity

History of soil fertility and plant nutrition. Factors affecting; features of good management; problems of supply and availability of nutrients; relation between nutrient supply and crop growth; Criteria of essentiality of nutrients; Essential plant nutrients – their functions, nutrient deficiency symptoms; transformation and dynamics of major plant nutrients.

Unit III: Soil fertility evaluation

Physico-chemical soil testing, biological methods for soil health evaluation, plant and tissue tests; soil quality in relation to sustainable agriculture. Nutrient requirement modeling based on soil health and resources availability.

Unit IV: Soil Conservation and Soil Water Management

Principles of soil and water conservation, general practices for soil and water conservation, soil carbon buildup and biomass recycling.

Unit V: Soil biology and role of microorganisms in soil fertility management

Soil as a habitat for microorganisms, Soil microorganisms, Soil microbial ecology, Soil microbial biomass, Soil enzymes – origin, activity and importance. Microbial management of agricultural, domestic and industrial wastes for potential application in organic farming. Microbiology of composting and bio-methanation. Biodegradation of xenobiotics. Bioremediation – principles and application.

Unit VI: Nutrient recycling

Nitrogen, phosphorus and potash cycles, management for nutrient recycling, methods for recycling and reducing nutrient losses.

Unit VII: Management practices

Management practices in organic agriculture (mulching, fallowing, intercropping, manuring, crop rotation, agro-forestry, mixed farming).

Unit VIII: Organic fertilizers and composting technology

Compositing principles and factors affecting composting, dynamics of compositing, methods of composting, different forms of composts with nutrient profiles, Rapid methods of composting, liquid manures, compost enrichment through concentrates, minerals and micronutrients. Field application of compost and their response to crops.

Unit IX: Vermicomposting technology

Earthworm biology, principles of vermicomposting, methods for vermicompost production, nutrient profiling, field application and its response to crop yields

Unit X: Biofertilizers

Different types of biofertilizers, their contribution to soil fertility and nutrient pool, factors affecting their application and response, assessment of biofertilizers application to crop yields.

Unit XI: Addressing nutrient deficiencies and mineral fortification of composts (P, K, S and micro nutrients)

Identification of deficiency, need assessment, identification of mineral resource, fortification of composts and impact assessment on application

Unit XII: Indigenous practices in soil fertility and nutrient management

Indigenous inputs such as liquid manures, Jivamrit, Panchgavya, on-farm protein hydrolysates, plant extracts, dung-urine slurries etc, their production methods and effect of their application on soil fertility and crop productivity.

VI. Practical

- Introduction of analytical instruments and their principles, calibration and applications, Determination of soil pH, electrical conductivity, organic carbon, total and available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and DTPA extractable micronutrients in soil and their interpretations.
- Biological health assessment through dehydrogenases, soil microbial carbon and soil respiration
- Making of composts through aerobic and anaerobic methods
- Making of vermicomost using earthworms
- Analysis of manures and composts for NPK and heavy metals
- Microbial profiling of Jivamrit/ panchgavya

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on soil fertility and management in organic farming

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers
- *Manufacture of Biofertilizer and Organic Farming.* AB publisher

I. Course Title : Organic Crop Production systems

II. Course Code : OF 503

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on organic crop production system

V. Theory

Unit I: Fundamentals of organic farm management and conversion

Salient features of organic farm management, strategies for conversion to organic, step-by-step planning, integration of contamination control measures, planning for on-farm input production and supplementary off-farm inputs, planning for rain water harvesting and water conservation approaches including efficient irrigation systems and moisture preservation techniques, visit to organic farms and study on farmer's best practices for conversion.

Unit II: Management of diversity and cropping systems

Importance of diversity, installation of diversity through plantation of utility trees, nitrogen fixing tree hedges, habitat management for friendly insects and birds and nitrogen fixing crops as intercrops. Importance of cropping systems management with long term planning, crop rotations, intercropping, multi cropping, relay cropping, multi-layered cropping.

Unit III: Nutrient management

Components of nutrient management in organic crop production, assessment of crop nutrient requirements, calculation of nutrient credits from on-farm practices and resources such as intercrops, cover crops, biomass mulching, calculating additional input requirements. Managing nutrient needs through use of organic manures, viz. FYM, compost, Vermicompost, oil cakes, *in-situ* and *ex-situ* green manuring, crop residue management, use of restricted organic nutrient sources, liquid organic manures and dung urine slurries, methods of manuring and biomass application, split application of manures, foliar feeding as replacement of top dressing, ITKs and farmers innovations in nutrient management

Unit IV: Integration of microbial and mineral inputs

Importance of bio fertilizers, types of biofertilizers, nutrient potential, methods of application, enriching manures/ composts with biofertilizers, identifying the need for use of supplementary mineral sources and their integration in nutrient management package.

Unit V: Weed management

Prevention of weeds through cropping systems management, crop geometry, stale seedbed technique, summer ploughing, soil solarisation, cover crops, mulching, flooding, biological weed management, selection of suitable physical and mechanical approaches and biological and plastic mulches.

Unit VI: Water and Irrigation Management

Soil-water relation, theories of water availability, water use efficiency management, methods of irrigation and automation in irrigation systems, irrigation scheduling in different crops.

Unit VII: Modeling of agronomic practices and nutrient management protocols for some important agricultural and horticultural crops

Identification of compatible associate and intercrops/ companion crops, placing trap crops and insectary plants in cropping geometry, making provisions for nutrient credits from biomass mulching, intercrops and green manures, making provisions for nutrient credits from microbial enrichment with microbial/ liquid manure inputs, balance nutrient requirement modeling and identification of inputs and planning for quantity and time of application.

Unit VIII: Crop growth and yield analysis

Crop growth expressions in plants, growth measurements, important growth indices and forms of growth analysis in field crops. Factors determining yield. Use of growth analysis technique to study variation in yield due to planting season, planting density, fertilizer treatment, other agronomic practices, light, temperature, water, growth substances, varietal differences. Crop response curves. Dynamics of crop growth and modeling.

Unit IX: Success stories of effective crop management with optimum yields of practicing organic farmers (one in irrigated systems and one in rainfed systems)

Field visit, documentation of farming system with inputs and outputs, identification of practices important for organic systems, nutrient management practices, pest management protocols, yields and economics. Salient features for success and for further replication in crop production modeling.

VI. Practical

- Visit to organic farms and study general nutrient management practices, documentation of farming system with inputs and outputs and crop growth analysis using crop growth analysis techniques
- Getting acquainted with different tilling methods and rain water harvesting and water conservation techniques
- Production of liquid manures and dung-urine slurries
- Production of customized composts using FYM/ Compost, mineral nutrients and biofertilizers, assessment of nutrient profiles in enriched composts
- Methods of application for biofertilizers
- Weed management practices, tools and efficacy of different approaches
- Modelling of agronomic practices for a given cropping system with use of available resources.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on organic crop production system

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.

I. Course Title : Plant Health Management

II. Course Code : OF 504

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on plant health management for optimization of crop yield due to organic farming

V. Theory

Unit I: Classification of pest organisms

Classification of pests, viz. weeds, bacteria, nematodes, fungi, insects, viruses, vertebrates, *etc*, identification of pests and beneficial organisms.

Unit II: General principles of plant health management in organic farming

Principles of pest management in organic crop production; Pest surveillance and pest population estimation; concept of economic injury levels (EILs) and economic threshold levels (ETLs), principles of Agro Eco-System Analysis (AESA) based pest management, estimation of Pest: Defender (P: D) ratio, understanding AESA methodology.

Unit III: Biology of pests and population dynamics

Population dynamics in relation to environment, distribution, identification; Life cycle of key pests of cereals, pulses, vegetables, stored grains, fruit crops and protected cultivation.

Unit IV: Ecological strategies for pest management

Proper sanitation, appropriate fertilization, necessary pruning, timing of planting to escape infection, crop rotation, avoidance of endemic sites, space management for sunlight and air, plant quarantine, *etc.*

Unit V: Cultural and physical control strategies

Importance and use of traps, coloured plates, pheromones, use of insectary plants, trap crops and planning for diversity plant integration as border crops, hedge rows, intercrops, *etc.*

Unit VI: Biological control

Conservation of natural enemies, classical biological control systems, important beneficial insects and their integration and use in different cropping systems.

Unit VII: Biopesticides

Biopesticides, types, mode of action, production, methods of application and impact assessment on crops and pest load.

Unit VIII: Botanical pest management

Using different plants for management of different pests, methods for using such plants and active ingredient extraction methodologies, formulation of usable solutions and methodologies for application. Integrated strategies, development of crop specific integrated management modules, importance and need for chemical alternatives permitted in organic farming, methods for use and application.

Unit IX: Indigenous practices and their importance in plant protection

Indigenous practices of avoiding pests, managing pests, important plants being used since ages and innovative botanical and fermentation inputs developed by farmers for pest management.

Unit X: Pest control of produce in storage

Physical, mechanical and biological approaches, modified environment, management of hygiene and phyto-sanitary approaches, use of organically acceptable fumigants such as carbon dioxide and nitrogen.

VI. Practical

- Collection and Identification of major/ key pests and plant diseases,
- Estimation of pest population, nature of damage, assessment of crop losses,
- Familiarization with important crop pests & diseases and their biological control agents,
- Demonstration/ familiarization with various tools of insect-pest & disease management,
- Mass rearing techniques of important biological control agents,
- Preparation of organic/ natural formulations for insect-pest & disease management,
- Evaluation of organic formulations for determining their pesticidal properties and field efficacy.
- Preparation and validation of traditional formulations.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Plant health will be taken care of for optimization of higher crop yield due to organic farming

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher

I. Course Title : Post Harvest-handling of Organic Produce

II. Course Code : OF 505

III. Credit Hours : 1+1

IV. Aim of the course

To provide knowledge on post harvest handling of organic produce for optimization of crop yield due to organic farming

V. Theory

Unit I: Pre/Postharvest Factors for Post-harvest Losses of Organic Produce

Pre and post-harvest factors responsible for causing organic produce losses.

Principles and practices responsible for losses of organic agricultural produce. Qualitative, quantitative, nutritional and socioeconomic losses. Loss assessment and estimation techniques and their limitations and methods for reducing postharvest losses.

Unit II: Introduction to Value Chain and Handling of Fresh Organic Products for Processing

Management of hygiene and phyto-sanitary measures, measures to reduce field heat, cleaning and washing, control of enzymatic and non-enzymatic changes, transportation, sorting, grading, peeling, sampling and size reduction, packaging, labelling; handling methods for fresh fruits, vegetables and flowers.

Unit III: Organic Food Processing and Preservation

Fundamental principles for food processing in organic farming, acceptable processing techniques, use of preservatives, processing aids, flavouring agents and nutrient supplement in organic food and feed processing.

Unit IV: Food Standards and Residue Analysis/ Toxicology

Fundamental principles of food standards, HACCP system, US and European Export/ Import standards for different crops, MRLs, sources of contamination, assessment and management of residues and toxins in food, critical control points, heavy metals and pesticide residue analysis, analytical methods and tools. Interpretation of residue analysis reports, analysis protocols and GMO report analysis.

Unit V: Principles of Packaging

Characteristics of packaging materials for organic food, packaging requirements for fresh and processed organic food for local and international markets, labelling requirements for fresh and processed organic food for local and international markets, labelling requirements and management integrity.

VI. Practicals

- Study of maturity indices for harvest of organic fruits, vegetables, spices and plantation crops.
- Determination of physiological loss in weight and respiration rate in fruits and vegetables.
- Determination of chemical constituents like sugar, starch, pigments, vitamin C, carotenes, acidity during maturation and ripening in fruits/ vegetables.
- Protective skin coating with organic wax emulsion to extend the shelf life of fruits and vegetables.
- Study of effect of precooling on shelf-life and quality of fresh fruits, vegetables and flowers.
- Study of packages-bulk and consumer packs for different fruits, vegetables, flowers and spices.
- Study of construction and working of zero energy cool chamber. Study of storage behaviour of different fruits and vegetables in zero energy cool chamber.
- Preparation and preservation of fruit-based beverages and blended products from fruits and vegetables.
- HACCP analysis, residue analysis in organic products. Visit to packaging centres, local markets, cooperative organisations, super markets dealing with marketing of organic perishables.

VII. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.

I. Course Title : Farming Systems Concepts and Practices for Organic Farming

II. Course Code : OF 506

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on practices of organic farming

V. Theory

Unit I: Introduction

Farming systems: Definition, importance, classification and scope, Classification of farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply, enterprises, Concept of sustainability in farming systems, role of integrated farming systems in agriculture, approaches

Unit II: Agro-ecology

Concepts and practices, Agro-ecology and the design of Sustainable Agro-ecosystems, Ecological processes to optimize in agro-ecosystems, Sustainable Agriculture: Basic Definitions and Concepts, Alternative Sustainable Farming Systems, Low external input sustainable agriculture

Unit III: Enterprises selection and Integration

Natural Farming Systems, Intentional Integrated Farming Systems, Pre-dominant farming systems in various regions, Eco-physiological approaches component selection and integration, Complementary and competitive interaction, Primary, Secondary, Complimentary and Supplementary enterprises for organic farming, livestock based systems, vertical farming, Principles and Practices of organic livestock production, Principles of organic aquaculture, Organic fruit and vegetable production practices, Models of integrated farming systems for irrigated ecosystems and rainfed ecosystems

Unit IV: Modeling of farming systems

Simulation models for intercropping, farming system design using farm design for various resource conditions, Linear programming, Multi-objective criteria decision making, Fuzzy logic analysis, Artificial Neural Network (ANN) based modeling, DSSAT, Infocrop, Cropsyst, Livesim

Unit V: Integrated Organic Farming Systems

Concepts, Principles, Strategies, Diversity plantations, Diversified cropping systems, crop rotations, soil fertility management, Selection of seeds, varieties and planting material, nutrient management, weed and pest management, integration of livestock, breeds and allied activities, *In-situ* recycling of Organic Wastes, Products and processes of composting, Component optimization, Market input chain, family employment generation, case studies, supplementary, Complimentary and substitution effects under dry-land, irrigated, wetland and hill-zone eco systems

Unit VI: Soil-crop-livestock-human chain

Bio-nutrition concepts, design of farming systems for nutrition, Household level production of food, feed, fodder, fertilizer, fuel and fibre from farming systems

Unit VII: Secondary Agriculture

Product diversification, Process diversification, processing of marketable surplus produces, packaging, branding and marketing

Unit VIII: Contract Farming

Farming system based cluster formation, production, processing and marketing, legal aspects of contract farming

Unit IX: Specialized farming systems

Protected cultivation, high value crops based systems, water based farming systems, region specific integrated farming systems, medicinal herb based systems

Unit X: Farming System diversification

Existing scenario of farming systems, need for diversification, methods of diversification, horizontal and vertical diversification

Unit XI: Four P Model of organic farming system

4P (Planning, Production, Processing and Promotion) model of organic farming systems

Unit XII: Ecological Engineering

Principles and Practices, Ecological engineering approach of soil fertility and pest management, examples of ecological engineering in traditional farming systems, case studies

VI. Practical

- Agro-ecosystem analysis: Field study of farming systems in the context of production flows, energy flows and pest dynamics using quantitative tools
- Farming System typology analysis and clustering of group of farmers
- Synthesis of organic farming system model for a given region using primary and secondary data
- Estimation of ecological, economic, social and sustainable livelihood indicators for a given farming system
- Design of alternative farming systems using Farm Design and other available modelling tools
- Experiential learning on different enterprises
- Documentation of farming system case studies

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion
Learning outcome: leadership development for an organic entrepreneur

VIII. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. **Course Title** : **Organic Certification, Standards and Regulations**
II. **Course Code** : **OF 507**
III. **Credit Hours** : **2+1**
IV. **Aim of the course**

To provide knowledge Organic Certification, Standards and Regulations

V. **Theory**

Unit I

National and international regulations on quality assurance and certification

National Programme for Organic Production (NPOP), National Standards for Organic Production (NSOP), USDA NOP Programme and standards, EU Organic standards, Codex Alimentarius, Canada Organic regulation and important differences between NPOP and international standards. FSS Act 2006 for organic food, basic requirements, enforcement, standard operating procedures and verification in value chain

Unit II

ISO systems for quality assurance (ISO 17065, ISO 17011, ISO 19011 etc) and accreditation processes

What is ISO, salient features and functions of ISO, ISO systems for auditing, ISO 17065 for auditing and certification agencies, ISO 19011 Inspection protocols, ISO17011 Accreditation requirements, ISO 17025 Accreditation of quality analysis laboratories. Accreditation procedure and policies under NPOP, Essential requirements and competence for making an organic certification body, Conflict of interest management

Unit III

Types of certification systems (NPOP and PGS), standards and procedures

NPOP - A third party certification systems, Certification bodies operational policies and functions, National standards for crop production, livestock, Aquaculture, Processing and handling and other miscellaneous systems. Tracenet the online data management tool and traceability management

PGS – Participatory Guarantee Systems – Evolution of PGS Systems, Guiding principles, PGS Standards, International scenario on PGS development Procedure for organic guarantee under PGS systems, PGS-India programme, operation of PGS-India programme, institutional structure, PGS-India Data management platform, management of traceability.

Unit IV

On-field management of standard compliance and documentation

Issues for implementation of standards on field such as conversion period, contamination control, fertility management, living condition requirement for livestock, management of integrity in processing and handling, Fundamental policy for inspections, step-by-step inspection protocols, Development of inspection formats and inspection checklists. Documentation requirements such as organic system plan, field operation register, input and cultural practices record, processing record, purchase and sales records and product flow in processing.

Unit V

Individual and grower group certification management

Basic requirements for certification management by (a) Individual producer and (b) Grower/ producer groups. Applicability and types of systems covered

Unit VI

Inspection (under NPOP) and peer review (under PGS) systems

Fundamental principles of inspection, checklists and inspection parameters, general policy frame work

NPOP – Third party inspection procedure, risk assessment, documentation and record keeping review, physical verification of facilities, fields and stables, production facilities, estimated yield/production assessment, tracking the product flow throughout the process, chain of custody. Review of inspection forms and checklists and certification decisions.

PGS-India – Peer review principles, making of peer review committees and peer review checklists, analysis of peer review checklists and certification decisions. Submission of summary sheets to Regional councils and assessment and endorsement of certification decisions.

Unit VII

Certification of crop, livestock, aquaculture and other systems

Standards, their implementation in production systems, measures for contamination control, integrity management, sanitation and hygiene, input evaluation procedures, development of process tracking checklists

Unit VIII

Certification of processing, handling, trading and management of traceability

Standards, their implementation in production/ processing and handling systems, measures for contamination control, integrity management, sanitation and hygiene, packaging and labelling, development of process tracking checklists

Unit IX

Internal control system management in large farmer groupsunder NPOP

Large farmer groups, essential requirements, internal control systems, development of ICS operating manual, management of ICS, internal inspections, risk assessment, assessment of internal inspections and certification decisions, additional documentation for groups, produce/ output management and sale record management

Unit X

PGS Group development and PGS certification management

Essential requirements for local groups, development of local group operating manuals, requirements of group meetings and trainings, decision making by farmers, operational policies for Regional Councils, developing operating manual for Regional councils, assessment of summary sheets and decisions of local groups, procedure for decision endorsement and certification granting

VI. Practical

- Documentation of certification procedures, acquaintance with record keeping, handling, labeling and preparation of farmers IDs for developing ICS.
- Visit to certification bodies, certified farms, certified processing and handling operations
- Development of organic system plan for specific production system
- Development of inspection format and checklists for specific production system
- Development of operating procedures on specific aspects
- Risk assessment on organic farms and possible mitigating measures
- Running of audit trails in certified operations
- Mock inspections of different production systems
- Exercise on inspection report/ peer evaluation checklist review and certification decision
- Exercise on methods of yield assessment

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Educating to become a real organic grower

IX. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Value Chain Management

II. Course Code : OF 508

III. Credit Hours : 2+2

IV. Aim of the course

To provide knowledge on value chain for optimization of crop yield due to organic farming

V. Theory

Unit I: Introduction

What is value chain? Defining value chain and its finance (Internal value chain finance, External value chain finance, Interest around value chain finance in agriculture, interest in value chain finance in agriculture); Overview of value chain management.

Unit II: Understanding agricultural value chain finance

Context, the concept of agricultural value chain finance, Agricultural value chain finance as an approach, Enabling environment (standards and certification, regulation and enforcement, macro-economic and social context), and Value chains and diversified livelihoods.

Unit III: Value chain business models

Producer-driven value chain models, Buyer-driven value chain models, Facilitated value chain models, and Integrated value chain models. Case Study 1. On commercial village approach.

Unit IV: Agricultural value chain finance instruments

Product overview, Product financing (trader credit, input supplier credit, marketing company credit, lead firm financing), Receivables financing (Trade receivables finance, factoring and forfeiting), Physical asset collateralization (warehouse receipts, repurchase agreements, financial lease), Risk mitigation products (crop/ weather insurance, forward contracting, futures), Financial enhancements (securitization, loan guarantees, joint ventures). Case Study 2. Producer-driven financing of farm inputs: informal inventory credit; Case Study 3. Integrated financial instruments and value chain services.

Unit V: Innovations

Value chain innovations, Financial innovations, Technological innovations (management systems, networks and exchanges, mobile phones and mobile banking), Infrastructural innovations, Policy and public sector innovations. Case Study 4. Technological innovations; Case Study 5. Avenues for sustainable agricultural development.

Unit VI: Leadership Approaches for Successful Food Value Chains

Values-Based Leadership, Values-Based Leadership in Practice, Leadership in succession.

Unit VII: Organic food value chain management

VI. Practicals

- Collection, aggregation and value addition
- Maintain quality and integrity of the product - practices and procedures, monitoring practices and procedures followed, record keeping systems, management practices and separation measures, handling and processing of organic products
- Pest control - Treatments with pest regulating agents – permitted [physical barriers, sound, ultra-sound, light and UV-light, traps (incl. pheromone traps and static bait traps), temperature control, controlled atmosphere and diatomaceousearth] and prohibited
- Ingredients - approved and prohibited ingredients (microorganisms, minerals, gases)
- Processingmethods - permitted and prohibited mechanical, physical and biological
- Packaging - permissible biodegradable, recyclable, reusable systems and eco-friendly packaging
- Labeling - labeling requirements for agricultural commodities and processed food
- Storage and Transport - permitted conditions of storage to maintain productintegrity
- Food additives including carriers for use in production of processed organic food
- Processing aids and other products for use for processing of ingredients of agricultural origin from organic production flavouring agents, Preparations of Micro-organisms, Ingredients
- Approved products for packaging of organic foodstuffs incl. Permissible packaging material for aquaculture

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

High value in organic products

IX. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition.
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Marketing

II. Course Code : OF 509

III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge on marketing of organic produce for economic profit of the grower

V. Theory

Unit I: What is Marketing?

Facets of marketing, Facilitating functions of a market, What's special about agricultural markets? Pricing policy and Role of prices.

Unit II: Basics of Supply and Demand–

Demand, Aggregate demand, Supply and Aggregate supply.

Unit III: Food Marketing Channel–

Understanding the food marketing channel, Scenario Analysis.

Unit IV: Market intelligence–

Marketresearch, Production cost assessment, Projecting Revenues, Accounting, Market Selection.

Unit V

Organic production and domestic market size, Institutional context and regulations (such as NPOP, NSOP, APGMC Act, PGS, FSSAI, Jaivik Bharat).

Unit VI: Organic Food Distribution System–

Domestic market structures, and classification framework, urban organic retail models, Organic specialty stores, markets and health food stores. Direct marketing and Community Supported Agriculture.

Unit VII: Market Potential for Organic Foods–

Consumer preferences and perceptions (organic sensitivity, building awareness on organic foods and consumer needs, shopping Behavior, factors influencing purchases of new foods), general trade and organized retail.

Unit VIII: e-Marketing and e-Consumer Perceptions and Behaviour–

Why organic food, source and perception of organic foods, uses of organic food, resistance to use organic products, source of awareness, organic food-is it a fad?, On-line retail and home delivery services, role of advertising and choice of media, understanding the role of quality in marketing, perception of health benefits and assurance/certification.

Unit IX

Accessibility of organic foods, premiums and willingness to pay premiums, role of retailer

Unit X

Efficient supply chains and retail channels, sustainability of supply chain.

Unit XI: Consumer purchase Behavior and habits–

Shopping Behavior, role of influencer in decision making, concern over adulteration, chemicals, loss of nutrients and vitamins during processing and manufacturing and its impact on marketing and sale.

Unit XII: Challenges and success stories–

Success stories in organic marketing, organizational models, their advantages, challenges, limitations and legal context.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VII. Learning outcome

Basic knowledge on marketing to get higher prices in organic produces.

VIII. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Research Methodology and Biostatistics

II. Course Code : OF 510

III. Credit Hours : 2 + 1

IV. Theory

Unit I

Experimental techniques: Research design, sampling, data collection, On-station experimentation, On-Farm experimentation, tabulation, Statistical tools and analysis techniques for interpretation of data.

Unit II

Geo-referenced characterization: Questionnaire design principles, Questionnaire design for consumers of organic products, Questionnaire design for farmers and producers of organic products, Questionnaire design for processors/ traders/ exporters, Geo-spatial analysis and mapping of organic farms/ producers/ traders/ consumers.

Unit III

Meta data analysis: Concepts, statistical methods, clustering research results, Holism, Positivism, Objectivism, Reductionism, Constructivism, Subjectivism, data source, Variable coding and analysis, interpretation.

Unit IV

Niche area and crops for organic farming: Parameters for niche area and crop, Different scales of niche area, Tools and steps in Niche area and crop identification, Parameterization and classification based on macro, regional and micro level.

Unit V

Climate resilience of organic farming: Methodology for identification of climate resilient production systems, GHG's estimation using IPCC, GHG's measurement using instrumentation, Global Warming Potential, Energy & Carbon budgeting.

Unit VI

Breeding for organic production system: Conventional breeding strategies for organic production, participatory plant breeding, Marker aided selection, Stability analysis, Molecular characterization of indigenous organic inputs, Bio-chemical and molecular signature of organic produces.

Unit VII

Commercial Project Formulation on Organic Farming: Internal rate of return, Pay Back period, B: C ratio, Net Present Value, Model project formulation for organic farming, Impact analysis tools and methods.

Unit VIII

Farming System model development: Synthesis of IFS models using primary and secondary data, classification, validation of farming systems.

Unit IX

Notations in statistics: Basics of statistical notation, Algebric rules, designing a variable, standard notation for statistics.

Unit X

Descriptive statistics: Measures of central tendency, measures of variability, relative scores, measures of relationship, skewness, kurtosis.

Unit XI

Introduction to statistical inference and testing of hypothesis: Statistical model, point estimation, confidence intervals, hypothesis testing, t-test, non-parametric alternative sign test.

V. Practical

- Synthesis of farming system model
- Estimation of GHG emission from IPCC tool
- Meta data analysis using published papers
- Identification and niche area and crops for a district or block
- Identification of Climate resilient production system using long term meteorological data
- Commercial project formulation
- Geo-spatial analysis using GIS platform
- Carbon and energy budgeting of an organic farm

I. Course Title : Organic Input Management and Production Technologies

II. Course Code : OF 511

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on various organic inputs, their production technologies, quality control and commercialization aspects

V. Theory

Unit I: Introduction

Need for on-farm and off-farm (external) organic inputs, types of organic inputs allowed under organic farming, regulatory scenarios and standards. Status of organic and biological input industry in the country.

Unit II: On-farm inputs soil fertility and nutrient management

Types of on-farm inputs for soil fertility and nutrient management, their need assessment under specific cropping systems *vis-à-vis* soil test reports, methodologies for recycling of on-farm biomass and crop residue, innovative traditional inputs such as jivamrit, beejamrit, panchgavya etc. their microbial profiling and nutrient mobilization potential and standardized production methods, Oil cakes and their applications.

Unit III: On-farm inputs, plant health management and pest control

Types of plant protection inputs and intervention approaches, use of biological and ecological approaches, preventive practices, Types of plants used in plant protection and their biological characterization for pest control, basic methodologies for active ingredient extraction and on-farm formulations.

Unit IV: Composts and their value added products

Types of composts, their characters, nutrient potential, composting methodologies (aerobic, anaerobic, NADEP, *etc*), value added composts, quality control parameters, commercial production methodologies for city waste compost, Phosphate Rich Organic manure (PROM), bio-organic manure, technologies for product formulations such as enrichment and granulations, *etc.*

Unit V: Biofertilizers

Types of biofertilizers, standards for commercial products, testing methodologies, characterization and efficiency parameters, management of microorganisms in laboratory, production methodologies such as mother culture development, mass production through fermentation and fermentation parameters, mass scale culture techniques, product formulations, carrier-based inoculants, liquid inoculants and lyophilized inoculants.

Unit VI: Microbial Biopesticides

Types of biopesticides, standards for commercial products, testing methodologies, characterization and efficiency parameters, management of microorganisms in laboratory, production methodologies such as mother culture development, mass production through fermentation and fermentation parameters, mass scale culture techniques, product formulations, carrier based inoculants, liquid inoculants and lyophilized inoculants. Types of polyhedrosis and granulosis viruses and their production methodologies.

Unit VII: Mass rearing of beneficial insects

Introduction to beneficial insects such as pest predators and parasites, classification and identification, mass rearing technologies including rearing of host insects, Production of egg cards of beneficial insects and their release in the field.

Unit VIII: Botanical pesticides and other non-chemical pest protectants

Type of non-chemical plant protection options, importance of soaps and oils, important plants having pesticidal properties, plant parts having pesticidal active ingredient and their extraction methodologies, product formulation and stabilization for increased shelf life, field assessment of efficacy. Regulatory scenario and quality parameters.

VI. Practical

- Getting familiarized with on-farm soil fertility management inputs (such as beejamrit, jivamrit, panchgavyaetc), ingredients needed and production methodology. Preparation and quality assessment
- Application of such inputs in small plots on selected crops and observation on growth
- Production of different composts including vermicompost
- Quality analysis of composts for nutrients and heavy metals
- Biofertilizer organisms, their laboratory characterization, sub-culturing and mother culture development
- Fermentation technology demonstration, production of bacterial broth in pilot scale fermenters
- Biofertilizer product formulations and quality analysis methods
- Study biopesticide organisms, laboratory culturing, mass cultivation using solid state fermentation, liquid fermentation and spore harvesting methods and product formulations
- Visit to beneficial insect rearing laboratory and handling of insects including demonstration on tricho-cards production
- Extraction of neem seed kernel extracts and neem oil. Production of botanical extracts and product formulation using emulsifiers
- Study effect of various botanical extracts on insect pests
- Preparation of Bordeaux mixtures and copper fungicides

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion. Practical in the laboratory, visit to production sites and demonstration of production protocols through industry visits, practical on analysis protocols

VIII. Learning outcome

Basic knowledge on marketing to get higher prices in organic produces.

IX. Suggested Reading

- *The Complete Technology Book on Vermiculture and Vermicompost*, NPCS Board of consultants and Engineers, Asia Pacific Business Press
- *Training material on Composting and Vermicomposting*, Published by Ecosan Services Foundation
- *Biofertilizers and Biopesticides*, A, Channabasava and H.C. Lakshman
- *Handbook of Biofertilizers and Biopesticides*, by AM Deshmukh, RM Khobrgade and PP Dixit
- *Mass Production of Beneficial Organisms*, by J. Morales-Ramos, M. Guadalupe and DS Ilan, Academic Press, 2013.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Social Sciences

– Agricultural Economics
– Agricultural Extension Education
– Agri-Business Management

Contents

Acknowledgements

The disciplines of Social Sciences deal with the study of society and the relationship among individuals within society. It includes study of business, sociology, commerce, demography, and allied areas. Research in Social science research provides authentic and scientifically validated information to the end users. The importance of social research is reflected in its ability to provide fact-checked and well-validated answers to questions involving human interactions. Hence, while technology can serve the purpose of taking agricultural sciences across society for bettering profits and livelihoods and also become food and nutritional-secure, social science research can enhance the social unity by providing solutions at the doorstep of the end-users with a societal acceptance. It is most important that Agricultural Universities develop their curriculum integrating the technology developing sciences into the social sciences and catalyse trained social science professionals. Deployment of technologies-be it cost-intensive cutting-edge agricultural technologies or simple local innovations is crucial for augmenting agricultural production for our country and social science professionals have a crucial role to play in the dissemination to the end-users.

Against this responsibility to develop such trained professionals, this committee of BSMA has done 360 degree evaluation of the current curriculum of three disciplines namely, Agricultural Extension, Agricultural Economics and Agri-Business Management adopting a multi-pronged approach. Hence, stakeholder interaction, expert consultation and analysis of curriculum of global-level agricultural universities formed the basis to match the needs as per the national vision. Specifically, the committee has also explored the essence of National Educational Policy (NEP) into the curriculum planning processes. The Fifth Dean Committee report and the earlier under-graduate curricula in three disciplines also formed an important base for the committee to ensure continuity with UG and PG curriculum. We would like to put on record our sincere thanks to Dr T. Mohopatra, Secretary, DARE and Director General (DG), ICAR; Dr N.S. Rathore, Former Deputy Director General (Education), and Dr R.C. Agrawal, Deputy Director General (Education), ICAR, New Delhi for constituting this committee. We are highly indebted to Dr Arvind Kumar, Vice Chancellor, RLBCAU and Chairman of National Core Group for PG/ PHD course revision for his patience and constant support. The role of Dr G.Venkateshwarlu, Former ADG (EQR) as Member Secretary, NCG has been extremely supportive and crucial during the two years of this activity for this committee. The committee puts on record with appreciation his constant support to it.

Our sincere gratitude and thanks to all the members of this BSMA Committee for Social Sciences namely Dr Rakesh Singh , Professor, Dept. of Agricultural Economics, IAS, BHU, Varanasi, Dr S. Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Lipi Das
Convenor
BSMA for Social Sciences

R.Kalpana Sastry
Chairperson
BSMA for Social Sciences

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agricultural Economics

Acknowledgements

Agricultural sector plays an important role in Indian Economy. Changes in agricultural sector are taking place at a faster rate and this sector is integrated globally and therefore facing global challenges. In the era of Information and Communication Technology, the knowledge which we gain becomes obsolete within few years therefore it is important to update/ reform our curriculum in line with the recent changes taking place. The major challenges faced by agricultural sector currently is related to distribution/ supply chain rather than production side. We are largest producer of food grain, horticultural products milk and livestock products but we are the host of large no of poor people and mal nutrition people. Farmers' distress has become the major cause of concern for policy makers, on the other hand climate change is posing many challenges.

The sub-committee on Agricultural Economics constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept all these challenges and development in view while revising the PG and PhD Curricula in Agricultural Economics. We reviewed the under-graduate, PG and Ph.D curricula. Moreover, student's prior knowledge is critical for learning any discipline and so we had to review and propose a new curriculum for Agricultural Economics at all levels. To do these, we identified first the core competencies that are required at the different levels and worked backwards based on the areas and organising them into courses.

We are also recommending internship at the Master's level for 5 credits and Teaching Assistantship at the Ph.D. level for 5 credits. We believe this will help the students to have more relevant practical experience and this will boost their job prospects. The committee also discussed about the need for organizing exposure visit for PG/Ph.D. students to universities abroad (student exchange).

The committee organized three national level stakeholders meeting and consultation with Agril Economics professionals representing different universities, ICAR institutions involved in teaching and research in Agricultural Economics first at PJTSAU, Hyderabad on 12 July 2018, second meeting at Institute of Agri Business Management, Swami Keshwanand Rajasthan Agril University, Bikaner during September 17-18, 2018 and third BSMA (Social Sciences) meeting on 28-01-2019 at Institute of Agricultural Sciences, BHU, Varanasi for reviewing the final drafts of three disciplines of Social Sciences.

Our sincere thanks to Prof. Suhasini, Head, Dr (Mrs) Vijayakumari and faculty members, research scholars of Dept of Agril Economics, PJTSAU, Hyderabad; Prof. Smita Sirohi, Head Agril Economics, NDRI, Karnal (Haryana); Prof. RL Shiyani, Junagarh Agril. University Gujarat; Prof. Sanjay Kumar Srivastava, GBPUA&T, Pantanagar, Prof. Rajesh Sharma, HOD and Prof. Madhu Sharma, SKRAU Bikaner; Prof. PS Badal, Prof Chandra Sen, Prof. HP Singh, Dr O.P. Singh, Dr Prashant Kumar Singh, Dr Manish Kumar Yadav, Dr Neeraj Singh and research scholar ofrom the Department of Agril Economics, Institute of Agril Sciences BHU, Dr Ranjit HOD ABM, NAARM Hyderabad for their participation and valuable inputs/ suggestion in the development of course curriculum of Aril Economics. We extend our gratitude to Prof. Jyoti Kacharoo, HOD Agril Economics, SKUAST, Jammu; Prof. Wani, HOD, SKUAST, Srinagar, Prof. HN Singh, HOD, GBPUAT, Prof. Alka Singh, IARI, New Delhi, Prof. Ram Singh, HOD, CAU, Barapani, Prof. KK Datta, CAU, Barapani, Shillong for their critical inputs and suggestion. We thank to Prof. Rakesh Bhatnagar, Vice-Chancellor, BHU, Prof. Ramesh Chand, Director, Institute of Agril. Sciences, Prof. AP Singh, Dean, Prof. PS Badal, Head for their support to organize the BSMA meeting at BHU Varanasi.

Our sincere gratitude and thanks to all the members of BSMA Committee for Social Sciences, namely, Prof. I Sreenivasa Rao, Professor, Dept. of Extension, PJTSAU, Hyderabad; Dr S Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Finally, we thank profusely Dr NS Rathore, Former Deputy Director General (Education), ICAR, New Delhi, Dr Venkateswarlu, Former ADG (EQR), ICAR for constituting the BSMA for undertaking curricula revision of PG and Ph.D. and their valuable guidance and support in this regard.

Prof. Rakesh Singh (Member, BSMA, Agricultural Economics)
Dr Lipi Das (Convener, BSMA, Social Sciences)
Dr Kalpana Sastry (Chairperson, BSMA, Social Sciences)

Course Title with Credit load
M.Sc. (Ag) in Agricultural Economics

Major Courses: 20 credits

Course Code	Course Title	Credit Hours
AEC-501*	Micro Economic Theory And Applications	3 (3+0)
AEC-502*	Agricultural Production Economics	2 (1+1)
AEC-503*	Agricultural Marketing and Price Analysis	3 (2+1)
AEC-504*	Macro Economics And Policy	2 (2+0)
AEC-505*	Econometrics	3 (2+1)
AEC- 506	Agricultural Development and Policy Analysis	2 (2+0)
AEC-507*	Agricultural Finance and Project Management	3 (2+1)
AEC-508*	Linear Programming	2 (1+1)
AEC-509*	Research Methodology for Social Sciences	2 (1+1)
AEC-510	Indian Economy: History and Contemporary Issues	2 (2+0)
AEC-511	International Economics	2 (1+1)

*courses to be taken compulsorily

Minor Courses: 08 credits

a. It is suggested the student may choose at least two out of three courses listed above as part of minor courses as these are related to policy advocacy and aim to build larger understanding of the subject.
b. Further, it is suggested that the student may also opt to choose the remaining Courses from any other discipline including the disciplines of Agrl. Extensions/ ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HOD.

Course Code	Course Title	Credit Hours
AEC-512	Institutional Economics	1(1+0)
AEC-513	Natural Resource and Environmental Economics	2 (1+1)
AEC-514	Commodity Future Trading	2 (2+0)
AEC-515	Development Economics	2 (2+0)
AEC-516	Rural Marketing	2 (2+0)
AEC-517	Evolution of Economic Thought	1 (1+0)

Minor courses may be taken from above list or subjects closely related to a student's major subject.

Supporting Courses: 6 credits

STAT-501	Statistical Methods For Applied/ Social Sciences	3 (2+1)
STAT-502	Mathematics For Applied Sciences/ Agricultural Economics	3 (2+1)
STAT/COMP	Computer Applications For Agri-Business & Economics	3 (2+1)

Common Courses: 05 credits

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Further, the subcommittee attempted to oversee the design of the entire course is such a way that students may opt to take extra courses to compete with MA Economics stream and Universities may consider to issue a certificate that the degree of M.Sc.(Ag) Agricultural Economics with special mention of extra credits in core Economics.

Course Contents
M.Sc. (Ag) in Agricultural Economics

I. Course Title : Micro Economic Theory and Applications
II. Course Code : AEC-501
III. Credit Hours : 3+0

IV. Why this course?

Markets form an integral part of the economy. They are governed by demand and supply mechanism with profit making its ultimate goal. Thus, it is imperative to expose the students towards how the markets function, their types and how the buyers and sellers behave. That will help them make correct decision when it comes to price setting and choice of product.

V. Aim of the course

The course envisages the concepts and principles embodying micro-economics. The economic problems, functioning of price mechanism, theory of household behaviour and consumer's demand function. Theory of firm, supply determinants, determination of price under different market structures and factor pricing (micro economic components).

VI. Organisation of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to micro-economics	1. Basic Concepts: A review
2.	Insight of consumer, production and cost involved	1. Consumer Choice 2. Production and Cost
3.	Overview of market	1. Market Forms 2. Factor Markets

VII. Theory

Block 1: Introduction to micro-economics

Unit 1: Basic Concepts: A review

Scarcity and Choice; Production possibility frontier, Positive and normative economics; concepts of opportunity cost, Demand and Supply: determinants of individual demand/supply; demand/ supply schedule and demand/ supply curve; market versus individual demand/ supply; shifts in the demand/ supply curve

Block 2- Insight of consumer, production and cost involved

Unit 1: Consumer Choice

Cardinal Utility Approach – Ordinal Utility Approach -Budget sets and Preferences under different situations – Hicks and Slutsky income and substitution effects –

Applications of Indifference curve approach – Revealed Preference Hypothesis – Consumer surplus – Derivation of Demand curve – Elasticity of demand – Demand and supply together; how prices allocate resources; controls on prices – price floor and price ceiling – applications in agriculture.

Unit 2: Production and Cost

Production functions: single variable - average and marginal product, variable proportions, stages of production. Two variables - isoquants, returns to scale and to a factor; factor prices; Technical progress; cost minimization and output maximization; Elasticity of substitution. Expansion path and the cost function Concept of economic cost; Short run and long run cost curves; increasing and decreasing cost industries; envelope curve; L-shaped cost curves; economies of scale; revenue and expenditure, elasticity and marginal revenue; Firm equilibrium and profit.

Block 3: Overview of market

Unit 1: Market Forms

Behaviour of profit maximizing firms and the production process- Perfect competition: Equilibrium of the market. Long run industry supply, applications: effects of taxes and subsidies; Monopoly: Equilibrium; supply; multiplant firm; monopoly power; deadweight loss; price discrimination; Monopolistic Competition: Product differentiation; equilibrium of the firm in the industry-with entry of new firms and with price competition. Comparison with pure competition. Duoploy: Cournot model and reaction curves; Stackelberg's model, Bertrand model; Oligopoly.

Unit 2: Factor Markets

Labour and land markets - basic concepts (derived demand, productivity of an input, marginal productivity of labour, marginal revenue product); demand for labour; input demand curves; shifts in input demand curves; competitive labour markets; Economic rent and quasi rent.

VIII. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on practises done by firms.
- Power point presentations by students.
- Exploring the agricultural market and identification of industries and their type.

IX. Learning outcome

After completion of the course the student will be able to:

- Get acquainted with the basic concepts of market functions.
- Build up vision towards how consumers makes choices and market reaches the equilibrium.
- Develop decision making skill for firms about product selections and scale of production to ensure maximum profit.
- Understand about different types of markets existing in the real world, their principles and whereabouts.

X. Suggested Reading

- Koutsoyiannis A. *Modern Micro Economics*. Macmillan Press Ltd

- Ferguson and Gould. *Micro Economic Theory*. Richard D Erwin Inc., USA
- Richard A. Bilas, *Micro Economic Theory*.
- Leftwich Richard H. *The Price System and Resources Allocation*
- Allen CL. *A Frame Work of Price Theory*.

I. Course Title : Agricultural Production Economics

II. Course Code : AEC-502

III. Credit Hours : 1+1

IV. Why this course?

Production in agriculture is the outcome of the input factors involved. In this competitive and uncertain market, it is important that the farmers take the right decision about the combination of inputs that will result in higher income. Thus, as an economist it is a pre-requisite that the students understand the interaction between output and input. And work out the most effective production plan.

V. Aim of the course

To expose the students to develop the concept, significance and uses of production economics. To understand the relationships between factors and output. To learn how to decide the combination of inputs to be used as per the resources available. Ensure that the production process works efficiently.

VI. Organization of the course

The course is organised as follows-

No	Block	Unit
1.	Introduction to production economics	1. Concepts of production economics
2.	Factors and costs	1. Factors and theory of production 2. Concepts of costs
3.	Assessment	1. Dynamics of assessment

VII. Theory

Block 1: Introduction to Production Economics

Unit 1: Concepts of production economics

Nature, scope and significance of agricultural production economics- Agricultural Production processes, character and dimensions-spatial, temporal - Centrality of production functions, assumptions of production functions, commonly used forms - Properties, limitations, specification, estimation and interpretation of commonly used production functions.

Block 2: Factors and costs

Unit 1: Factors and theory of production

Factors of production, classification, interdependence, and factor substitution -Determination of optimal levels of production and factor application -Optimal factor combination and least cost combination of production - Theory of product choice; selection of optimal product combination.

Unit 2: Concepts of cost

Cost functions and cost curves, components, and cost minimization -Duality theory

– cost and production functions and its applications -Derivation of firm's input demand and output supply functions -Economies and diseconomies of scale.

Block 3: Assessment

Unit 1: Dynamics of economic assessment

Technology in agricultural production, nature and effects and measurement - Measuring efficiency in agricultural production; technical, allocative and economic efficiencies - Yield gap analysis-concepts-types and measurement - Nature and sources of risk, modeling and coping strategies.

VIII. Practical

- Different forms of production functions
- Specification, estimation and interpretation of production functions
- Returns to scale, factor shares, elasticity of production
- Physical optima-economic optima
- Least cost combination
- Optimal product choice
- Cost function estimation, interpretation
- Estimation of yield gap
- Incorporation of technology in production functions
- Measuring returns to scale-risk analysis.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Group/individual)
- Group Discussions on working out
- Power point presentations by students
- Exploring the agricultural market and identification of industries and their type.

X. Learning outcome

After the successful completion of the course the student will be able to— Understand how the factors and output interact with each other. - Work out whether the production system is working efficiently and point out the loop holes.- Apply the knowledge of costs and profits to work out the demand and supply functions. This will result into more efficient decision making.

XI. Suggested Reading

- EO Heady. *Economics of Agricultural Production and resources use.*
- John P Doll and Frank Orazem. *Production Economics: Theory with application*
- Heady EO & Dillon JL. 1961. *Agricultural Production functions.* Kalyani Publishers, Ludhiana, India. 667 p.
- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli.626 p.
- Gardner BL & Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.

I. Course Title : Agricultural Marketing and Price Analysis

II. Course Code : AEC 503

III. Credit Hours : 2+1

IV. Why this course?

The ultimate aim of production process is to sell the produce in the market and generate income. Markets serves as platform where this exchange takes place. Agriculture markets are different from other markets due to the nature of the commodity. Thus, it is important to develop a strong foundation of agricultural marketing, its components and issues. The student needs to know about the multi-pronged ways of marketing the produce, agencies involved. In this modern era, it is important to understand how technology is transforming this sector.

V. Aim of the course

The course is designed to acquaint the students about the basics of dynamics of agricultural marketing. The content includes supply, demand and marketing of farm production, marketing functions and channels, marketing costs, margins and efficiency, agricultural prices, New marketing formats like e-marketing, e-NAM future trading, supply chain management, market intelligence etc.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to agricultural marketing	1. Introduction to agricultural marketing
2.	Agricultural markets	1. Aspects of agricultural marketing 2. Future marketing and government
3.	Advances in agricultural marketing	1. Use of information technology 2. Dynamics of price

VII. Theory

Block 1: Introduction to Agricultural Marketing

Unit 1: Introduction to agricultural marketing

New Concepts in Agricultural Marketing - Characteristic of Agricultural product and Production – Problems in Agricultural Marketing from Demand and Supply and Institutions sides. Market intermediaries and their role - Need for regulation in the present context - Marketable & Marketed surplus estimation. Marketing Efficiency - Structure Conduct and Performance analysis - Vertical and Horizontal integration - Integration over space, time and form-Vertical co-ordination.

Block 2: Agricultural Markets

Unit 1: Aspects of agricultural marketing

Different Forms of marketing: Co-operatives Marketing – APMC Regulated Marketing - Direct marketing, Farmer Producer Companies, e-NAM and marketing under e-NAM, e-marketing Contract farming and Retailing, Organized retailing - Supply Chain Management - State trading, Warehousing and other Government agencies -Performance and Strategies -Market infrastructure needs, performance and Government role - Value Chain Finance.

Unit 2: Future marketing and government

Introduction to Commodities markets and future trading - Basics of commodity futures - Operation Mechanism of Commodity markets – Price discovery - Hedging and Basis - Fundamental analysis - Technical Analysis – Role of Government/SEBI in promoting commodity trading and regulatory measures.

Block 3: Advances in Agricultural Marketing

Unit 1: Use of Information Technology

Role of Information Technology and Market Intelligence in marketing of agricultural commodities, -electronic auctions (e-bay), e-Chaupals, Agmarknet and Domestic and Export market Intelligence Cell (DEMIC).

Unit 2: Dynamics of price

Price forecasting – time series analysis – time series models – spectral analysis. Price policy and economic development – non-price instruments.

VIII. Practical

- Supply and demand elasticities in relation to problems in agricultural marketing.
- Price spread and marketing efficiency analysis.
- Marketing structure analysis through concentration ratios.
- Performance analysis of Regulated market and marketing societies. Analysis on contract farming and supply chain management of different agricultural commodities, milk and poultry products.
- Supply Chain Analysis - quantitative estimation of supply chain efficiency.
- Market Intelligence – Characters, Accessibility, and Availability Price forecasting.
- Online searches for market information sources and interpretation of market intelligence reports – commodity outlook.
- Technical Analysis for important agricultural commodities.
- Fundamental Analysis for important agricultural commodities.
- Presentation of the survey results and wrap-up discussion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on price volatility and control measures prevailing.
- Power point presentations by students on government schemes.
- Visit to eNAM mandies, Warehouses, etc.

X. Learning outcome

After the completion of this course the student will be able to–

- Understand the whereabouts of agricultural marketing.
- The different forms of marketing existing in this sector.
- Gain expertise in market intelligence and price forecasting.

XI. Suggested Reading

- Acharya SS & Agarawal NL. 2004. *Agricultural Marketing in India*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Acharya SS & Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Richard H Kohls and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.

I. **Course Title** : **Macro Economics and Policy**
II. **Course Code** : **AEC-504**
III. **Credit Hours** : **2+0**

IV. Why this course?

The economy of the nation is governed by certain rules, regulation and principles. The students has to gain knowledge of the mechanism through which the large economies are controlled and ensure that welfare prevails. They are entitled to know the transactions between different markets and policies framed to keep value of money under control.

V. Aim of the course

The course envisages the concepts and principles of macroeconomics from classical to Keynesian theories. The other component deals with the monetary system-money, credit and banking system, value of money and economic activities, national income accounting and approaches to estimate national income theory of income and employment determination and inflation.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Conceptualising Macro economics	1. Introduction: Measurement and Concepts
2.	Theories of macroeconomics	1. Classical Macroeconomics 2. Income and spending: Keynesian Framework
3	Money, Consumption and Inflation	1. Money, Interest and Income 2. Theories of Aggregate Consumption and Investment 3. Inflation and Unemployment

VII. Theory

Block 1: Conceptualising Macro Economics

Unit 1: Introduction: Measurement and Concepts

Basic concepts and scope of Macro-economics, National Income Accounting: Methods of measurement of key macro-economic aggregates, relationship of national income and other aggregates (with numerical exercises), real and nominal income

Block 2: Theories of macroeconomics

Unit 1: Classical Macroeconomics

Say's Law, Quantity Theory of Money, aggregate labour supply and demand of labour, Classical theory of determining output, wages and prices.

Unit 2. Income And Spending: Keynesian Framework

Simple Keynesian model of income determination; Keynesian Multiplier- aggregate spending, taxation, transfer payments, foreign spending, balanced budget; budget surplus (with numerical exercises).

Block 3- Money, Consumption and Inflation

Unit 1: Money, Interest and Income

Goods market equilibrium-IS curve; Demand for Money, the Liquidity Preference

Theory – Liquidity Trap; asset market equilibrium- LM curve; simultaneous equilibrium in goods and asset market- effect of fiscal and monetary policy

Unit 2: Theories of Aggregarte Consumption and Investment

Absolute Income Hypothesis, Relative Income Hypothesis, Fisher's Inter-temporal Choice Model, Life-Cycle and Permanent Income Hypotheses; Profits and Accelerator Theory.

Unit 3: Inflation and Unemployment

Inflation: Nature, Effects and control; Types of inflation – demand pull, cost push-stagflation, core inflation, hyperinflation; Phillips curve.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concepts of national income, theories build up to understand macroeconomics. Understand better about the policies and government steps taken to control the economic transaction of the nation. Workout how the investment acts as a catalyst in national development.

X. Suggested Reading

- Stonier & Hegue. *A Text Book of Economic Theory*
- Samuelson PA. 1948. *Foundation of Economic Analysis*. Harvard University Press
- MC Vaish Allid. 1983. *Macro–Economics Theory*
- Gardner Ackley. 1961. *Macro–Economics Theory*: Macmillan, New York.
- TF Dernburg & DM Mcdougali-*Macro Economics*
- G. Sirkin – *Introduction to Macro–Economics Theory*
- RL Heibroker-*Understanding Macro–Economics*
- JK Mehta –*Macro Economics*
- Michael R Edgemand – *Macro-Economics: Theory & Policy*
- David' W Pearce –*The dictionary of modern Economics*

I. Course Title : Econometrics

II. Course Code : AEC 505

III. Credit Hours : 2+1

IV. Why this course?

Development of analytical skills is imperative to make students proficient in conducting quality research work. The knowledge of variables, their models, and problems encountered when dealing with variables will build up a compatibility with the analytical aspects.

V. Aim of the course

The course provides knowledge of the econometric methods like time series analysis, linear regression models and their application in economic analysis. The course provides an insight into the econometric problems in analyzing time series and cross section data.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to econometrics	1. Introduction
2.	Classical Regression	1. Classical Linear Regression 2. Breaking down of Classical assumptions
3.	Qualitative Variables	1. Qualitative variables and simultaneous equation models

VII. Theory

Block 1: Introduction to Econometrics

Unit 1: Introduction

Relationship between economic theory, mathematical economics, models and econometrics, methodology of econometrics-regression analysis.

Block 2: Classical Regression

Unit 1: Classical Linear Regression

Basic two variable regression – assumptions estimation and interpretation approaches to estimation – OLS and their properties – extensions to multi-variable models-multiple regression estimation and interpretation.

Unit 2: Breaking down of Classical assumptions

Violation of assumptions – identification, consequences and remedies for Multicollinearity, heteroscedasticity, autocorrelation – data problems and remedial approaches – model misspecification.

Block 3: Qualitative Variables

Unit 1: Qualitative variables and simultaneous equation models

Use of dummy variables- Introduction to simultaneous equations- identification problem

VIII. Practical

- Single equation two variable model specification and estimation
- Hypothesis testing transformations of functional forms and OLS application
- Estimation of multiple regression model
- Testing and correcting specification errors
- Testing and managing Multicollinearity
- Estimation of regressions with dummy variables

IX. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).

X. Learning outcome

After the completion of the course, the student will be able to-Understand the variables and the properties of regression models. Identify the problems in variables and remove them before conducting the analysis and avoid biased results.

XI. Suggested Reading

- Dorfman R. 1996. *Linear Programming and Economic Analysis*. McGraw Hill.
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis, A. 1997. *Theory of Econometrics*. Barner & Noble.
- Maddala GS. 2002. *Econometrics*. Mc Graw-Hill.
- Pinndyck RS and Rubinfeld DL. 1990. *Econometric Models and Econometric Forecasts*. McGraw Hill.

I. Course Title : Agricultural Development and Policy Analysis

II. Course Code : AEC-506

III. Credit Hours : 2+0

IV. Why this course?

The ultimate aim of the economies is to attain a satisfactory level of development. Development ensures that there is not only increase in income but also the distribution is such that lesser inequalities exist. The students need to know what is development and its related concepts. All the policies framed are with one sole objective of increasing the welfare. Thus, once concept of development is build up, students can better understand policies and their genesis.

V. Aim of the course

Concept of economic development and policy, theories of development, performance of Indian agriculture. The process and implementation of policies over a period of time.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Basic concepts	1. Introduction
2.	Theoretical Concepts	1. Theories of Agricultural Development
3.	Performance and policies	1. Performance of Indian Agriculture
		2. Agricultural Policy: Process and Implementation

VII. Theory

Block 1: Introduction

Unit 1: Introduction

Role of agriculture in economic/ rural development – Evolution of thinking on agriculture and development; Agricultural development – meaning, stages and determinants – Population and food supply – need for sound agricultural policies

Block 2: Theoretical Concepts

Unit 1: Theories of Agricultural Development

Resource exploitation model- Conservation model- Location (Urban impact) model- Diffusion model- High pay-off input model-Induced Innovation Model- Agricultural R&D and Linkages

Block 3: Performance and policies

Unit 1: Performance of Indian Agriculture

Agrarian structure and land relations; trends in performance and productivity; agrarian structure and technology; credit, commerce and technology; capital formation; subsidies; pricing and procurement; Post Green Revolution agriculture; Production and productivity crisis in agriculture; Regional differences; Food Security, PDS system and Malnutrition.

Unit 2: Agricultural Policy: Process and Implementation

Instruments of Agricultural Policy; Process of agricultural policy formulation, implementation, Monitoring and Evaluation in India; Global experiences in participatory approach to Agricultural policy process; critical review of various elements of Indian agricultural policy-resource policies – credit policies – input and product marketing policies – price policies; WTO – Agreement on Agriculture; Planning models. Planning for utilization of resources and Indian Five Year Plans.

VIII. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).
- Group Discussions on evolution of Indian Agriculture and Development indices.
- Power point presentation by students on policies and their relevance.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concept of development and its preference over growth. Visualize how the agriculture sector is performing in this aspect. Understand the motive behind the policies and their implementation.

X. Suggested Reading

- Albert O. Hirschman 1958. *Strategy of Economic Development.* New Man Yale University
- Simon Kuznets 1965. *Economic Growth and Structures.* Oxford New Delhi.
- Das Gupta AK. 1965. *Planning and Economic Growth.* George Allen and Unwin London
- Robert E. Baldwin 1966. *Economic Development and Growth.* John Willey, New York

I. Course Title : Agricultural Finance and Project Management

II. Course Code : AEC 507

III. Credit Hours : 2+1

IV. Why this course?

Money is the fuel of driving all the economic activities. India is a land of small and marginal farmers. The financial conditions of the farmers is not so strong that they can finance themselves. They require credit to meet the requirements of inputs. Thus, the student should know the sources, principles involved and types of credit available. The institutions involved and on what grounds the finance is given to the farmer. What are the risks involved and how to overcome them.

V. Aim of the course

This course is designed with an objective to deliver knowledge of the principles, procedures, problems and policies relating to financing agricultural firms. In addition to this the students are also given knowledge about the research developments in the subject. The approach is analytic.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1	Introduction to Agricultural Finance	1. Basic Concepts: A review
2.	Credit and financial analysis	1. Credit and its aspects 2. Financial analysis
3	Project and risk management	1. Project Overview 2. Risk and its Management

VII. Theory

Block 1: Introduction to Agricultural Finance

Unit 1: Basic concepts: A Review

Role and Importance of Agricultural Finance. Financial Institutions and credit flow to rural/priority sector. Agricultural lending – Direct and Indirect Financing - Financing through Co-operatives, NABARD and Commercial Banks and RRBs. District Credit Plan and lending to agriculture/priority sector. Micro-Financing and Role of MFI's - NGO's, and SHG's.

Block 2: Credit and Financial Analysis

Unit 1: Credit and its aspects

Lending to farmers – The concept of 3 C's, 7 P's and 3 R's of credit. Estimation of Technical feasibility, Economic viability and repaying capacity of borrowers and appraisal of credit proposals. Understanding lenders and developing better working relationship and supervisory credit system. Credit inclusions – credit widening and credit deepening.

Unit 2: Financial analysis

Financial Decisions – Investment, Financing, Liquidity and Solvency. Preparation of financial statements - Balance Sheet, Cash Flow Statement and Profit and Loss Account. Ratio Analysis and Assessing the performance of farm/ firm.

Block 3- Project and Risk Management

Unit 1: Project Overview

Project Approach in financing agriculture. Financial, economic and environmental appraisal of investment projects. Identification, preparation, appraisal, financing and implementation of projects. Project Appraisal techniques – Undiscounted measures. Time value of money – Use of discounted measures - B-C ratio, NPV and IRR. Agreements, supervision, monitoring and evaluation phases in appraising agricultural investment projects. Net work Techniques – PERT and CPM.

Unit 2: Risk and its Management

Risks in financing agriculture. Risk management strategies and coping mechanism. Crop Insurance programmes – review of different crop insurance schemes - yield loss and weather based insurance and their applications.

VIII. Practical

- Development of Rural Institutional Lending;

- Branch expansion, demand and supply of institutional agricultural credit and Over dues and Loan waiving;
- An overview, Rural Lending Programmes of Commercial Banks, Lead Bank Scheme;
- Preparation of District Credit Plan, Rural Lending Programmes of Co-operative Lending Institutions;
- Preparation of financial statements using farm/firm level data, Farm credit appraisal techniques and farm financial analysis through financial statements;
- Performance of Micro Financing Institutions;
- NGO's and Self-Help Groups, Identification and formulation of investment projects;
- Project appraisal techniques – Undiscounted Measures and their limitations;
- Project appraisal techniques – Discounted Measures;
- Network techniques – PERT and CPM for project management;
- Case Study Analysis of an Agricultural project;
- Financial Risk and risk management strategies – crop insurance schemes;
- Financial instruments and methods – E banking, Kisan Cards and core banking.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on inflation

X. Learning outcome

After the completion of the course the student will be able to-Understand the key issues of finance in Agriculture. Learn the techniques of assessing the worth of a project.

XI. Suggested Reading

- E Die Sollem H and Heady EO. (Ed.). *Capital and Credit Needs in Changing Agriculture*, Bauman.
- Hopkins A Barry, Peter Jo and Baker CB. *Financial Management in Agriculture*.
- Murray WG and Nelson AG. 1960. *Agricultural Finance*. Iowa State University
- Chanona C. 1969. *Agricultural Finance in India: Role of Commercial Banks*. Marketing and Economics Research Bureau, New Delhi.
- Gittinger JP. 1972. *Economic analysis of agricultural projects*, John Hopkins Univ. Press, Baltimore.
- Little IMD and JA Mirrless. 1974, *Project appraisal and planning for developing countries*, Oxford and IBH publishing Co. New Delhi.
- Arnold CH. 1972. *Project Evaluation, collected papers*, Macmillan.

I. Course Title : Linear Programming

II. Course Code : AEC-508

III. Credit Hours : 1+1

IV. Theory

Unit I

Decision Making- Concepts of decision making, introduction to quantitative tools, introduction to linear programming, uses of LP in different fields, graphic solution to problems, formulation of problems.

Unit II

Simplex Method: Concept of simplex Method, solving profit maximization and cost minimizations problems. Formulation of farms and non farm problems as linear programming models and solutions.

Unit III

Extension of Linear Programming models: Variable resource and price programming, transportation problems, recursive programming, dynamic programming.

Unit IV

Game Theory- Concepts of game theory, two person constant sum, zero sum game, saddle point, solution to mixed strategies, the rectangular game as Linear Programming.

V. Practical

- Graphical and algebraic formulation of linear programming models.
- Solving of maximization and minimization problems by simplex method.
- Formulation of the simplex matrices for typical farm situations.

I. Course Title : Research Methodology for Social Sciences
II. Course Code : AEC 509
III. Credit Hours : 1+1

IV. Why this course

Planning of research is very crucial to conduct a successful research. There is need to give an insight to the student about how to conduct a research, right from data collection to analysis and finally writing the references.

V. Aim of the course

The course deals with scientific methods of research, the initiation of an inquiry, formulation of research problems and hypotheses, the role of induction and deduction in research, collection and analysis of date and interpretation of results

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to research methodology	1. Concepts of research methodology
2.	Building up hypothesis and sample selection	1. Hypothesis: Framing and Testing 2. Sampling
3.	Data collection and analysis	1. Data collection 2. Data Analysis

VII. Theory

Block 1: Concepts of research methodology

Unit 1: Concepts of research methodology

Importance and scope of research in agricultural economics. Types of research – Fundamental vs. Applied. Concept of researchable problem – research prioritization – selection of research problem. Approach to research – research process.

Block 2- Building up hypothesis and sample selection

Unit 1: Hypothesis: Framing and Testing

Hypothesis – meaning – characteristics – types of hypothesis – review of literature – setting of Course Objective and hypotheses – testing of hypothesis.

Unit 2: Sampling

Sampling theory and sampling design – sampling error - methods of sampling – probability and non-probability sampling methods - criteria to choose. Project proposals – contents and scope – different types of projects to meet different needs – trade-off between scope and cost of the study. Research design and techniques – Types of research design.

Block 3- Data Collection and Analysis

Unit 1: Data Collection

Data collection – assessment of data needs – sources of data collection – discussion of different situations. Mailed questionnaire and interview schedule – structured, unstructured, open ended and closed-ended questions. Scaling Techniques. Preparation of schedule – problems in measurement of variables in agriculture. Interviewing techniques and field problems - methods of conducting survey – Reconnaissance survey and Pre testing.

Unit 2: Data Analysis

Data coding, tabulation, cleaning. –Multivariate analysis –factor analysis' PCA' cluster analysis. Universal procedures for preparation of bibliography – writing of research articles.

VIII. Practical

- Exercises in problem identification.
- Project proposals – contents and scope.
- Formulation of Objective and hypotheses.
- Assessment of data needs – sources of data – methods of collection of data.
- Methods of sampling – criteria to choose – discussion on sampling under different situations.
- Scaling Techniques – measurement of scales.
- Preparation of interview schedule.
- Field testing. Method of conducting survey.
- Exercise on coding, editing, tabulation and validation of data.
- Preparing for data entry into computer.
- Hypothesis testing – Parametric and Non-Parametric Tests.
- Exercises on format for Thesis/ Report writing.
- Presentation of the results.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After the successful completion of this course, student will be able to-Understand fundamentals of research. How to carefully plan out the research work and conduct it.

XI. Suggested Reading

- Baker CB. *Research Methodology in Agricultural Economics*
- Cohen MR and Nagel R. *An Introduction to Logic and Scientific Method*
- Devey J Logic. *The Theory of Enquiry*
- Dhondhyal SP. *Social Science Research and Thesis Writing*
- Ezekiel M. *Correlation Analysis*
- Heady EO. *Linear Programming Methods*
- Willson ER. *An Introduction to Scientific Research*
- Kumar A. 2008. *Research Methodology: A Survey*. Alts, New Delhi,

I. Course Title : Indian Economy: History and Contemporary Issues Credit

II. Course Code : AEC-510

III. Credit Hours : 2+0

IV. Why this course?

India is a developing economy. The evolution of the Indian economy will enlighten the student with how an economy develops. Students will understand how the policies and measures taken shape up the economy of the country.

V. Aim of the course

To introduce the students to the economic history over a period of time. It also highlights the contemporary issues of Indian economy.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	History of Indian Economy	1. India from Independence to Liberalization 2. India since 1980’s (Liberalization and Beyond): Overview 3. Macro Trends Since 1990
2.	Contemporary Issues	1. Contemporary Issues

VII. Theory

Block 1- History of Indian Economy

Unit 1: India from Independence to Liberalization

An overview of the economic developments during the period 1947-1980; Objectives and strategies of planned economic development and the role of the State; Sectoral growth performance; savings and investment; Demographic trends and issues; education; health and malnutrition; Trends and policies in poverty; inequality and unemployment.

Unit 2: India Since 1980's (Liberalization And Beyond): Overview

Policy Changes since 1980s. The 1990 Crisis. Causes and Effects of liberalization. Regional differences: infrastructure, primary, secondary and tertiary sector.

Unit 3: Macro Trends Since 1990

Growth; Savings and Investment, Employment; productivity; diversification; Agro-based industries; competition policy; foreign investment, Regional differences.

Block 2- Contemporary Issues

Unit 1: Contemporary Issues

Monetary and Financial trends- areas of government spending in India, Capital expenditure, revenue expenditure, plan expenditure, non plan expenditure, Deficits (fiscal, primary, revenue), impact of fiscal deficit on economy, Capital receipts, revenue receipts, tax and non tax revenue, direct and indirect taxes, need to rationalize tax structure. Goods and Services Tax (GST). Union Budget, Zero base budgeting, Gender budgeting, Fiscal devolution and centre state financial relations in India, WPI, CPI implicit deflators. Foreign Trade policy.

VIII. Teaching Methods/ Activities

- Lectures
- Power point presentation by students on monetary and fiscal policy in past and present.
- Assignments (Group/individual).
- Group Discussions on Tax and its reforms.

IX. Learning outcome

After the completion of the course the student will be able to-Visualize how the Indian economy has evolved. Get acquainted with the basic steps involved in the working of the national economy.

X. Suggested Reading

- Dutt and Sundaram. *Indian Economy*

I. Course Title : International Economics

II. Course Code : AEC 511

III. Credit Hours : 2+1

IV. Why this course?

The era of Globalisation, liberalization and privatization has unified the whole world. There is trade across national boundaries and one economy has effect on the other. Getting familiar with national economy is not sufficient to understand the mechanism of trade and economic aspects. Thus, this course is designed to teach student about the trade as international level.

V. Aim of the course

The major objective of this course is to give an insight of the interactions between national economies. What are the theories governing the trade across national boundaries. The methods involved to regulate the international trade and institutions involved.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Concepts of International Economics
2.	Models, Rate and terms of trade	1. Barriers to trade
		2. Models of trade
		3. Rates and Terms of trade
3	Institutions	1. Trades Institutions

VII. Theory

Block 1- Introduction

Unit 1: Concepts of International Economics

Scope and Significance of International Economics – The role of trade- General Equilibrium in a Closed Economy (Autarky Equilibrium) – Equilibrium in a Simple Open Economy - Possibility of World Trade - Trade gains and Trade Equilibrium.

Block 2- Models, Rate and Terms of Trade

Unit 1: Barriers to trade

Tariff, Producer Subsidy, Export Subsidy, Import Quota and Export Voluntary Restraints- The Case of Small Country and Large Country Case.

Unit 2: Models of trade

Ricardian Model of Trade- Specific Factors Model- Heckscher - Ohlin Model - Trade Creation and Trade Diversion – Offer Curve - Export Supply Elasticity and Import Demand Elasticity – Comparative Advantage and Absolute Advantage.

Unit 3: Rates and Terms of trade

Official Exchange Rate and Shadow Exchange Rate - Walra's Law and Terms of Trade – Trade Blocks.

Block 3- Institutions

Unit 1: Trades Institutions

IMF, World Bank, IDA, IFC, ADB – International Trade agreements – Uruguay Round – GATT – WTO.

VIII. Practical

- Producer's Surplus, Consumer's Surplus, National Welfare under Autarky and Free Trade Equilibrium with small and large country assumption.
- Estimation of Trade Gains
- Estimation of competitive and comparative measures like NPC, EPC, ERP and DRC
- Estimation of Offer Curve Elasticity
- Estimation of Effect of Tariff, Export Subsidy, Producer Subsidy, Import Quota and Export Voluntary Restraints on National Welfare
- Estimation of Ricardian Model
- Estimation of Effect of Trade under Specific Factor Model
- Estimation of trade Equilibrium under Heckscher -Ohlin model

- Trade Creation and Diversion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentation on International Trade in current scenario.

X. Learning outcome

After successful completion of the course the student will be able to –Understand how trade take place between nations. Be able to work out strategies to maintain a favourable trade balance. Understand how the institutions play role in regulating the cross country trade and deal with the issues.

XI. Suggested Reading

- Kindelberger and Joshi PK. 2016. *International Economics* AITBS Delhi-110051
- Brouwer F. *International Trade and Food Security*. LEI - Wageningen UR, The Netherlands.

I. Course Title : Institutional Economics

II. Course Code : AEC 512

III. Credit Hours : 1+0

IV. Why this course?

Institutions are involved in framing of economic development. The human behavior is governed by the institutions working in their environment. Thus, the student need to understand the institutions and their working.

V. Aim of the course

To develop critical and informed understanding about institutions, their role in the working of economy. Exposure of issues, policies & regulations and its application in agricultural system

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1	Introduction	1. Basics of Institutional Economics
2.	Approaches	1. Institutional changes & Resource allocation 2. Group and collective Approach
3.	Law Protection and Institutions	1. Property rights 2. Agrarian Institutions

VII. Theory

Block 1: Introduction

Unit 1: Basics of Institutional Economics

Old and New Institutional Economics – Institutional Economics vs Neo-classical Economics. Definition of institutions – Distinction between institutions and organizations – Institutional evolution.

Block 2: Approaches

Unit 1: Institutional changes & Resource allocation

Institutional change and economic performance - national and international economic institutions. Transaction cost economics – Transaction costs and the allocation of resources. Transaction costs and efficiency. Asymmetric information - Moral hazard and Principal-Agent problem.

Unit 2: Group and collective Approach

Free rider problem – path dependency – Interlinked transactions. Collective action and the elimination of free-rider problem - The logic of collective action and its role in reducing free rider problem – theory of Groups. Rent seeking – interest groups and policy formulation.

Block 3: Law Protection and Institutions

Unit 1: Property rights

Economic analysis of property rights- property rights regimes – private property – State Property - Common property Resources (CPRs) – public goods and club goods.

Unit 2: Agrarian Institutions

Special features of institutional arrangements in agriculture – Transaction costs in agriculture - Case Studies - Theories of agrarian institutions - tenancy institutions.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on Property rights

IX. Learning outcome

After successful completion of this course the student will be able to-Understand institutions and their roles in economic development. Know about the policies and their issues in an institutions.

X. Suggested Reading

- Pearce DW –*The dictionary of modern Economics*

I. Course Title : Natural Resource and Environmental Economics

II. Course Code : AEC 513

III. Credit Hours : 1+1

IV. Why this course?

Sustainable development is the need of the hour. The economic activities affect not only the society but also the environment. Every activity has its social cost. The students, hence will be taught about the economic aspect of environment.

V. Aim of the course

To understand about economics of environment and social costs incurred due to economic development. Work out methods to maintain environment quality and reduce social costs

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to natural resource and environmental economics	1. Basic Foundation
2.	Insight of the subject	1. Theories and economics of natural resources 2. Functioning of Market
3	Dealing with Issues and sustainability	1. Environmental Issues 2. Regulations 3. Sustainability aspects

VII. Theory

Block 1- Introduction to natural resource and environmental economics

Unit 1: Basic Foundation

Concepts, Classification and Problems of Natural Resource Economics – Economy Environment interaction – The Material Balance principle, Entropy law-Resources Scarcity - Limits to Growth - Measuring and mitigating natural resource scarcity – Malthusian and Recardian scarcity – scarcity indices - Resource Scarcity and Technical Change.

Block 2- Insights of the subject

Unit 1: Theories and economics of natural resources

Theory of optimal extraction renewable resources –economic models of oil extraction-efficiency - time path of prices and extraction - Hotelling's rule, Solow-Harwick's Rule. Theory of optimal extraction exhaustible resources – economic models of forestry and fishery.

Unit 2: Functioning of Market

Efficiency and markets – market failures - externalities – types - property rights – transaction costs – Coase's theorem and its critique - public goods - common property and open access resource management - Collective action.

Block 3- Dealing with the issues and sustainability

Unit 1: Environmental Issues

Environmental perspectives - biocentrism, sustainability, anthropocentrism - Environmental problems and quality of environment - Sources and types of pollution -air, water, solid waste, land degradation – environmental and economic impacts - Economics of pollution control - efficient reduction in environmental pollution.

Unit 2: Regulations

Environmental regulation – economic instruments - pollution charges – Pigovian tax - tradable permits – indirect instruments – environmental legislations in India.

Unit 3: Sustainability aspects

Concept of sustainable development – Economic Perspective – Indicators of sustainability Relation between development and environment stress-Environmental Kuznet's curve Environmental Accounting – resource accounting methods –

International Environmental Issues – climate change – likely impacts – mitigation efforts and international treaties.

VIII. Practical

- Exhaustible resource management – optimum rate of oil extraction.
- Renewable resource management – optimum harvest of Forestry/fishery.
- Exercise on pollution abatement-I.
- Exercise on pollution abatement-II.
- Concepts in valuing the environment.
- Taxonomy of valuation techniques.
- Productivity change method – substitute cost method – Hedonic price method – Travel cost method – Contingent valuation methods.
- Discount rate in natural resource management.
- Environment impact assessment
- Visit to Pollution Control Board.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).

X. Learning outcome

After successful completion of this course, the student will be able to-Work out the plan for extraction / use of natural resource in most economical way. Understand the environment and its pollution. Learn how markets are affected if environment is not taken into consideration. Gain proficiency in rules and regulation governing economic aspect of environment.

XI. Suggested Reading

- Pearce DW and Turner RK. *Economics of Natural Resource and Environment*
- Kwak J. *Economism: Bad Economics and the Rise of Inequality*
- Tietenberg T and Lewis L. *Environmental and Natural Resource Economics*
- Schwarz PM. *Energy Economics*

I. Course Title : Commodity Future Trading Credits

II. Course Code : AEC 514

III. Credit Hours : 2+0

IV. Why this course?

Risk is involved in marketing. Price fluctuation is a very common phenomenon in agriculture marketing. In such situation selling of commodity in future market serves as a resort to insulate from this uncertainty. Thus, knowledge of futures market is helpful in ...

V. Aim of the course

To disseminate the knowledge about risk mitigating measures especially future trading. The future trading in agricultural commodities is increasing day by day therefore the role of SEBI, functioning of commodity exchanges are discussed.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to commodity market	1. Concepts of commodity future trading
2.	Techniques and risks in commodity market	1. Technical aspects 2. Risk and its Management
3.	Commodity exchange and market analysis	1. Commodity Exchange–A review 2. Analysis of commodity market

Theory

Block 1- Introduction to commodity market

Unit 1: Concepts of commodity future trading

History and Evolution of commodity markets – Terms and concepts: spot, forward and futures Markets – factors influencing spot and future markets. Speculatory mechanism in commodity futures.

Block 2- Techniques and Risks in Commodity Market

Unit 1: Technical aspects

Transaction and settlement – delivery mechanism - role of different agents - trading strategies -potential impact of interest rate, Foreign Exchange, FDI in Commodity Markets.

Unit 2: Risk and its Management

Risk in commodity trading, importance and need for risk management measures - managing market price risk: hedging, speculation, arbitrage, swaps - pricing and their features.

Block 3- Commodity exchange and market analysis

Unit 1: Commodity Exchange – A review

Important global and Indian commodity exchanges - contracts traded – special features -Regulation of Indian commodity exchanges - FMC and its role.

Unit 2: Analysis of commodity market

Fundamental Vs Technical analysis – construction and interpretation of charts and chart patterns for analyzing the market trend – Market indicators – back testing. Introduction to technical analysis software – analyzing trading pattern of different commodity groups.

VII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions.
- Power point presentations by students.

VIII. Learning outcome

After successful completion of this course, the student will be able to-The basic concepts of commodity markets. The national and international commodity markets.

IX. Suggested Reading

- Kaufman PJ. *The Concise Handbook of Futures Markets*: Jhon Wiley & Sons
- Purcell WD. *Agricultural Futures and Options: Principles and Strategies*: MacMillan Publications
- Wasendorf RR & McCaffery *All About Commodities from the Inside Out*. McGraw Hill

I. Course Title : Development Economics Credit

II. Course Code : AEC-515

III. Credit Hours : 2+0

IV. Why this course?

Development is more important than growth. The development of a nation ensures that condition of welfare prevails. The students has to understand different measures of development. How to measure them and relevant theories.

V. Aim of the course

To develop concept of growth and development. Methods and theories of measuring development. Study of different developed economies will give exposure towards measures to create economic upliftment.

VI. Learning outcome

After successful completion of this course, the student will be able to-Measure the development using different methods. Understand the theories of development and relate it to real world.

VII. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to development economics	1. Conceptions of Development
2.	Theories and comparison	1. Theories of Economic growth and development 2. Comparative Economic Development

VIII. Theory

Block 1- Introduction to Development Economics

Unit 1: Conceptions of Development

Development Economics – Scope and Importance - Economic development and economic growth - divergence in concept and approach - Indicators and Measurement of Economic Development –GNP as a measure of economic growth – New Measures of Welfare – NEW and MEW – PQLI – HDI – Green GNP - Criteria for under development – Obstacles to economic development –Economic and Non-Economic factors of economic growth- Development issues, poverty, inequality, unemployment and environmental degradation.

Block 2- Theories and comparison

Unit 1: Theories of Economic growth and development

Classical theories- Adam smith - Ricardo- Malthus, Marx's theory of economic development; Schumpeter's theory, Approaches to development- low income equilibrium trap - critical minimum effort- The Strategy of economic development- Balanced vs. Unbalanced growth, choice of technique, investment criteria, big push theory, Rostow's stages of Economic Growth, unlimited supply of labour; social and technological dualisms; roles of capital accumulation, human capital and technological change in economic development, Models of economic growth Harrod-Domar, Kaldor, Mahalanobis, Lewis, FeiRanis, Input-Output, multisectoral models.

Unit 2: Comparative Economic Development

Countries selected for case studies -USA, Japan, China and India; Overview of economic development is selected countries; agrarian surplus and the role of the peasantry in economic development; industrial revolution; division of labour, organisation of work and industrial production, the role of the State in developmental transition

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation

X. Suggested Reading

- Blaug M. 1986. *Economic History and the History of Economic Thought*
- Chenery HB and TN Srinivasan. *Handbook of Development Economics*
- Baldwin RE. *Economic Development and Growth*. John Willey, New York

I. Course Title : Mathematics for Agricultural Economics

II. Course Code : STAT/AEC

III. Credit Hours : 3+0

IV. Why this course?

Knowledge of calculus is basic requirement for carrying out simple calculations.

V. Aim of the course

To solve various mathematical problems in economic research. Calculations are integral part of research analysis therefore it has wide application in economic studies.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Preliminaries
2.	Variables and functions	1. Variables and functions 2. Differentiation of functions
3.	Overview of linear algebra	1. Linear Algebra 2. Optimization of functions 3. Integration of functions

VII. Theory

Block 1- Introduction

Unit 1: Preliminaries

Logic and proof techniques; sets and set operations; relations; functions and their properties; number systems

Block 2- Variables and functions

Unit 1: Variables and functions

Specific functions is economic theory. Elementary analytical geometry-gradient and equation of straight line. Standard equations and simple properties of circle, parabola and rectangular hyperbola.

Unit 2: Differentiation of functions

Limit and continuity. Differentiation, theorems of differentiation, differentiation of logarithmic and exponential functions, function of a function, derivative of higher order, partial derivatives. Application of derivatives to determine average and marginal values in economic analysis; determination of elasticities; points of inflexion; linear homogenous production functions; derivation of average and marginal curves.

Block 3- Overview of Linear Algebra

Unit 1: Linear Algebra

Determinants, evaluation and properties of determinants, Vectors and vector spaces, Matrices, notations and operations, laws of matrix algebra; transpose and inverse of matrix; Solution of linear and quadratic equations involving one variable, simultaneous equations, application of determinants and matrices in solution of equation for economic analysis.

Unit 2: Optimization of functions

Optimization- unconstrained, maxima and minima, constrained optimization, Lagrange multiplier and their economic applications for optimization problems of cost, production, demand and supply.

Unit 3: Integration of functions

Integration as a reverse process of differentiation, methods of integration, reduction formulae, definite integral, use of integration to determine relation between average and marginal value. Capitalization over time, estimation of returns from capital goods over time. Pareto distribution.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentations

IX. Learning outcome

After successful completion of this course, the student will be able to-Develop expertise in calculus operations.

Course Title with Credit Load
Ph.D. in Agricultural Economics

Major Courses: 12 credits

Course Code	Course Title	Credit Hours
AEC-601	Advanced Micro Economic Analysis	2 (1+1)
AEC-602	Advanced Macro Economic Analysis	2 (2+0)
AEC-603	Advanced Econometrics	3 (2+1)
AEC-604	Advanced Production Economics	3 (2+1)
Common	Research and Publication Ethics	2(2+0)

Minor Courses: 06 credits

a. It is suggested the student may choose at least one out of three courses listed below as part of minor courses as these are related to policy advocacy and bring in global perspectives with an aim to build a larger understanding of the subject to the student.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agril. Economics/ ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HoD.

AEC-606	Advanced Agricultural Marketing and Price Analysis	3 (2+1)
AEC-607	Quantitative Development Policy Analysis	2 (1+1)
AEC-608	Natural Resource Management	3 (2+1)
AEC-609	Environmental Economics	3(2+1)

Minor courses may be taken from above list or subjects closely related to a student's major subject

Supporting Courses: 05 credits

AEC-605	Operations Research	3 (2+1)

One course of 600 series of 2 credits from Statistics or computer discipline may be taken depending upon availability.

- Some of these courses are available in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform.
- If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the HoD/ BoS.

- It is also suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HoD".

AEC-660	Doctoral Seminar -I	1(1+0)
AEC-661	Doctoral Seminar -II	1(1+0)
	RESEARCH	75
	Total	100

There will be two Doctoral Seminar and a research scholar has to published one review paper as output of these seminar. At Ph.D. level, Research Plan Proposal (RPP) be delivered by the end of SEM II

Course Contents
Ph.D. in Agricultural Economics

I. Course Title : Advanced Micro Economic Analysis
II. Course Code : AEC 601
III. Credit Hours : 1+1

IV. Why this course?

This course is required to upscale the knowledge of students about micro economics. So that they can get a deeper and better understanding of the subject.

V. Aim of the course

To gain fundamental understanding of consumer behavior, producer's strategy, market structure through which transactions take place and human and firms interact. Develop foundation of scarce resource allocation for optimum results.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1.	Consumer Theory	1. Consumer Theory
2.	Market and General quilibrium	1. Market 2. General Equilibrium
3.	Market failure and welfare	1. Market Failure 2. Welfare Economics

VII. Theory

Block 1- Consumer Theory

Unit 1: Consumer Theory

Theory of consumer behavior – Duality in consumer theory - expenditure function and indirect utility function - Measurement of Income Effect and Substitution Effect. Measurement of Changes in Consumers' Welfare – Consumer's Surplus, Compensating Variation and Equivalent Variation - Dynamic versions of demand functions – Integrability of demand functions. Demand Models – Linear Expenditure System, Almost Ideal Demand System. Applications of consumer theory – Household model and time allocation – Labour supply decisions by households.

Block 2- Market and General Equilibrium

Unit 1: Market

Perfect competition – Monopoly, monopolistic competition and oligopoly. Oligopoly models – collusive and non-collusive models of oligopoly - Cournot model, Chamberlin model, Stackleberg solution.

Unit 2: General Equilibrium

General equilibrium theory – Conceptual overview - General equilibrium conditions with Production and Consumption. Existence, Uniqueness and Stability of general competitive equilibrium. Walrasian general equilibrium – Mathematical derivation of conditions for general equilibrium.

Block 3- Market Failure and Welfare

Unit 1: Market failure

Market failure - Incomplete markets - Asymmetric information – Principal-Agent problem, adverse selection and moral hazard. Externalities – Network externalities, Public goods – Optimal provision of public goods.

Unit 2: Welfare Economics

Welfare Economics - Concepts, problems, approaches and limitations of Welfare Economics, Pareto conditions of maximum welfare – Criteria for social welfare - Social Welfare functions, Social versus Private costs and benefits.

VIII. Practical

- Problems in consumer utility maximization
- Estimation of income and substitution effects;
- Estimation and comparison of Consumer's surplus, equivalent variation and compensating variation.
- Estimation of demand models – Derivation and estimation of labour supply equations from household models comparative static analysis in consumption.
- Advanced problem solving in price determination under perfect competition, monopoly, oligopoly and monopolistic competition.
- Game theory models.
- Problems solving in General Equilibrium Theory and Welfare Economics.
- Problems in public goods provision.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to-Understand the different market competition. Work out strategies for attaining equilibrium in the market.

XI. Suggested Reading

- Henderson JM and Quandt RE. *Microeconomic Theory: A Mathematical Approach* Tata McGraw Hill Publishing Co Ltd
- Koutsoyiannis A. *Modern Micro Economics*. Macmillan Press Ltd
- Ferguson and Gould. *Micro Economic Theory*. Richard D Erwin Inc USA

I. Course Title : Advanced Macro Economics

II. Course Code : AEC-602

III. Credit Hours : 2+0

IV. Why this course?

A deeper understanding of the conceptual and structural framework is imperative to develop vision of a student about how the knowledge of various macroeconomic models is applied in real economy.

V. Aim of the course

To understand the functioning of national economy, its history and models. The policies governing the modern economic system and concerned institutions.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1.	Introduction	1. Overview
2.	Economic Models	1. Open Economy Models 2. Dynamic Macroeconomic Models
3.	Business cycle and pollicies	1. Business Cycles 2. Macroeconomic Polices

VII. Theory

Block 1- Introduction

Unit 1: Overview

Conceptual framework - Classical, Keynesian, Neo-Classical, and Neo-Keynesian macroeconomics; Review of Keynes-Classical Synthesis; Aggregate Demand and Supply in the closed economy with fixed and variable price level- determination of wage, prices, output and employment

Block 2- Economic Models

Unit 1: Open Economy Models

Exchange rate determination; purchasing power parity; asset market approach; Short-run open economy models; Mundell-Fleming model- exchange rate regime: perfect capital mobility under fixed and flexible exchange rate; effectiveness of fiscal policy and monetary policy; Dornbusch's overshooting model; monetary approach to balance of payments; international financial markets

Unit 2: Dynamic Macroeconomic Models

Introduction to dynamic macroeconomic Models; Dynamic aggregate demand and supply – short and long term equilibrium- rational expectations approach

Block 3: Business Cycle and Policies

Unit 1: Business Cycles

Business cycle and its alternative equilibrium model, Stability analysis Economics of Great Events-Depression, Hyperinflation and Deficits; Advances in Business Cycle Theory; Real Business Cycles & Neo-Keynesian Economics

Unit 2: Macroeconomic Polices

Monetary policy - Design of Monetary Policy; Inflation Targeting, Fiscal Policy - Government Budget Constraint: The Arithmetic of Deficits and Debt, Current versus Future Taxes, the Evolution of Debt-to-GDP Ratio; Public Borrowing-Internal and external aid, Deficit financing, Development Financing; BOP & Adjustment Policies - Foreign Exchange Policy -International macro-economic policies, IMF, IBRD, UNCTAD.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Learning outcome

After successful completion of this course the student will be able to-Figure out how policies are framed to safe guard the national economy. Understand the rationale behind the working of different economy.

X. Suggested Reading

- Heibroker RL. *Understanding Macro Economics.*
- Mehta JK. *Macro Economics.*
- Edgemand MR. *Macro-Economics: Theory & Policy.*
- David' W Pearce. *The dictionary of modern Economics.*
- Allen RGD. 1968. *Macro–Economic Theory: A Mathematical Treatment*. London: Macmillan.
- Stanlake GF. *Macro–Economics: An Introduction*. Longman, London.
- Mithai DM. 1981. *Macro–Economics: Analysis and Policy*. Oxford and IBH, New Delhi.
- Hicks JR *Critical Essays in Monetary Theory.*
- Nawiyn WT. *Theory of Money.*

I. Course Title : Advanced Econometrics

II. Course Code : AEC 603

III. Credit Hours : 2+1

IV. Why this course?

The heart of any research is carrying out the analysis with the most appropriate model. The results obtained are crucial for the researchers. Thus, this course acts as the centre point of building up analytical framework of research. The students need to learn building up of models that will be used to test the hypothesis framed. Use different analysis depending upon the requirement and type of data.

V. Aim of the course

The course aims at providing the knowledge and command over analysis of data collected to get the desired result. Train the student in use of econometric models.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Review
2.	Least squares and dummy variables	1. Concept of Least Squares 2. Dummy Variable
3.	Econometric models	1. Models and their extensions 2. Simultaneous equation modles

VII. Theory

Block 1: Concepts

Unit 1: Review

Review of classical regression model – review of hypothesis testing – restrictions on parameters – single equation techniques.

Block 2: Least Squares and Dummy Variables

Unit 1: Concept of least squares

Ordinary least squares – weighted least squares - generalized least squares – method of principal components – instrumental variables method - maximum likelihood method - errors in variables, non-linearity and specification tests – non spherical error terms.

Unit 2: Dummy Variable

Dummy variables - Qualitative and truncated dependent variables - limited dependent variables –LPM, probit and logit models, their multinomial extensions.

Block 3: Econometric Models

Unit 1: Models and their extensions

Autoregressive distributed lag models – panel data fixed and random effects models and their extensions.

Unit 2: Simultaneous equation models

Simultaneous equation methods –identification – estimation by indirect least squares 2SLS, PIML, SURE, 3SLS

VIII. Practical

Estimation of multiple regression model - GLS estimation methods - testing misspecification errors – Testing and Managing multicollinearity, heteroscedasticity and autocorrelation - estimation of LPM, Logit and Probit models - comparing two regressions - Chow test - estimation of distributed lag models – panel data random and fixed effects models - Indirect least squares 2SLS, SURE, 3SLS, estimation of simultaneous equation models.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/ individual).
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to–

- Analyse the data collected for testing the framed hypothesis.
- Get expertise in analytical framework.

XI. Suggested Reading

- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Production Economics

II. Course Code : AEC 604

III. Credit Hours : 2+1

IV. Why this course?

There is requirement of getting acquainted with decision making process in case of factors and products. The researcher needs to understand about working on production process and work out suitable suggestions to improve it.

V. Aim of the course

The course deals with the concept of advanced production economics. The exposition would be mathematically oriented. The course would also cover the analysis of production functions, its interpretation, decision making with multiple input use, factor sharing and decision making under risk and uncertainty.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Consumer Theory	**1.** Production Process
2.	Market and General quilibrium	1. Production Functions and characteristics
3.	Market failure and welfare	1. Decision Making in Production 2. Technology, Efficiency and Risk Management 3. Programming

VII. Theory

Block 1: Production process

Unit 1: Production Process

Agricultural Production process – Relationship between farm planning and production economics-scope of agricultural production and planning-methods/ procedures in agro-economic research and planning.

Block 2: Production Function

Unit 1: Production Functions and characteristics

Production functions, components, assumptions, properties and their economic interpretation - Concepts of homogeneity, homotheticity,, APP, MPP, elasticities of substitution and their economic relevance – Production relations – optimality- Commonly used functional forms, nature, properties, limitations, estimation and interpretation - linear, Spillman - Cobb Douglas, quadratic, multiplicative (power) functional forms - Translog, and transcendental functional forms - CES, production functional forms-Conceptual and empirical issues in specification, estimation and application of production functions- Analytical approaches to economic optimum - Economic optimum – determination of economic optimum with constant and varying input and output prices - Economic optimum with production function analysis - input use behaviour.

Block 3: Dynamics of production process

Unit 1: Decision Making in Production

Decision making with multiple inputs and outputs – MRT and product relationship-cost of production and adjustment in output prices-single input and multiple product decisions- Multi input, and multi product production decisions - Decision making with no risk -Cost of wrong decisions - Cost curves – Principles and importance of duality theory - Correspondence of production, cost, and profit functions - Principles and derivation of demand and supply functions

Unit 2: Technology, Efficiency and Risk Management

Technology, input use and factor shares -effect of technology on input use-decomposition analysis-factor shares-estimation methods- Economic efficiency in agricultural production – technical, allocative and economic efficiency – measurement -Yield gaps analysis – concepts and measurement - Risk and uncertainty in agriculture – incorporation of risk and uncertainty in decision making – risk and uncertainty and input use level-risk programming.

Unit 3: Programming

Simulation and programming techniques in agricultural production-Multiple Objective Programming (MOP) – Goal programming, Weighted sum and Compromise programming – applications.

VIII. Practical

Estimation of different forms of production functions- Optimal input and product choice from estimated functions-Derivation of demand and supply functions and estimation-Estimation of cost function and interpretations-Optimal product and input choice under multi input and output system-Estimation of factor shares from empirical functions estimated-Estimating production functions incorporating technology changes: Decomposition analysis and incorporation of technology-Estimation of efficiency measures – Stochastic, probabilistic and deterministic frontier production functions-Risk programming – MOTAD-Quadratic programming-Simulation models for agricultural production decisions-Goal programming – Weighted, lexicographic and fuzzy goal programming-Compromise programming.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After successful complétion of the course, the student will be able to-Get familiar with different production function and use them in practise and come out with useful decision. Work out the efficiency of the production process and use models for finding the optimum solution.

XI. Suggested Reading

- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli. 626 p.
- Gardner BL and Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.
- Heady EO. 1952. *Economics of Agricultural Production and resources use*. Practice Hall of India.
- Heady EO and Dillon JL. 1961. *Agricultural Production functions*. Kalyani Publishers, Ludhiana, India. 667 p.

I. Course Title : Operations Research

II. Course Code : AEC-605

III. Credit Hours : 2+1

IV. Why this course?

In sphere of management it is important, to take correct decision of assigning tasks and roles to individuals. The business is full of uncertainity and in this situation the manager has to take decision. It becomes imperative to gain knowledge of models used for finding this solution of performing well.

V. Aim of the course

To gain elementary knowledge of solving problems and decision making for managing farming and organisation in resource constraint in order to achieve the objective.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1	Concepts	1. Concepts
2	Inventory and models	1. Inventory- A Review 2. Models
3	Decision making	1. Decision making 2. Game theory

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Elementary concepts and objectives of Operations Research, Review of Linear programming - Assumptions & Methods, Non-linear programming problem - Quadratic programming, Multi Objective Programming (MOP)

Block 2: Inventory and Models

Unit 1: Inventory- A Review

Inventory control models, costs involved in Inventory management, types of inventory, Economic order quantity model, Waiting line models: Waiting line problem, Characteristics of a waiting line system, Single channel model,

Unit 2: Modles

Markov Chains, Sequencing, Replacement models, Transportation and Assignment problems.

Block 3: Decision Making

Unit 1: Decision Making

Decision making under risk and uncertainties, decision problem, maximax criterion, maximin criterion, minimax regret criterion, Laplace criterion, Pay off tables, Decision trees, Expected value of perfect information.

Unit 2: Game Theory

Game Theory – Two-person Zero sum game, Simulation, Network Analysis- PERT & CPM.

VIII. Practical

- Linear and Non-linear programming problem,
- Quadratic programming, Multi-Objective Programming- Goal Programming,
- Lexicographic, Weighted Sum, Determining economic order quantity, reorder levels of EOQ model.

- Waiting line problem, Problems on Markov Chains, Sequencing and Replacement models.
- Formulating and solving transportation type problems, Assignment problems as a special type of transportation problem.
- Solving deterministic and probabilistic queuing models Structuring and solving decision trees for optimal decisions Game theory, Simulation, Developing network (PERT/CPM) diagrams and determining the critical path.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After successful completion of this course, the student will be able to-
Gain expertise in formulating problems of management into mathematical form and work out the optimum solutions.
Apply the knowledge of different models in better decision making and controlling of the firm.

XI. Suggested Reading

- Taha HA. *Operations Research: An Introduction*.
- Veerabhadrappa H. *An Introduction to Operations Research*.
- Gupta PK and Hira DS. *Operations Research*.
- Sharma R. *Operations Research*.
- Sharma JK. *Operation Research*.
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Agricultural Marketing And Price Analysis
II. Course Code : AEC 606
III. Credit Hours : 2+1

IV. Why this course?

Efficient markets, connectivity in markets, facilities of transport and storage ensure that there is growth in marketing of the produce as well as the industries based on those produce. The decision of selling the produce at the right time, and at a higher price is crucial to ensure remunerative returns to the farmer. Thus, this course is required to enhance the knowledge to students in agricultural markets and price analysis.

V. Aim of the course

To impact adequate knowledge and analytical skills in the field of agricultural marketing and enhance expertise in improving the performance of the marketing institutions and the players in marketing of agricultural commodities. Learning outcome: After successful completion of this course, the student will be able to- Gain the knowledge of marketing and agricultural prices. Work out the interaction between different markets and analyse their working. Gain expertise in forecasting of price and build up market intelligence.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Agricultural Marketing- Insights
2.	Marketing Institutions and Dynamics	1. Institutions and their functions 2. Market Dynamics
3.	Techniques	1. Commodity marketing 2. Models for Analysis

VII. Theory

Block 1: Concepts

Unit 1: Agricultural Marketing-

Insights Importance of market analysis in the agricultural system - types of marketing-advantages and disadvantages - quantitative estimation -the distinguishing characteristics and role of agricultural prices -data sources for agricultural products and prices - softwares used in market analysis.

Block 2: Marketing Institutions and Dynamics

Unit 1: Institutions and their functions

Role of various formal institutions in agricultural marketing - and functions - measuring their efficiency - public - private partnership - institutional arrangements. Successful case studies.

Unit 2: Market Dynamics

Multi market estimation, supply response models. Market integration and price transmission - supply / value chain management. GAP analysis. Current trends in information in the changing agrifood system.

Block 3: Techniques

Unit 1: Commodity Marketing

Agricultural commodity marketing -spot and futures- marketing of derivatives- speculation, hedging, swap, arbitrage etc. commodity exchanges - price discovery and risk management in commodity markets-Regulatory mechanism of futures trading.

Unit 2: Models for Analysis

Lag operators and difference equations; stationary and stochastic processes; Unit roots and cointegration; conditional heteroscedasticity: ARCH and GARCH models -forecast evaluation; methods of forecasting. price indices and econometric estimation and simulation.

VIII. Practical

- Estimation of demand/ supply forecasting,
- Supply chain/ value chain analysis for different commodities
- Commodity models- multi market estimation- time series analysis
- Market integration studies- price discovery price volatility estimation
- Commodity price forecasting using econometric softwares.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Suggested Reading

- Acharya SS and Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Acharya SS and Agarawal NL. 2004. *Agricultural Marketing in India*. Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Kohls RH and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.
- Rhodes VJ. 1978. *The Agricultural Marketing System*. Grid Pub. Ohio.

I. Course Title : Quantitative Development Policy Analysis

II. Course Code : AEC 607

III. Credit Hours : 1+1

IV. Why this course?

Policy reforms are inevitable. They are continuously required to deal with the loop holes of previous policy and control the present situation in a better manner. Reforms take place in both microeconomic and macroeconomic polies. The analysis of these policies help us to develop a framework for designing and implementing the policies.

V. Aim of the course

To develop expertise in understanding the rationale behind development of policies. Conceptualization of equilibrium and working out the economic implications of development policy. Learning outcome: After the completion of the course, the student will be able to-Conceptualize policy framework. Get acquainted with analysisng the policy and work out corrective solutions.

VI. Organization of the course

The course is organised as follows

No	Block	Unit
1.	Concepts	1. Policy Framework
2.	Demand-supply and household behaviour	1. Demand- Supply Analysis 2. Household Behaviour and models
3.	Approaches to review policy and welfare	1. Multi-Pronged approach to policy review 2. General equilibrium and programming

Theory

Block 1: Concepts

Unit 1: Policy Framework

olicy framework – goals, value, beliefs and welfare maximization. Market – Policy and State – State vs. Market – Failure of Policy – Failure of Markets - Rationale for Government Intervention. Role of Quantitative Policy Analysis.

Block 2: Demand-supply and household behaviour

Unit 1: Demand- Supply Analysis

Demand analysis for policymaking – Alternative approaches to demand analysis – Policy implications. Supply response – Alternative approaches to measurement of supply response – Nerlovian models of supply response – Policy implications.

Unit 2: Household Behaviour and models

Household behaviour and policy analysis – Household models.

Block 3: Approaches to review policy and welfare

Unit 1: Multi-Pronged approach to policy review

Partial equilibrium analysis – Concept of reference prices – Price distortions – indicators and impact. Transaction costs – Implications for efficiency and productivity – Institutional solutions - Multi market approach to policy analysis.

Unit 2: General equilibrium and programming

Social Accounting Matrices and multipliers -– Computable General Equilibrium models to assess economy wide impact of policy changes. fuzzy goal programming-Compromise programming.

VII. Practical

- Review of criteria for policy evaluation
- Estimation of price elasticities
- Review of estimation of complete demand systems
- Estimation of Nerlovian supply Response model
- Review of Household models
- Specification and estimation of household models
- Partial equilibrium analysis
- Input–output table
- Social Accounting Matrix
- Construction of a SAM
- Computation of Multipliers
- Multi Market Analysis
- Review of Computable General Equilibrium Models.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

I. Course Title : Natural Resource Management
II. Course Code : AEC 608
III. Credit Hours : 1+1

IV. Why this course?

The environment envisages the whole living creatures' within it. There are resources we obtain from the nature and at the same time spoil the environment by exploiting the resources. Thus, it is necessary for the student to develop environment friendly plans to utilize the scarce resources.

V. Aim of the course

Concept building on natural resources. Gaining expertise in economic aspect of natural resources and maintain a balance between economic gains and environment conservation. Learning outcome-After the completion of the course, the student will be able to-Understand the natural resources and methodolies to develop plans for their optimal use. Work out the economics of forest, fisheries and ground water. Be able to deal with the legal matters of the natural resourses.

VI. Organization of the course

The course is organised as follows:

NoBlockUnit			
1.	Concepts	1.	Concepts
2.	Models and Management	1.	Models for economic view of natural resources
		2.	Management of water resources
3.	Regulations and planning	1.	Property Rights
		2.	Dynamics of resource economics

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Natural resources - definition - characteristics and classification. Stock dynamics of renewable and non-renewable resources. Equation of motion for renewable and non-renewable resources. Fundamental equation of renewable resources.

Block 2: Models and Management

Unit 1: Models for economic view of natural resources

Growth curves of fishery and forest resources. The role of time preference in natural resource use. Simple two-period model of optimal use of renewable and non-renewable resources. Advanced models of optimal resource use – Static Vs. dynamic efficiency in natural resource use Applications of dynamic programming and optimal control.

Unit 2: Management of water resources

Economics of groundwater use - optimal extraction of groundwater. Analytical and numerical solutions for optimal inter-temporal allocation of natural resources. Optimal harvesting of single rotation and multiple rotation forests. Optimal management of fishery.

Block 3: Regulations and planning

Unit 1: Property Rights

Property rights in natural resources and their implication for conservation and management of natural resources. Management of common property natural resources – Institutional arrangements for conservation and management of common pool fishery, groundwater and forestry resource.

Unit 2: Dynamics of resource economics

Resource scarcity – Natural resource degradation – Poverty and resource degradation

– Natural resource accounting - Pricing and valuation of natural resources – Natural resources policy. Practical Derivation of the fundamental equation of renewable resources-Estimation of growth curves and stock dynamics for fishery and forestry resources. Simple two period problem of optimal resource use – Numerical solution for simple two-period model of dynamic efficiency in natural resource extraction. Multi-period dynamic efficiency – Using Excel Solver in solving dynamic natural resource harvesting problems. Using analytical solution procedures for solving natural resource management problems – Optimal control.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Suggested Reading

- Hackett SC. 2001. *Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society*. M.E. Sharpe, Armonk, NY.
- Hartwick JM and Olewiler ND. 1998. *The Economics of Natural Resource Use*. 2nd Ed. Addison-Wesley Educational Publ.
- Kerr JM, Marothia DK, Katar Singh, Ramasamy C and Bentley WR. 1997. *Natural Resource Economics: Theory and Applications in India*. Oxford & IBH.
- Pearce DW and Turner K. 1990. *Economics of Natural Resources and the Environment*. John Hopkins Univ. Press.
- Prato T. 1998. *Natural Resource and Environmental Economics*. Iowa State Univ. Press.
- Sengupta R. 2000. *Ecology and Economy, an Indian Perspective*. Oxford Univ. Press.
- Tietenberg T. 2003. *Environment and Natural Resource Economics*. 6th Ed. Addison Wesley.

I. Course Title : Environmental Economics

II. Course Code : AEC 609

III. Credit Hours : 2+1

IV. Why this course?

Economics not only deals with transaction taking place between human beings within and across national boundaries. Each economic activity has a price to pay to the environment. The activity causes loss to the environment in various ways. Thus, as a student of economics it is necessary to work out the costs and returns in terms of losses to environment while carrying out these development/production activities.

V. Aim of the course

To understand the economic outcomes of environmental degradation. Make students proficient in decision making regarding environment protection, resource use, and conservation policy.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Overview	1. Overview of Environmental Economics
2.	Assessment and Development Dynamics	1. Economic assessment 2. Developmental Aspects

No	Block	Unit
3.	Regulations and Issues	1. Accounting, Policies and Regulations 2. Environmental Issues

VII. Theory

Block 1: Overview

Unit 1: Overview of Environmental Economics

Environmental pollution as a consequence of market failure - Causes and consequences of market failure - Externalities - Public goods and externalities -Economics of pollution – Private vs. Social cost of environmental pollution – Property rights, environment and development – Theory of environmental policy.

Block 2: Assessment and Development Dynamics

Unit 1: Economic assessment

Environmental cost benefit analysis - Environmental impact assessment techniques Non-market valuation of environmental resources (WTP / WTA) - Environment, market and social welfare.

Unit 2: Developmental aspects

Economic growth and environmental cost - Growth oriented economic policies and their environmental impacts - Population and environmental quality - poverty and environmental degradation – Sustainable development – Indicators of sustainable development – Issues in sustainable development.

Block 3: Regulations and Issues

Unit 1: Accounting, Policies and Regulation

Environment, ecology and environmental accounting - Environmental pollution with respect to water and air - Land and forest resources related environmental pollution - Coastal externalities - Urbanization and environment - Basic approaches to environmental policy (Tax, subsidy, pollution permits, *etc*.) Green taxes - Political economy of environmental regulation and management.

Unit 2: Environmental Issues

Transboundary environmental problems - Economics of global warming, climate change and emission trading - Environment, international trade and development.

VIII. Practical

- Contemporary global environmental global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms
- Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques
- Recreation demand models of environmental valuation
- Contingent valuation techniques
- Environmental Resource Accounting Techniques
- Discussion on the techniques dealing with air pollution and review of case studies on air pollution and its impacts - forest environment and wild life conservation
- Green GDP and Green house insurance
- Practical considerations and comparison of instruments of environmental policy

- Non-point source pollution control methodologies
- Environment in macroeconomic modeling
- Meta-analysis, economic valuation and environmental economics
- Multi-criteria methods for quantitative, qualitative and fuzzy evaluation problems related to environment
- Input output analysis, technology and the environment
- Computable general equilibrium models for environmental economics and policy analysis.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After the successful completion of the course, the student will be able to-Understand the concept of pollution and externalities caused by economic activity. Work out the economics of productions activities in terms of losses to environment. Learn about accounting of environmental costs and other issues related.

XI. Suggested Reading

- Hackett SC. 2001. *Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society*. ME. Sharpe, Armonk, NY.
- Hartwick JM and Olewiler ND. 1998. The Economics of Natural Resource Use. 2nd Ed. Addison-Wesley Educational Publ.
- Kerr JM, Marothia DK, Katar Singh, Ramasamy C and Bentley WR. 1997. *Natural Resource Economics: Theory and Applications in India*. Oxford & IBH.
- Pearce DW and Turner K. 1990. *Economics of Natural Resources and the Environment*. John Hopkins Univ. Press.
- Prato T. 1998. *Natural Resource and Environmental Economics*. Iowa State University Press.
- Sengupta R. 2000. *Ecology and Economy, an Indian Perspective*. Oxford University Press.
- Tietenberg T. 2003. *Environment and Natural Resource Economics*. 6th Ed. Addison Wesley.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agricultural Extension Education

Acknowledgements

Curriculum reform essentially means bringing about changes to the subject content, delivery, and assessment of a curriculum. In the field of agricultural extension, curriculum reforms are important for several reasons. Firstly, farmers face several new challenges related to changing climate, uncertain markets and deteriorating and declining natural resource which sustain agriculture. These challenges mean that extension today needs to tackle an increased diversity of objectives that not only include but also go beyond transfer of new technology and increasing production. While some of these roles still continue to be important, extension services are required to play an increasingly important intermediation and facilitation role to support application of new knowledge.

Agriculture extension is no longer only a public sector phenomenon. It now involves a more complex range of actors providing a wide range of services, together bracketed as EAS. These include organizations in the private sector dealing with agriculture inputs, agribusiness, and financial services; non-governmental organizations (NGOs) (international as well as local); producer groups, cooperatives and associations; consultants (independent as well as associated with or employed by agri-business/ producer associations) and information and communication technology (ICT)-based services. The job market for extension professionals has thus changed and now demands quite different competencies than what the current curricula tries to provide.

Moreover, the theory and practice of extension has evolved considerably in the recent past based on new research in the area of diffusion, innovation and communication studies. These new insights are important tools in any effort to reinvent extension to meet the evolving needs of stakeholders in the Agricultural Innovation Systems (AIS).

The sub-committee on Agricultural Extension constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept above development in view while revising the PG and Ph.D. Curricula in Agricultural Extension. We also addressed the issue of repetitions of content at different levels and in this process, and considered the Fifth Dean Committee report and the earlier under-graduate curricula in extension. Moreover, student's prior knowledge is critical for learning any discipline and therefore identified first the core competencies that are required at the different levels and worked backwards based on the areas and organizing them into courses.

We are also recommending internship at the Master's level for 5 credits and Teaching Assistantship at the Ph.D. level for 5 credits. We believe this will help the students to have more relevant practical experience and this will boost their job prospects. The committee also discussed about the need for organizing exposure visit for PG/Ph.D. students to universities abroad (student exchange).

We have organized the curricula under different block and units and each course has an introduction explicitly stating the purpose of this course (why this course?), aim of the course (what it tries to provide?) and learning outcomes. Several new and relevant references including appropriate web links to different resources are also provided at the end of each course. The committee strongly proposes training programmes in collaboration with the concerned organizations for the teachers of Agrl Extension of all SAUs to gear them up for dealing the new revised courses effectively.

The report is based on several rounds of stakeholders meeting and consultation with extension professionals representing different universities, ICAR institutions, NGOs etc. involved in teaching and training in extension . The first such workshop was at Hyderabad on 12 July 2018. Our sincere thanks to Dr R.K. Samantha, Former VC, BCKV, Mohanpur, West Bengal; Dr Raji Reddy, Director of Extension, PJTSAU, Hyderbabad; Dr Biswanath Sadangi, Former Head, ICAR-CIWA, Bhubaneswar; Dr Mahesh Chander, Head, Division of Extension Education, ICAR-IVRI, Izatnagar; Dr Debabrata Basu, Porfessor and HoD, BCKV, Nadia; Dr R.N. Padaria, Principal Scientist (Extension) IARI, New Delhi; Dr K. Ponnusamy, Principal Scientist, NDRI, Karnal; Dr Sreenath Dixit, Head, ICRISAT; Dr Basavaprabhu Jirli, Professor (Extension), I.A.S, BHU, Varanasi; Dr D. Sandhya Shenoy, Principal Scientist (Extension), ICAR-NAARM, Hyderbabad; Dr Bharat S. Sontaki, Principal Scientist, ICAR-NAARM, Hyderbabad; Dr Rasheed Sulaiman, Director, CRISP, Hyderbabad; Dr Sarvanan Raj, Director (Agriculture Extension), MANAGE, Hyderbabad; Dr P.V.K. Sasidhar, Professor and Director, SOEDS, IGNOU, New Delhi; Dr P. Amala Kumari, Professor (Retd.), College of Home Science, Hyderbabad; Dr Srinivas Surisetti, Professor, TISS, Hyderbabad; Dr V. Sudha Rani, Professor and Head, Dr G. Samuel, Professor, Dr A. Sailaja, Professor, Dr M. Sreenivasulu, Professor, Ms Aruna, Assistant Professor from the Department of Agricultural Extension, College of Agriculture, Hyderbabad; Prof. K. Madhu Babu, Director, Prof. B. Jamuna, Prof. S. Chandra Shekar, Prof. R. Vasantha. Prof. M.Preethi, Prof. M. Prasuna, Extension Education Institute, Hyderbabad; Prof. Ch. Venugopal Reddy, PAIO; Dr V. Ravinder Naik, Senior Scientist, Agricultural Information and Communication Centre, PJTSAU, Hyderbabad; Dr P. Prashanth, Scientist, Electronic wing, PJTSAU, Hyderbabad; Dr B. Savitha, Assistant Director of Extension, PJTSAU, Hyderbabad; Dr P. Archana, Scientist (ToT), DAATTC, Mahboobnagar, Dr K. Madan Mohan Reddy, Scientist (ToT), DAATTC, Karimnagar, Dr R. Vishwatej, S.M.S (Agriculture Extension), KVK, Bhadradri, Kothagudem for their valuable inputs which paved way for right direction to identify the lacunae in the existing curricula and to prepare the revised curricula.

The committee also interacted closely with the Sub-Committee constituted by the National Institute of Agricultural Extension Management (MANAGE) for development of Extension curricula and this joint effort of two committees represents a much wider number of extension professionals.

Our special thanks to Ms V. Usha Rani, IAS, Director General, MANAGE and all the sub-committee members of MANAGE Sub-Committte on Extension Curricula Reforms (Dr Saravanan Raj, MANAGE, Dr Rasheed Sulaiman, CRISP-AESA, Dr P.S. Sivakumar, ICAR-CTCRI, Dr Mahesh Chander, ICAR-IVRI, Dr M. Chandragowda, ICAR-ATARI, Dr M.A. Ansari, GBPUAT, Dr P.V.K. Sasidhar, IGNOU, Dr P.S. Ananthan, ICAR-CIFE, Dr Ritu Chakravarty, ICAR-NDRI, Dr Sagar Wadkar, VAMNICOM and Dr Souvik Ghosh, Visva Bharati University) for their specific contributions to development of this revised curricula. The two days joint consultation and brain storming on each of the courses, the two committees organized together at Hyderabad on 28-29 September 2018 helped us in development of this final output. Our special thanks to Dr Onima, V.T., Research Officer, Centre for Research on Innovation and Science Policy (CRISP) for supporting this exercise both intellectually and operationally.

The committee organized third BSMA (Social Sciences) meeting on 28-01-2019 at Institute of Agricultural Sciences, BHU, Varanasi for reviewing the final drafts of three

disciplines of social Sciences. Our sincere thanks to Dr Basavaprabhu Jirli, Professor and Head, Prof. A.K. Singh and Prof. Kalyan Ghadee from the Department of Extension Education, I.A.S, BHU, Varanasi for their critical comments and suggestions with regard to revised curricula.

The suggestions at National Core Group review on April 24, 2019 were valuable and incorporated in the report. The detailed insights and advice from Dr N.S. Rathore as Chairman of the Special Meeting of BSMA on May 10, 2019 were crucial in shaping of final report.

Our sincere gratitude and thanks to all the members of BSMA Committee for Social Sciences namely Dr Rakesh Singh, Professor, Dept. of Agricultural Economics, IAS, BHU, Varanasi, Dr S. Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Our sincere and heartfelt thanks to Dr V. Praveen Rao, Hon'ble Vice Chancellor, PJTS AU, Rajendranagar, Hyderabad for permitting the committee to conduct the national level stakeholders meeting in the University on 20th July 2018. Our special thanks to Dr S. Sudheer Kumar, Registrar and Dr D. Raji Reddy, Director of Extension, PJTSAU for their unstinted support and cooperation to the BSMA committee.

Finally, we thank profusely Dr N.S. Rathore, Former Deputy Director General (Education), and Dr R.C. Agrawal, Current Deputy Director General (Education) ICAR, New Delhi for constituting the BSMA for undertaking curricula revision of PG and Ph.D. in Social Sciences and for their valuable guidance and support in this regard.

I. Sreenivasa Rao
(Member, BSMA, Agricultural Extension)
Dr Lipi Das
(Convener, BSMA, Social Sciences)
Dr Kalpana Sastry
(Chairperson, BSMA, Social Sciences)

September, 2020

Preamble

Justification for modification of Present Courses and recommendation of New Courses
Innovativeness in the present curricula development:

- The developed curricula is the result of sincere and coordinated effort of multi-stakeholders and experts in the discipline of Extension Education with a aim to enhance the value of the discipline, relevance to field and develop the graduates with multi core competencies to face the challenges in TOT.
- The content of the courses are perfectly related to the present changes and scenario in the Ecosystem of Extension Education at National and Global level.
- The practical content coverage will give multiple opportunities to the graduates to have hands on experience and demonstrate what they learn in variety of contexts i.e. various extension teaching methods, Big data, IOTs, project development and evaluation, organizations of groups/FPOs, etc.
- The recommended curricula is perfect match and having high relevancy to the developments and innovations in the field.
- The curricula is developed by benchmarking the core competencies that are expected from the Extension graduates, thus the approach is bottom-up.
- The recommended Extension Research methodology courses will help the students to identify the contemporary problems and their solving could lead to develop quality extension models for effective TOT and policy making.
- The recommended Internships and Teaching assistantships will help the students to have more relevant practical experience and this will boost their job prospects.

Course Title with Credit Load
M.Sc. in Agricultural Extension Education

Major Courses 20

Course Code	Course Title	Credit Hours
EXT-501*	Extension Landscape	2(2+0)
EXT-502*	Applied Behaviour Change	3(2+1)
EXT-503*	Organisational Behaviour and Development	3(2+1)
EXT-504*	Research Methodology in Extension	3(2+1)
EXT-505*	Capacity Development	3(2+1)
EXT-506*	ICTs for Agricultural Extension and Advisory Services	3(2+1)
EXT-507*	Evaluation and Impact Assessment	3(2+1)

Minor Courses 08

a. It is suggested the student may choose at least two out of three courses listed below as part of minor courses as these are related to policy advocacy and aim to build larger understanding of the subject.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agrl. Economics/ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HoD.

EXT-508	Managing Extension Organisations	3(2+1)
EXT-509	Enabling Innovation	2(1+1)
EXT-510	Gender Mainstreaming	3(2+1)

Supporting Courses 06

STAT	Statistical Methods for Applied/ Social Sciences	3(2+1)
STAT/COMP	Computer Applications for Agricultural Extension Research	3(2+1)

It is suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HoD".

Common Courses 05

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on

SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

EXT-591	Master's Seminar	**01**
	Thesis/Research	30
	Total	70

Course Contents
M.Sc. in Agricultural Extension Education

I. Course Title : Extension Landscape
II. Course Code : EXT 501
III. Credit Hours : 2+0

IV. Why this course?

Extension and advisory services (EAS) need to support farmers to deal with several new challenges they face currently. To effectively support farmers, EAS should perform several new functions and it should have capacities to perform these functions. EAS have evolved considerably especially during the last 3 decades. Several new approaches have emerged and many new funding and delivery models emerged in response to reforms (economic policies and new governance structure) implemented in several countries. Apart from these, new insights from communication and innovation studies have also started to influence the practice of extension. There is a lot of interest globally in strengthening pluralistic EAS and enhancing its contribution towards development of an effective Agricultural Innovation System (AIS). Keeping these in view, there is a need to orient students of extension on how extension is shaped globally and the policy level challenges it faces so that the extension students fit well to the global demand for competent extension professionals who can appreciate and understand this changing context.

V. Aim of the course

The aim of this course is to introduce the new challenges before extension and how extension is evolving globally. It presents the new capacities that are needed by EAS providers to provide a much wider support to farmers and it orient students to the new insights from communication and innovation studies that are influencing the practice of extension globally. The course also help students to appreciate the process and the impact of extension reforms implemented in many countries, the new approaches that are evolving globally in different regions and the policy challenges in managing a pluralistic extension system.

The course is organized as follows:

No	Blocks	Units
1	Globally, What is new in Extension?	1. Challenges Before Extension and Advisory Services 2. New Functions and New Capacities 3. Pluralism in EAS
2.	Insights from Communication & Innovation Studies & New Extension Approaches	1. From the Linear Paradigm To Systems Paradigm 2. Evolving Extension Approaches
3	Extension Reforms And Policy Challenges	1. Changes In Governance, Funding and Delivery of EAS 2. Challenges In Managing Pluralistic EAS

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the changing global extension landscape
- Broaden their understanding on the role of EAS in agricultural innovation system
- Critically evaluate the reforms in extension and the evolving approaches in extension
- Analyse the policy level challenges in extension funding and delivery

Block 1: Globally, What Is New In Extension?

Unit 1: Challenges before Extension and Advisory Services (EAS)

Extension and Advisory Services (EAS)- Meaning (embracing pluralism and new functions) New Challenges before farmers and extension professionals: Natural Resource Management-Supporting farmers to manage the declining/deteriorating water and soil for farming; Gender Mainstreaming- How extension can enhance access to new knowledge among women farmers; Nutrition- Role of extension in supporting communities with growing nutritious crop and eating healthy food; Linking farmers to markets- Value chain extension including organizing farmers, strengthen value chain and supporting farmers to respond to new standards and regulations in agri-food systems; Adaptation to climate changes-How extension can contribute to up-scaling Climate Smart Agriculture; Supporting family farms-strengthening the capacities of family farms; Migration-Advising farmers to better respond to opportunities that emerge from increasing mobility and also supporting migrants in enhancing their knowledge and skills; Attracting and Retaining Youth in Agriculture including promotion of agripreneurship and agri-tourism; Urban and peri-urban farming- How to support and address issues associated with urban and peri-urban agriculture; Farmer distress, suicides- Supporting farmers in tackling farm distress.

Unit 2: New Functions and New Capacities

Beyond transfer of technology: Performing new functions to deal with new challenges; Organising producers into groups-dealing with problems that need collective decision making such as Natural Resource Management (NRM) and access to markets; Mediating conflicts and building consensus to strengthen collective decision making; Facilitating access to credit, inputs and services-including development of service providers; Influencing policies to promote new knowledge at a scale Networking and partnership development including convening multi-stakeholder platforms/ innovation platforms.

New Capacities needed by extension and advisory services at different levels –at the individual (lower, middle management and senior management levels), organizational and enabling environment levels; –Core competencies at the individual level; Varied mechanisms for capacity development (beyond training).

Unit 3: Pluralism in EAS

Pluralism in Extension Delivery: Role of private sector (input firms, agri-business companies, consultant firms and individual consultants)- Trends in the development of private extension and advisory services in India and other countries; challenges faced by private extension providers; Role of Non-Governmental Organizations (National/international)/ Civil Society Organizations (CSOs) in providing extension-Experiences from India and other countries; Producer Organizations- Role in strengthening demand and supply of extension services; their strength and weaknesses-experiences from different sectors; Role of Media and ICT advisory service providers; global experiences with use of media and ICTs in advisory services provision.

Block 2: Insights From Innovation Studies and New Extension Approaches

Unit 1: From the Linear Paradigm to Systems Paradigm

Diffusion of Innovations paradigm- strengths and limitations; multiple sources of innovation-farmer innovation, institutional innovation; farmer participation in technology generation and promotion; strength and limitations; Agricultural Knowledge and Information Systems (AKIS); strength and limitations; Agricultural Innovation Systems (AIS); Redefining Innovation- Role of Extension and Advisory Services in AIS-From information delivery to intermediation across multiple nodes; Role of brokering; Innovation Platforms, Innovation Management; Strength and weaknesses of AIS. Rethinking Communication in the Innovation Process – Network building, support social learning, dealing with dynamics of power and conflict.

Unit 2: Evolving Extension Approaches

Evolution and features of extension approaches: Transfer of technology approach; educational approach, farmer participatory extension approach, demand-driven extension, market led extension (value chain extension), extension for climate smart agriculture, gender sensitive extension, extension for entrepreneurship Extension systems in different regions: Asia-Pacific, Europe, Latin America, Australia, North America Networking for Strengthening EAS: GFRAS (Global Forum for Rural Advisory Services) and its regional networks.

Block 3: Extension Reforms and Policy Challenges

Unit 1: Changes in Governance, Funding and Delivery

Reduction in public funding: public withdrawal from extension provision (partial/full); Examples/Cases; Privatization: Public funding and private delivery; cost sharing and cost recovery; Examples/Cases; Decentralisation of extension services; Examples/Cases; Lessons from extension reforms in different countries; Extension and Sustainable Development Goals (SDGs).

Unit 2: Challenges in Managing Pluralistic Extension Systems

Pluralism: Managing pluralism and Co-ordination of pluralistic extension provision; Public private partnerships in extension (including the role of local governments/panchayats and producer organisations); Examples, challenges in co-ordination; Achieving convergence in extension planning and delivery, Financing Extension: Mobilising resources for extension: public investments, donor support (grants/loans); Monitoring and Evaluation of Extension: Generating appropriate data for Assessment and Evaluation of pluralistic extension; Strengthening extension policy interface; generating evidence on impact of extension and policy relevant communication.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Book Review by students
- Student presentation
- Group Work

VIII. Suggested Reading

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Colverson KE. 2015. *Integrating Gender into Rural Advisory Services.* Note 4. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/integrating-gender-into-rural-advisory-services.html#SNote1

David S. 2018. *Migration and rural advisory services.* GFRAS Issues Paper 2. Global Forum for Rural Advisory Services. https://www.g-fras.org/en/knowledge/gfras-publications/category/97-gfras-issues-papers.html?download=856: migration-and-rural-advisory-services

Davis K and Heemskerk W. 2012. *Coordination and Collective Action for Agricultural Innovation* Overview Module 1 Investment in Extension and Advisory Services as Part of Agricultural Innovation Systems. In Agricultural Innovation Systems: An Investment Sourcebook. Agricultural and Rural Development. World Bank. © World Bank. http://siteresources.worldbank.org/INTARD/Resources/335807-1330620492317/9780821386842ch3.pdf

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Faure G, Pautrizel L, de Romémont A, Toillier A, Odru M and Havard M. 2015. *Management Advice for Family Farms to Strengthen Entrepreneurial Skills***.** Note 8. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/management-advice-for-family-farms-to-strengthen-entrepreneurial-skills.html#SNote8

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Rao S. 2015. *Using Radio in Agricultural Extension.* Note 18. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/using-radio-in-agricultural-extension.html#SNote8

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Websites

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- **FAO**- Food and Agricultural Organisation (Research and Extension) http://www.fao.org/research-and-extension/en/
- **GFRAS**- Global Forum for Rural Advisory Services http://www.g-fras.org/en/
- **INGENEAS**- Integrating Gender and Nutrition within Agricultural Extension Services https://ingenaes.illinois.edu/
- **IFPRI**- International Food Policy Research Institute (Extension) http://www.ifpri.org/topic/agricultural-extension
- **KIT**- Royal Tropical Institute (KIT)-Sustainable Economic Development https://www.kit.nl/sed/
- **WUR**- Wageningen University and Research Research (Knowledge, Technology and Innovation Group (KTI)) https://www.wur.nl/en/Research-Results/Chair-groups/Social-Sciences/KnowledgeTechnology-and-Innovation-Group.htm

I. Course Title : Applied Behaviour Change

II. Course Code : EXT 502

III. Credit Hours : 2+1

IV. Why this course?

The behavioural change of the stakeholders is the key objective in extension profession, which is reflected through their enhanced capacity, attitude change, modification of perceptions and beliefs, improved understanding of a system, adoption of improved technologies, empowerment, and resilience to adverse phenomenon and improved decision-making. Irrespective of their role and profession, all the key stakeholders in agriculture like farmers, extension agents, scientists/ academicians, development managers and policy makers are human beings, whose behaviour is the product of internal psychological processes influenced by external environment. Since human behaviour is a psychological phenomenon, expressed through interaction of internal psychological processes, social systems and external environment, there is an essential need to understand how these psychological processes guide the behavioural change. These psychological processes may be expressed at individual, group, community and organisational level involving human learning, choices, judgement and decisions about an extension intervention.

V. Aim of the course

This course aims to build capacities of students to understand the fundamental psychological processes which guide human behaviour at individual, group and community levels in specific contexts, to develop sound extension strategies.

The course is organized as follows:

No	Blocks	Units
1	Foundations of Behaviour Change	1. Foundations of Human Behaviour
2	Cognitive Processes and Learning	1. Cognitive Processes affecting Human Behaviour 2. Information Processing 3. Learning 4. Judgement, Choice and Decision-making
3	Human Behaviour in the Society	1. Attitudes and Influence 2. Social Judgement, Social Identity and Inter-Group Relations

VI. Theory

Block 1: Foundations of Behaviour Change

Unit 1: Foundations of Human Behaviour

Human behaviour – Meaning, importance and factors influencing human behaviour; Biological bases of human behaviour – Nervous system, brain, endocrine system and genes; Individual variations – intelligence, ability and creativity– foundations and theories, personality and temperament - foundations, approaches, theories of personality, measuring personality (traits, locus of control, self-efficacy; Personal, social and moral development – meaning, concepts – self-concept, self-esteem and self-worth and theories. Motivation – foundations, approaches, theories, managing human needs and motivations; perceiving others – impression, attitude, opinions; Emotions - foundations, types and functions, measuring emotional intelligence.

Block 2: Cognitive Processes And Learning

Unit 1: Cognitive Processes affecting Human Behaviour

Sensory organs and their role cognition; Cognitive processes – Attention, perception, remembering and forgetting, knowledge and expertise – foundations and theories; Principles and processes of perception; Consciousness – meaning, types, sleep and dreams; Learning and Memory – Memory - meaning, types and mechanisms of storage and retrieval of memories in the Human brain; Complex cognitive processes - Concept formation, Thinking, Problem solving and transfer – foundations, theories and approaches.

Unit 2: Information Processing

Information processing – meaning, principles; Models of information processing - Waugh and Norman model of primary and secondary memory; Atkinson and Shiffrin's stage model of memory; other models including blooms taxonomy and Sternberg's Information Processing Approach; Attention and perception – meaning, types, theories and models; Consciousness.

Unit 3: Learning

Learning – foundations, approaches and theories; Cognitive approaches of learning – meaning, principles theories and models; Memory – foundations, types; Behavioural approaches of learning – foundations and theories - classical conditioning, operant conditioning, applied behaviour analysis; Social cognitive and constructivist approaches to learning – foundations and theories – social cognitive theory, Self-regulated learning; learning styles – meaning, types and applications in learning.

Unit 4: Judgement, Choice and Decision-making

Human judgement – meaning, nature, randomness of situations, theories and models; Choice – meaning, criteria for evaluating options; theories and models of human choice; Choice architecture; Decision-making – Meaning, problem analysis; steps and techniques of decision-making under different contexts.

Block 3: Human Behaviour in the Society

Unit 1: Attitudes and Influence

Attitudes - meaning, assumptions, types, theories and models of attitude formation; methods of changing attitudes, Relating to others - liking, attraction, helping behaviour, prejudice, discrimination and aggression; Liking/ affect – meaning, types and theories; Attraction – meaning, types and theories; Persuasion – meaning, theories and techniques; Social influence and groups – conformity, compliance and obedience.

Unit 2: Social Judgement, Social Identity and Inter-Group Relations

Social judgement – meaning, frame of reference, stereotyping; The judgement of attitude models; Attribution – meaning, theories; Rational decision making; Social identify – meaning, types; assessment; Groups – meaning, types, group processes; sustainability of groups; Inter group processes and theories social learning.

VII. Practicals

- Understanding perception – Attentional Blink and Repetition Blindness exercise
- Understanding attention - Testing selective attention capacity and skills and processing speed ability through Stroop test
- Hands-on experience in the techniques for assessing creative thinking – divergent and convergent thinking
- Lab exercise in applying Maslow's need hierarchy to assess motivation
- Learning - Classical conditioning and operant conditioning
- Assessing learning styles through Barsch and Kolb inventories
- Practical experience in building self-esteem
- Assessment of emotional intelligence

- Exercises in problem solving
- Exercises in visual perception
- Measuring self-concept using psychometric tools
- Experiment on factors influencing information processing
- Assessment of attitudes
- Hands on experience in methods of persuasion
- Field experience in assessing social judgement
- Simulation exercise to understand decision-making under different situations
- Exercise in rational decision-making.

Teaching methods/activities

– Lecture cum discussion
– Class exercises
– Group Presentation

Learning outcome

The students should:

- Understand the biological and cognitive processes determining human behaviour
- Understand the process of learning under different context
- Develop competencies in influencing the human decision process in various contexts
- Design effective strategies to influence attitude and behaviour

Suggested Reading

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Eysenck MW and Keane M T. 2010. *Cognitive psychology: A student's handbook*. Sixth Edition, Hove: Psychology Press.
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Gilovich T, Keltner D, and Nisbett RE. 2011. *Social psychology*. New York: W.W. Norton & Co.
Moreno R. 2010. *Educational Psychology*. Hoboken, NJ: John Wiley & Sons Inc.
Nevid JS. 2012. *Essentials of psychology: Concepts and applications* Belmont, CA: Wadsworth, Cengage Learning.
Rachlin H. 1989. *Judgment, decision, and choice: A cognitive/behavioral synthesis*. New York: W.H. Freeman.

I. Course Title : Organisational Behavior and Development
II. Course Code : EXT 503
III. Credit Hours : 2+1

IV. Why this course?

In changing and competitive world, the survival of any organization is dependent on its ability to adjust to the new challenges, adapt its structure and develop the competencies needed among its staff. This course is designed to understand the theory and practice relating to the processes of organizational behavior, development and change. It attempts to bring about change in the different levels of the organization (the individual, group and organization) using a wide variety of interventions.

V. Aim of the course

- To understand the theory and practice relating to the processes of organizational behavior, development and change.
- To develop insight and competence in diagnostic and intervention processes and

skills for initiating and facilitating change in organizations.
- To gain necessary self-insight, skills in facilitation, organizational development (OD) skills, group process and techniques, to become an effective change agents and OD consultants.
- To understand the behavior of individuals and small groups in organization with special focus on beliefs, attitudes and values, human inference - attribution, self-concept, motivation, active listening, interpersonal communication, conflicts management.

The course is organized as follows:

No	Blocks	Units
1.	Organisational Behaviour	1. Basics of Organisation 2. Basics of Organisational Behaviour 3. Individual Behaviour in Organizations 4. Group Behaviour in Organizations 5. Productive Behaviour and Occupational Stress 6. Organisational Systems
2.	Organisational Development	1. Overview of Organisational Development 2. Managing the Organisational Development Process 3. Organisational Development Interventions 4. Organisational Development Practitioner or Consultant

VI. Theory

Block 1: Organizational Behavior

Unit 1: Basics of Organization

Introduction to organizations-concept and characteristics of organizations; Typology of organizations; Theories of organizations: nature of organizational theory, Classical theories, Modern management theories, System Theory - Criticisms and lessons learnt/ analysis.

Unit 2: Basics of Organizational Behaviour

Concepts of Organisational Behaviour, Scope, Importance, Models of OB.

Unit 3: Individual Behaviour in Organizations

Introduction, Self-awareness, Perception and Attribution, Learning, Systems approach to studying organization needs and motives – attitude, values and ethical behavior, Personality, **Motivation**-Concept & Theories, Managing motivation in organizations.

Unit 4: Group Behaviour in Organization

Foundations of group, group behaviour and group dynamics, Group Development and Cohesiveness, Group Performance and Decision Making, Intergroup Relations; Teams in Organizations-Team building experiential exercises, Interpersonal Communication and Group; Leadership: Meaning, types, Theories and Perspectives on Effective Leadership, Power and Influence, managing Conflict and Negotiation skills, Job/ stress management, decision-making, problem-solving techniques.

Unit 5: Productive Behaviour and Occupational Stress

Productive behaviour - Meaning, dimension; Job analysis and Job performance – meaning, dimensions, determinants and measurement; Job satisfaction and organizational commitment - meaning, dimensions and measures roles and role clarity; Occupational stress – meaning, sources, theories and models, effects, coping mechanism, effects and management; Occupational stress in farming, farmer groups/ organizations, research and extension organizations.

Unit 6: Organizational System

Organizations Structure- Need and Types, Line & staff, functional, committee, project structure organizations, centralization &decentralization, Different stages of growth and designing the organizational structure; Organizational Design-Parameters of Organizational Design, Organization and Environment, Organizational Strategy, Organization and Technology, Power and Conflicts in Organizations, Organizational Decision-Making; Organizational Culture vs Climate; Organizational Change; Organizational Learning and Transformation.

Block 2: Organisational Development

Unit 1: Overview of Organizational Development

Concept of OD, Importance and Characteristics, Objectives of OD, History and Evolution of OD, Implications of OD Values.

Unit 2: Managing the Organizational Development Process

Basic Component of OD Program-Diagnosis-contracting and diagnosing the problem, Diagnostic models, open systems, individual level group level and organizational level diagnosis; Action-collection and analysis for diagnostic information, feeding back the diagnosed information and interventions; Program Management- entering OD relationship, contracting, diagnosis, feedback, planned change, intervention, evaluation.

Unit 3: Organizational Development Interventions

Meaning, Importance, Characteristics of Organization development Interventions, Classification of OD Interventions-Interpersonal interventions, Team Interventions, Structural Interventions, Comprehensive Interventions.

Unit 4: Organizational Development Practitioner or Consultant

Who is OD consultant? Types of OD consultants and their advantages, qualifications, Comparison of traditional consultants Vs. OD consultants, Organizational Development process by the practitioners skills and activities.

VII. Practicals

- Case Analysis of organization in terms of process – attitudes and values, motivation, leadership.
- Simulation exercises on problem-solving – study of organizational climate in different organizations.
- Study of organizational structure of development departments, study of departmentalization, span of control, delegation of authority, decision-making patterns.
- Study of individual and group behaviour at work in an organization.
- Conflicts and their management in an organization.

- Comparative study of functional and nonfunctional organizations and drawing factors for organizational effectiveness.
- Exercise on OD interventions (Interpersonal, Team, Structural, Comprehensive) with its procedure to conduct in an organization

VIII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Group Presentation

IX. Learning outcome

This course will equip the students to become potential change agents and OD practitioners. They should be able to learn how to improve individual, group/team and organizational performance through the use of OD techniques or interventions.

X. Suggested Reading

Bhattacharyya DK. 2011. *Organizational Change and Development*, Oxford University Press.

Hellriegel D, Sloccum JW and Woodman. 2001. **Organizational Behaviour.** Cincinnati, Ohio: South-Western College Pub.

Luthans F. 2002. *Organizational Behaviour*. Tata McGraw-Hill, New York

Newstrom JW and Davis K. 2002. *Organizational Behaviour: Human behaviour at Work*. Tata-McGraw Hill, New Delhi.

Peter MS. 1998. *The Fifth Discipline: The Art and Practice of Learning Organization*. Random House, London.

Pradip NK. 1992. *Organizational Designs for Excellence.* Tata McGraw Hill, New Delhi.

Shukla, Madhukar. 1996. *Understanding Organizations*. Prentice Hall of India, New Delhi.

Stephens PR and Timothy AJ. 2006. *Organizational Behaviour*, 12th Edition. Prentice Hall Pub.

Thomas GC and Christopher GW. 2013. *Organizational development and change*, 10th edition, South-Western college publishing.

Wendell LF and Cecil HB. 1999. *Organizational Development: Behavioural science interventions for organization improvement*, Pearson. 368 pp.

I. Course Title : Research Methodology in Extension

II. Course Code : EXT 504

III. Credit Hours : 2+1

IV. Why this course?

Growth of any discipline is directly proportional to the creation of knowledge in that discipline. Extension research is the backbone of extension discipline. Extension research is a unique social science inquiry where research ideas are gathered from the field problems and put through a systematic cycle of objective investigations that result in significant solutions. Apart from developing theories and models that advance scientific knowledge, extension research should also provide new insights for improving extension policy and practice. As extension is a field oriented discipline seeking to improve the welfare of its stakeholders, the extension professionals require critical competencies in conducting empirical research for developing sound extension models, methods and tools.

V. Aim of the course

This course aimed to create a workforce which has sound fundamental knowledge

and critical competencies in planning, conducting and applying behavioural research for developing quality extension models, methods and tools.
The course is organized as follows:

No.	Blocks	Units
1.	Introduction to behavioural research	1. Nature of Behavioural Research 2. The Behavioural Research Process
2.	Steps in behavioural research process	1. Formulating a Research Problem 2. Reviewing the Literature 3. Identifying Variables and Hypotheses 4. Formulating Research Designs, Methods and Tools 5. Selecting Sample 6. Collecting Data 7. Analysing and Interpreting the Data 8. Reporting and Evaluating Research

VI. Theory

Block 1: Introduction To Behavioural Research

Unit 1: Nature of Behavioural Research

Methods of knowing; Science and scientific method; Behavioural research – Concept, aim, goals and objectives; Characteristics and Paradigms of research; Types of behavioural research based on applications, objectives and inquiry; Types of knowledge generated through research – historical, axiological, theoretical and conceptual knowledge, prior research studies, reviews and academic debate; Role of behavioural research in extension; Careers in behavioural research.

Unit 2: The Behavioural Research Process

Basic steps in behavioural research – Formulating a Research Problem; Reviewing the Literature; Identifying the variables and hypotheses; Formulating research designs, methods and tools; Selecting sample; Collecting data; Analyzing and Interpreting the Data; Reporting and Evaluating Research; Skills needed to design and conduct research; Writing research proposals.

Block 2: Steps in Behavioural Research Process

Unit 1: Formulating a Research Problem

The research problem and research topic - definitions; Importance of formulating a research problem; Sources of research problems; Characteristics of a good research problem; Research problems in quantitative and qualitative research; Steps in formulating a research problem; Strategies for writing research problem statement; Research purpose statement; Research questions – Types, Criteria for selecting research questions, techniques for narrowing a problem into a research question; Objectives - Meaning, types and criteria for judging the objectives.

Unit 2: Reviewing the Literature

Review-meaning and importance; Types of literature review – Context, Historical, Integrative, methodological, self-study and theoretical; Literature review for quantitative and qualitative studies; Steps in conducting literature review – Identify key terms, locate literature, critical evaluation and selection; organising literature and writing literature review.

Unit 3: Identifying Variables and Hypotheses

Developing theoretical, conceptual, empirical frameworks; Approaches for identifying concepts, constructs and variables; Role of theory in behavioural research; Steps in identifying variables – Domain, Concepts, Constructs, Dimensions; Indicators; Variables, Definitions, premises, propositions and hypotheses; Techniques of identifying concepts, constructs and variables - Types of concepts; Types of variables –causal relationship, the study design; and the unit of measurement; Types of definitions-Types of propositions and hypotheses. Characteristics of good hypotheses; Measurement – Meaning, levels of measurement – nominal, ordinal, interval and ratio; Criteria for choosing measurement levels for variables.

Unit 4: Formulating Research Designs, Methods and Tools

Research designs – Definition, purpose and functions; Research Design as Variance Control - MAXMINCON Principle; Criteria for selecting a suitable Research Design; Classification of research designs: Quantitative designs - experimental, descriptive, comparative, correlational, survey, ex-post facto and secondary data analysis; Qualitative designs - ethnographic, grounded theory, phenomenological and Narrative research; Mixed method designs – Action research design; Translational research; Elements of research design - Research strategies, Extent of researcher interference, Study setting, Unit of analysis and Time horizon. Sources of errors while specifying research designs. Internal and external validity; Choosing right research design; Triangulation - Importance in behavioural research, Types of triangulation. Research methods: Designing research Instruments – questionnaires, interview schedules; tests – knowledge tests, behaviour performance tests; scales – scales and indexes, checklists, focus groups; Steps in developing and using research methods and tools; participatory rural appraisal.

Unit 5: Selecting Sample

Sampling - population, element, sample, sampling unit, and subject; Sampling strategies for quantitative and qualitative research; Principles of sampling; Factors affecting the inferences drawn from a sample; Types of sampling, Methods of drawing a random sample, Sampling with or without replacement, Types of sampling - Probability Sampling - Simple random sampling, Cluster sampling, Systematic sampling, Stratified random sampling and Unequal probability Sampling; Non-probability Sampling - Reliance of available subjects, Purposive or judgmental sampling, accidental sampling, expert sampling, Snowball sampling, and Quota sampling; Sample size requirements for quantitative and qualitative studies. Methods for estimating sample size; Generalisation – Importance, Types of generalisations.

Unit 6: Collecting Data

The process of collecting data – Selection, training, supervision, and evaluation of field investigators; Online data collection; Errors and biases during data collection. Testing goodness of measures through item analysis - Reliability and validity; Types of validity – Content validity: Face and content validity, Criterion-related validity: concurrent and predictive validity, Construct validity: convergent, and discriminant validity, factorial validity, and nomological validity; Types of reliability – Test-Retest, Parallel forms, Inter-item consistency reliability, Split-half reliability.

Factors affecting the validity and reliability of research instruments, Strategies for enhancing validity and reliability of measures. Validity and reliability in qualitative research.

Unit 7: Analyzing and Interpreting the Data

Data coding, exploration and editing; Methods of data processing in quantitative and qualitative studies; Quantitative data analysis - parametric and non-parametric statistical analyses; Parametric analysis – Descriptive and inferential statistics, Hypothesis testing - Type I and Type II errors. Concepts in hypothesis testing - Effect Size, á, â, and Power, P Value; Multivariate data analysis – regression, factor analysis, cluster analysis, logistic regression and structural equation modelling. Guidelines for choosing appropriate statistical analysis; Statistical packages for data analysis; Methods of interpreting data and drawing inferences - The Ladder of Inference; Methods of communicating and displaying analysed data.

Unit 8: Reporting and Evaluating Research

Writing reports and research publications; Evaluation Methodology

VII. Practicals

- Selecting a research problem and writing problem statement
- Narrowing down research problem to purpose, research questions and objectives
- Choosing, evaluating and reviewing research literature
- Selection of variables through construct conceptualisation and defining variables
- Choosing research design based on research problem
- Choosing right sampling method and estimating sample size
- Developing research methods and tools – questionnaires, interview schedule, check lists and focus group guides
- Writing a research proposal
- Field data collection using research methods and tools
- Testing reliability and validity of research instruments
- Hands on experience in using SPSS for coding, data exploration, editing, analysis and interpretation Formulation of secondary tables based on objectives of research
- Writing report, writing of thesis and research articles
- Presentation of reports

VIII. Teaching methods/activities

– Lecture cum discussion
– Class exercises
– Assignment(Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Research Report

IX. Learning outcome

– Understand the concepts, paradigms, approaches and strategies of behavioural research
– Enable to choose research design, methods and tools suitable for the research problem
– Design research instruments skilfully and conduct research in an objective and unbiased way

– Analyse the data through appropriate analytical methods and tools and derive meaningful interpretations

X. Suggested Reading

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I. Course Title : Capacity Development

II. Course Code : EXT 505

III. Credit Hours : 2+1

IV. Why this course?

Competent and skilful extension professionals are not naturally born. Their capacities need to be improved primarily at three different levels:

1. Pre-service capacity development – Under graduation and post-graduation studies
2. Induction capacity development – Just before job entry
3. In-service capacity development – During job

If undergone appropriately, pre-service studies help extension professionals to mainly acquire knowledge related to development. However, they are not fully ready for development work with required attitude and skills needed by an organisation. Properly planned and organized induction / in-service capacity building programmes help them to use development concepts, apply methods, exhibit attitude and skills required for development work at different levels. In short, the essence of this course is to make you understand these notions and help you to think up, manage, put into practice and evaluate capacity development programmes.

V. Aim of the course

- To understand the concepts of training, capacity building, capacity development and human resource development in the context of roles and responsibilities of extension professionals
- To discuss capacity development- approaches, strategies, needs assessment and methods / tolls
- To help you devise, organize, implement and evaluate capacity development programmes

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Capacity Development	1. Capacity Development - An Overview 2. Capacity Development - Approaches and Strategies 3. Planning and Organization of Capacity Development Programmes
2.	Capacity Development Needs Assessment	1. Capacity Development Needs Assessment - An Overview 2. Capacity Development Needs Assessment Methods
3.	Capacity Development Institutions and Management	1. Capacity Development Institutions 2. Capacity Development Project Formulation
4.	Capacity Development Process and HRD	1. Capacity Development Methods and Tools 2. Evaluation 3. Impact Assessment 4. Human Resource Development

VI. Theory

Block 1: Introduction to Capacity Development

Unit 1: Capacity Development–An Overview

Training, capacity building, capacity development and HRD-Meaning and differences; Need and principles of capacity development; Types and levels of capacities - Institutional capacities (include the rules, regulations and practices that set the overarching contextual environment), Organisational capacities (how various actors come together to perform given tasks), Individual capacities (technical, functional and leadership skills). Types of capacity building - Based on structure (structured, semi-structured &unstructured), Based on context (orientation, induction and refresher), and other categories (online, Webinar, distance etc.). Components of capacity development; Capacity development cycle.

Unit 2: Capacity Development- Approaches and Strategies

Capacity Development Dilemma- Theory versus Practice, Trainee versus Task, Structured versus Unstructured, Generic and Specific; Approaches in Capacity Development -Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach; Capacity Development Strategies - Academic strategy, Laboratory strategy, Activity strategy, Action strategy, Personal development strategy, Organizational development strategy.

Unit 3: Planning and Organization of Capacity Development Programmes

Steps in Designing and Planning of Capacity Development- Step 1. Select the participants, Step 2. Determine the participants' needs, Step 3. Formulate goal and objectives, Step 4. Outline the content, Step 5. Develop instructional activities, Step 6. Prepare the design, Step 7. Prepare evaluation form, Step 8. Determine follow-up activities; Organising capacity development programme; Operational arrangements at different stages- Before the programme, During the programme, Middle of the programme, At the end of the programme, After the programme, Follow up; Stakeholders' responsibilities.

Block 2: Capacity Development Needs Assessment

Unit 1: Planning and Organization of Capacity Development Programmes

Concept of Need Assessment; Approaches in Need Analysis- Performance Analysis, Task Analysis, Competency Study; Needs Survey.

Unit 2: Capacity Development Needs Assessment Methods

Data Collection Methods in Identifying Needs - Rational Methods (Observation, Informal talks, Complaints, Comparison, Analysis of report, Opinion poll, Buzz session, Analysis of the new programme), Empirical Methods (Job analysis, Performance evaluation, Checklist or Questionnaire Method, Tests, Critical Incident Technique, Card Sort Method, Focus Group Discussion, Interview, SWOT Analysis); Information and Skills required in Need Analysis; Identification of Needs through Task Analysis - Task identification, Task Analysis, Gap Analysis.

Block 3: Capacity Development Institutions and Management

Unit 1: Capacity Development Institutions

Capacity Developer (Trainer): Meaning and concept; Types of Capacity Developers (regular, *ad-hoc*, part time, guest and consultants); Roles of Capacity Developer (explainer, clarifier, supporter, confronter, role model, linker, motivator, translator/ interpreter, change agent); Good Capacity Developer – Qualities, skills and roles Qualities, Skills (Intrapersonal & Inter personal), Roles (Manager, Strategist, Task Analyst, Media Specialist, Instructional Writer, Marketer, Facilitator, Instructor, Counsellor, Transfer Agent, Evaluator); Capacity Development Centres and Locations; Organisation's Role in Capacity Development.

Unit 2: Capacity Development Project Formulation

Project Proposal: Concept and Meaning; Steps in Project Formulation- Review of past proposals, Consulting experts, consultants, and previous organizers, Review past project evaluation reports, Interact with the prospective beneficiaries; Format for Writing Project Proposal (LFA).

Block 4: Capacity Development Process and HRD

Unit 1: Capacity Development Methods and Tools

Capacity Development Methods –Lecture, Discussion, Syndicate, Seminars, Conference, Symposium, Role Play, Case study, Programmed Instruction, T - group/ Laboratory methods; Factors Determining Selection of Methods - Capacity development objectives, subject matter, categories of participants, and the available resources like time, location, budget; Capacity Development Aids.

Unit 2: Evaluation

Capacity Development Programme Evaluation - Meaning & Importance; Purpose of Evaluation; Principles of Evaluation; Types of Evaluation – Formative, Summative, Kirkpatrick's four levels of evaluation; Process of Evaluation- Evaluation at the beginning, Evaluation during the programme, Evaluation at the end; Use of evaluation findings; Statistical Tools for evaluation.

Unit 3: Impact Assessment

Impact Assessment- Meaning, Need, Features, Benefits, Concepts; Indicators for Impact Assessment - Direct indicators, Indirect or proxy indicators, Quantitative indicators, Qualitative indicators, Result chain / hierarchy of indicators; Methods of Impact Evaluation- Learning retention of participants (KOSA), Impact on the job performance, Impact on organizational effectiveness, Impact on stakeholder's competency.

Unit 4: Human Resource Development

HRD: Meaning, Importance and Benefits; Types of HRD Systems & Sub-systems Career system (Manpower planning, Recruitment, Career planning, Succession planning, Retention), Work system (Role analysis, Role efficacy, Performance plan, Performance feedback and guidance, Performance appraisal, Promotion, Job rotation, Reward), Development system (Induction, Training, Job enrichment, Self-learning mechanisms, Potential appraisal, Succession development, Counselling, Mentor system), Self-renewal system (Survey, Action research, Organisational development interventions), Culture system (Vision, mission and goals, Values, Communication, Get together and celebrations, Task force, Small groups); Components of HRD System - Performance Appraisal, Potential Appraisal, Task System, Development System, Socialisation System, Governance; Functions of HRD-Organisational Development, Career Development, Capacity Development.

VII. Practicals

- Capacity development needs assessment exercise
- Capacity development project formulation exercise
- Planning organizing and conducting an extension capacity development programme
- Designing a programme
- Writing learning objectives
- Developing objectives into curriculum
- Training plan
- Organizing capacity development workshop
- Evaluation with pre- and post-training tests
- Training methods – Practicing each method mentioned in contents as group exercise

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group work
- Case Analysis
- Guest Lectures
- Review of training manuals and training evaluation studies
- Short attachments to a nearby training institute.

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Differentiate between training, capacity building, capacity development and human resource development
- Explain different levels of capacities, needs assessment approaches & methods, capacity development methods and tools
- Formulate, implement and evaluate need based capacity development programmes

X. Suggested Reading

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Bentaya GM, and Hoffmann V (Eds). 2011. *Rural Extension* Volume 3 -Training Concepts and Tools. Margraf Publishers GmbH, Scientific books, KanalstraBe 21; D-97990, Weikersheim, 191 pp.

DFID .2003. *Promoting Institutional and Organisational Development. A Source Book of Tools and Techniques,* Department for International Development, United Kingdom

DoPT.2014. *Civil Services Competency Dictionary: Strengthening Human Resource Management of Civil Service.* Department of Personnel and Training, Government of India

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ICAR 2015. *Training Policy 2015*, Indian Council of Agricultural Research.

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UNDP. 2009. *Capacity Development: A UNDP Primer*, United Nations Development Programme
WAC. 2013. *Assessing Capacity Needs and Strategy Development for Grassroots Rural Institutions: A Guide for Facilitators.* World Agroforestry Centre (WAC)

Websites

TAP–Tropical Agriculture Platform for Capacity Development– https://www.tapipedia.org/
FAO–FAO Capacity Development– http://www.fao.org/capacity-development/en/
GFRAS–Global Forum for Rural Advisory Services– http://www.g-fras.org/en/
AESA–Agricultural Extension in South Asia– http://www.aesanetwork.org/

I. Course Title : ICTs for Agricultural Extension and Advisory Services
II. Course Code : EXT 506
III. Credit Hours : 2+1

IV. Why this course?

Information and Communication Technologies (ICTs) are continuously evolving. More ICT applications having better relevance to extension and advisory services (EAS) are currently available considering the human and other resource constrains faced by EAS, ICTs can supplement and complement EAS extension efforts in a cost-effective way. Extension professionals should have sound knowledge of ICTs and comprehensive understanding on its various applications for effectively deploying these in EAS provision. This course will provide knowledge and hands-on-experience on ICT applications relevant for EAS.

V. Aim of the course

- To discuss different ICT initiatives, knowledge management process and application aspects

- To orient students on advances in smart/ disruptive technologies and data analytics
- Hands on experience in navigating ICTs

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Information and Communication Technologies (ICTS) and e-Extension	1. ICTs- Concepts and Status 2. ICTs in Knowledge Management 3. e-Extension initiatives in Agriculture and allied sectors
2.	Application of ICTs in Extension and advisory services	1. ICT Applications 2. ICT Expert Systems 3. ICT Networks
3.	Knowledge management and Standards	1. Policies in Knowledge Management 2. Web Standards 3. Social Media Applications to engage audience
4.	Smart and disruptive Technologies and advanced analytics for agricultural extension	1. Smart Technologies 2. Human Computer Interactions

VI. Theory

Block 1: Introduction to Information and Communication Technologies (ICTs) and E-extension

Unit 1: ICTs- Concepts and Status

ICTs- meaning, concepts, basics of ICTs, global and national status, types and functions of ICTs, innovations, meaning of e-Governance, e-learning, mLearning, advantages and limitations of ICTs.

Unit 2: ICTs in Knowledge Management

Knowledge management-meaning, approaches and tools. Role of ICTs in Agricultural Knowledge Management.

Unit 3: e-Extension initiatives in Agriculture and allied sectors

e-Extension, overview on Global and national e-extension initiatives, Inventory of e-Extension initiatives in Agriculture and allied sectors from Central and State governments, ICAR, SAUs, private sector and NGO initiatives in India.

Block 2: Application of ICTs in Extension and Advisory Services

Unit 1: ICT Applications

Knowledge centres (tele centres), digital kiosks, websites and web portals, community radio, farmers call centres, mobile phone based advisory services and mobile applications (mExtension, mLearning), Self-learning CDs on Package of practices, social media, digital videos, Market Intelligence and Information Systems- ICT enabled Supply-Chains and Value-Chains/ e-Marketing (e-NAM, Agmarknet, *etc.*).

Unit 2: ICT Expert Systems

Expert System/ Decision Support System/ Management Information Systems, Farm Health Management & Intelligence System for Plant Health, Animal Health, Soil Health, Fishery, Water, Weather, etc.

Unit 3: ICT Networks

Global and regional knowledge networks, international information management systems, e-Learning platforms (MOOCS, Course CCRA, EduEx, *etc*), e-Governance Systems; digital networks among extension personnel, Farmer Producers Organisations (FPOs)/ SHGs/ Farmers Groups.

Block 3: Knowledge Management and Standards

Unit 1: Policies in Knowledge Management

Global policy/ Standards on e-Governance, National policy on e-governance, Open Data / Open Gov Standards and Open Source etc; Language Technology Applications; National e-Agriculture policy/ Strategies/ guidelines.

Unit 2: Web Standards

Web standards, creating and writing for webportals, development of mobile applications, developing digital videos- story board- video recording- video editing, types of blogs and writing guidelines.

Unit 3: Social Media Applications to engage audience

Video conference, live streaming and webinars, types and functions of social media applications, guidelines for preparing social media content, engaging audience and data-analytics.

Block 4: Smart and Disruptive Technologies and Advanced Analytics for Agricultural Extension

Unit 1: Smart Technologies

Open technology computing facilities, System for data analytics/ mining/ modelling/ Development of Agricultural simulations; Remote Sensing, GIS, GPS, Information Utility (AIU); disruptive technologies- Analysis; Internet of Things (IoTs), Drones, Artificial intelligence (AI), block chain technology, social media and Big Data analytics for extension.

Unit 2: Human Computer Interactions

Human Centered Learning/Ergonomics/ Human Computer Interactions-Meaning; Theories of multimedia learning - Sweller's cognitive load theory, Mayer's cognitive theory of multimedia learning, Schnotz's integrative model of text and picture comprehension, van Merriënboer's four-component instructional design model for multimedia learning; Basic Principles of Multimedia Learning - Split-attention, Modality, Redundancy, Coherence, Signaling, segmenting, pre-training, personalisation, voice embodiment; Advanced principles - Guided discovery, worked examples, Self-explanation, drawing, feedback, multiple representation, Learner control, animation, collaboration, prior knowledge, and working memory. Designing ICT gadgets based on human interaction principles - Interactive design-Meaning, importance; Approaches of interactive design - user-centered design, activity-centered design, systems design, and genius design; Methods of interactive design - Usability testing methods.

VII. Practicals

- Content and client engagement analysis
- Designing extension content for ICTs
- Creating and designing web portals, blogs, social media pages
- Developing digital videos

- Live streaming extension programmes and organising webinars
- Working with Farmers call centres
- Engaging with professional digital networks
- Writing for digital media

VIII. Teaching methods/activities

- Lecture
- Guest Lectures
- Assignment (Reading/Writing/ developing mApps/ media management/Social media initiatives)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Student's interview of ICT practitioners/ champions
- Documenting good practices and case studies
- Review of ICT policy documents and guidelines/ standards
- Short internship with ICT projects

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of the ICTs in EAS
- Understand the ICT application aspects
- Critically evaluate ICT initiatives and smart/disruptive technologies
- To execute extension functions by applying ICTs and
- Engage stakeholders in knowledge management process

X. Suggested Reading

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CTA–The Technical Centre for Agricultural and Rural Cooperation: Digitalization– https://www.cta.int/en/channel/digitalisation-sid05951b8c7-e611-4f34-9ae6-8c0fc0c822bc

GFRAS–Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

AESA–Agricultural Extension in South Asia– http://www.aesanetwork.org/

I. Course Title : Evaluation and Impact Assessment

II. Course Code : EXT 507

III. Credit Hours : 2+1

IV. Why this course?

Many organizations now look for experts to evaluate development projects and developmental interventions. It is now required that impact be assessed whenever any development programme is implemented. Thus, the extension professionals need to have good understanding of the theory and practice of programme evaluation and impact assessment. This course, thus, has been designed to help students develop as extension professionals who can plan and conduct systematic assessments of the results and impacts of extension programmes.

V. Aim of the course

- To orient students on the importance of evaluation and impact assessment
- To develop capacities for evaluation and impact assessment
- Discuss ways of conducting evaluations and impact assessment

The course is organized as follows:

No	Blocks	Units
1.	Programme Evaluation	1. Introduction to Evaluation 2. Evaluation Theories
2.	Evaluation Process	1. How to Conduct Evaluation 2. Evaluating the Evaluation

No	Blocks	Units
3.	Programme Management Techniques	1. SWOT Analysis and Bar Charts 2. Networks
4.	Programme Evaluation Tools	1. Bennett's Hierarchy of Evaluation 2. Logic Framework Approach
5.	Impact Assessment	1. Introduction to Impact Assessment 2. Impact Assessment Indicators 3. Approaches to Impact Assessment 4. Environment Impact Assessment

VI. Theory

Block 1: Programme Evaluation

Unit 1: Introduction to Evaluation

Concept of Evaluation: Meaning and concept in different contexts; Why Evaluation is Done and When? Programme planning, analyse programme effectiveness, decision making, accountability, impact assessment, policy advocacy; Objectives, types, criteria and approaches of programme evaluation, evaluation principles; the context of program evaluation in agricultural extension; Role and Credibility of Evaluator: Role as educator, facilitator, consultant, interpreter, mediator and change agent. Competency and credibility of evaluator.

Unit 2: Evaluation Theories

Evaluation theory vs. practice – synergistic role between practice and theory in evaluation; Evaluation theories - Three broad categories of theories that evaluators use in their works - programme theory, social science theory, and evaluation theory (other theories/ approaches - Utilization-Focused Evaluation & Utilization-Focused Evaluation (U-FE) Checklist, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation). Integration between theory and practice of evaluation: –evaluation forums, workshops, conferences and apprenticeship/ internship.

Block 2: Evaluation Process

Unit 1: How to Conduct Evaluation

Ten Steps in programme evaluation: (1) Identify and describe programme you want to evaluate (2) Identify the phase of the programme(design, start-up, on-going, wrap-up, follow-up) and type of evaluation study needed (needs assessment, baseline, formative, summative, follow-up) (3) Assess the feasibility of implementing an evaluation (4) Identify and consult key stakeholders (5) Identify approaches to data collection (quantitative, qualitative, mixed) (6) Select data collection techniques (survey interviews and questionnaires with different types) (7) Identify population and select sample (sampling for evaluation, sample size, errors, sampling techniques (8) Collect, analyse and interpret data (qualitative and quantitative evaluation data analysis) (9) Communicate findings (reporting plan, evaluation report types, reporting results, reporting tips, reporting negative findings (10) Apply and use findings (programme continuation/ discontinuation, improve on-going programme, plan future programmes and inform programme stakeholders).

Unit 2: Evaluating the Evaluation

Evaluating the Evaluation - 10 Steps as above with focus on conceptual clarity, representation of programme components and stakeholders, sensitivity, representativeness of needs, sample and data, technical adequacy, methods used for data collection and analysis, costs, recommendations and reports.

Block 3: Programme Management Techniques

Unit 1: SWOT Analysis and Bar Charts

SWOT Analysis – Concept, origin and evolution; SWOT As a Programme Management Tool; Conducting SWOT Analysis - Common Questions in SWOT Analysis; Advantages and Disadvantages of SWOT; Bar Charts (Gantt Charts and Milestone Charts) - Characteristics, advantages and limitations.

Unit 2: Networks

Networks – Introduction, origin and widely used networks (Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM), differences between PERT and CPM, advantages and disadvantages. Networks Terminology – Activity, Dummy activity, Event (predecessor event, successor event, burst event, merge event, critical event), Earliest Start Time (EST), Latest Start Time (LST), Critical Path, Critical Activity, Optimistic time (T_o), Pessimistic time (P_o), Most likely time (T_M), Expected time (T_E), Float or Slack, Event Slack, Lead time, Lag time, Fast tracking, Crashing critical path, Acclivity Table, Danglers, Normal Time. Rules for Preparation of Networks and Steps in Network Preparation with example.

Block 4: Programme Evaluation Tools

Unit 1: Bennett's Hierarchy of Evaluation

Introduction to Bennett's hierarchy – Background and description; Relation between programme objectives & outcomes at 7 levels of Bennett's hierarchy – Inputs, activities, participation, reactions, KASA changes, practice and behaviour changes, end results. Advantages and Disadvantages of Bennett's hierarchy

Unit 2: Logic Framework Approach (LFA)

Introduction to LFA – Background and description; Variations of LFA - Goal Oriented Project Planning (GOPP) or Objectives Oriented Project Planning (OOPP); LFA Four-by-Four Grid – Rows from bottom to top (Activities, Outputs, Purpose and Goal & Columns representing types of information about the events (Narrative description, Objectively Verifiable Indicators (OVIs) of these events taking place, Means of Verification (MoV) where information will be available on the OVIs, and Assumptions). Advantages and Disadvantages of LFA.

Block 5: Impact Assessment

Unit 1: Introduction to Impact Assessment

Concept of Impact Assessment: Meaning, concept and purpose in different contexts; Impact Assessment Framework: Meaning of inputs, outputs, outcomes, impacts and their relation with monitoring, evaluation and impact assessment.

Unit 2: Impact Assessment Indicators

Indicators for impact assessment – meaning and concept; Selecting impact indicators; Types of impact indicators for technology and extension advisory services - social and behavioral indicators, socio-cultural indicators, technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.

Unit 3: Approaches for Impact Assessment

Impact assessment approaches – Quantitative, qualitative, participatory and mixed methods with their advantages and disadvantages; Quantitative Impact Assessment Types – Based on Time of Assessment (Ex-ante and ex-post), Based on Research Design (Experimental, quasi experimental, Non-experimental). Econometric Impact Assessment: - (Partial Budgeting Technique, Net Present Value, Benefit Cost Ratio, Internal Rate of Return, Adoption Quotient, *etc*). Qualitative and Participatory Impact Assessment Methods.

Unit 4: Environment Impact Assessment (EIA)

Concept of EIA – Introduction, What it is? Who does it? Why it is conducted? How it is done?; Benefits and important aspects of EIA-risk assessment, environmental management and post product monitoring. Environmental Components of EIA – air, noise, water, biological, land; Composition of the expert committees and Steps in EIA process - screening, scoping, collection of baseline data, impact prediction, mitigation measures and EIA report, public hearing, decision making, monitoring and implementation of environmental management plan, assessment of alternatives, delineation of mitigation measures and EIA report; Salient Features of 2006 Amendment to EIA Notification - Environmental Clearance/Rejection, participants of EIA; Shortcomings of EIA and How to improve EIA process?

VII. Practicals

- Search the literature using web / printed resources and identify evaluation indicators for the following:
  - Utilization-Focused Evaluation
  - Values Engaged Evaluation
  - Empowerment Evaluation
  - Theory-Driven Evaluation
- Visit Directorate of Extension in your university and enquire about extension programmes being implemented / coordinated by Directorate. Develop an evaluation proposal of any one programme using 'Ten Steps in Programme Evaluation' discussed in the theory class.
- Review any comprehensive programme evaluation report from published sources. Evaluate the report and write your observations following the 'Evaluating the Evaluation' approach.
- Identify at least four agriculture development programmes and their objectives being implemented in your state. Write two attributes each on Strengths, Weaknesses, Opportunities and Threats related to the identified programme objectives in the SWOT grid.
- Identify an on-going development programme and make-out 6 activities from the programme.
- Draw a Gantt chart for 12 months programme activities.
- Write a report on evaluation hierarchy levels and indicators as per Bennett's hierarchy of evaluation for any development programme or project.
- Develop LFA four-by-four grid for any development programme or project with activities, outputs, purpose and goal and objectively verifiable indicators, means of verification & assumptions.
- Visit a nearby KVKs / ATIC. Select any agriculture technology with package of practices and extension advisory services promoted by KVK / ATIC. Identify impact assessment indicators for social and behavioral indicators, socio-cultural indicators,

technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.

- Refer any Environment Impact Assessment report and analyse steps in EIA. Write your observations.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Develop competencies in the areas of evaluation planning, indicator development, conducting evaluation and impact assessment and writing reports.

X. Suggested Reading

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Better Evaluation– www.betterevaluation.org

TAP– Tropical Agriculture Platform: Monitoring and Evaluation - www.tapipedia.org

GFRAS– Global Forum for Rural Advisory Services http://www.g-fras.org/en/

AESA– Agricultural Extension in South Asia http://www.aesanetwork.org/
USAID– United States Agency for International Development: Evaluation https://www.usaid.gov/evaluation
https://education.illinois.edu/faculty/jennifer-greene

I. Course Title : Managing Extension Organizations

II. Course Code : EXT 508

III. Credit Hours : 2+1

IV. Why this course?

Organizations need to follow management principles, objectives and organizational processes. The extension organizations including management of agricultural extension services need to be managed for effectiveness and efficiency. This calls for key business management skills to be learnt by the students so that they can run extension organizations, and extension and advisory services efficiently using the principles, practices, knowledge and skills required for effective management.

V. Aim of the course

- To orient students on the importance of knowledge and skills on various management functions, as applicable to extension organizations
- Discuss ways of running extension services as managers of agri-ventures
- To develop capacities for becoming effective managers of agri-ventures

The course is organized as follows:

No	Blocks	Units
1.	Basics of Management	1. Management- An Over view
2.	Management in different types of Extension organizations	1. Extension Management in public, private sector and other sectors 2. Concepts in Management
3	Motivation and Organizational Communication	1. Motivation and Communication 2. Supervision and Control

VI. Theory

Block 1: Basics of Management

Unit 1: Management- An Over view

Management and Extension management – Meaning, concept, nature and importance;
and theories of management. Management, administration and supervision - meaning, definition and scope; Approaches to management, Principles, functions and levels of management; Qualities and skills of a manager; Interpersonal relations in the organization; Reporting and budgeting

Block 2: Management in different types of Extension Organizations

Unit 1: Extension Management in public, private sector and other sectors

Extension management (POSDCORB) in public sector, Department of Agriculture, Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendra (KVK), SAUs, ICAR Institutes, Private sector, Cooperatives, NGOs, FPOs etc. Organisational Structure, Relations between different units- Challenges in management

Unit 2: Concepts in Management

Decision making – Concept, Types of decisions, Styles and techniques of decision making, Steps in DM Process, Guidelines for making effective decisions; Human Resource Management: Manpower planning, Recruitment, Selection, Placement and Orientation, Training and Development; Dealing with fund and staff shortages in different extension organizations (KVK, ATMA etc.); Leadership – Concept, Characteristics, Functions, Approaches to leadership, Leadership styles; Authority and responsibility, Delegation and decentralization, line and staff relations; Challenges of co-ordination in extension organizations; Managing interdepartmental coordination and convergence between KVK, ATMA and line departments; Coordinating pluralism in extension services; Challenges in managing public-private partnerships (PPPs) at different levels in agricultural development in general and extension in particular; Performance appraisal – Meaning, Concept, Methods.

Block 3: Motivation and Organizational Communication

Unit 1: Motivation and Communication

Managing work motivation – Concept, Motivation and Performance, Approaches to motivation, team building; Organizational Communication – Concept, Process, Types, Networks, Barriers to Communication; Mentoring, Time management, Team work and team-building strategies; Modernization of information handling

Unit 2: Supervision and Control

Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision; Managerial Control – Nature, Process, Types, Techniques of Control, Observation, PERT and CPM, Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organizations.

VII. Practicals

- Simulated exercises on techniques of decision making
- Study the structure and function of agro-enterprises, Designing organizational structure/ organograms.
- Group activity on leadership development skills
- Simulated exercise to understand management processes
- Field visit to extension organizations (ATARI, KVKs, NGOs), FPOs, dairy cooperatives to understand the functions of management
- Practical exercises on PERT & CPM
- Group exercise on development of short term and long term plans for agro-enterprises
- Developing model agriculture-based projects including feasibility study, financial planning and cost-benefit analysis

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Student's interview of officers engaged in EAS
– Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Turn good managers of extension and advisory services including agri-ventures, FPOs, cooperatives etc.
– understand the key business skills needed for managing agribusinesses and managing the value chains
– critically evaluate the Management functions to make extension systems efficient by applying management principles and good practices of effective management
– engage in management of extension organizations

X. Suggested Reading

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I. Course Title : Enabling Innovation

II. Course code : EXT 509

III. Credit Hours : 1+1

IV. Why this course?

An effective process of agricultural innovation is a pre-condition for meeting the global challenge of feeding the growing world population and reducing poverty. Ideas about innovation have evolved considerably over the past 4 decades. A frequently used term in the discussions around innovation in agriculture is 'Agricultural Innovation Systems' (AIS). The AIS is increasingly recognized as a useful framework to diagnose innovation capacity, design investment and organise scaling up interventions. Extension and Advisory Services (EAS) are integral to AIS. Extension professionals should have sound knowledge on how to scale up new knowledge and thereby enabling innovation and impact and their roles in strengthening AIS. This course aims to provide these perspectives.

V. Aim of the course

The aim of this course is to introduce the new perspectives related to "innovation" and help learners to apply the AIS framework especially in dealing with scaling up knowledge. It discusses the different ways to explore AIS including the roles of different actors and the enabling environment (including institutions and policies) in enabling innovation. The course also aims to broaden the understanding of students in scaling up knowledge and orient students to varied tools and approaches to scaling up

The course is organized as follows:

No	Blocks	Units
1	Agricultural Innovation Systems	1. Agricultural Innovation Systems: Concepts and Elements 2. Enabling Innovation
2	Scaling Up Knowledge for Innovation	1. Scaling Up: Tools, Approaches and Pathways

VI. Theory

Block 1: Agricultural Innovation Systems

Unit 1: Agricultural Innovation Systems: Concepts and Elements

Origins of the innovation systems concept-Innovation vs Invention; Agricultural Innovation System (AIS) -ToT, FSR, AKIS and AIS compared, Key insights from AIS: How Innovation takes place; Role of different actors in AIS; Importance of interaction and knowledge flows among different actors, Role of Communication in Innovation Process; Role of Extension in AIS, Different views to analyze AIS: structural view, functional view, process view and capacity view.

Unit 2: Enabling Innovation

Role of enabling environment: Policies and institutions in enabling innovation; Role of Government-Innovation Policy: Achieving coordination and policy coherence;

Innovation Platforms; Role of Innovation Brokers, Methodologies for AIS Diagnosis: Typologies of existing methodologies-strengths and limitations; Assessing Extension and Advisory Services within AIS; Capacity Development in AIS: Strengthening capacities to innovate.

Block 2: Scaling Up Knowledge for Innovation

Unit 1: Scaling Up: Tools, Approaches and Pathways

Scaling Up: Definitions; Changing views on scaling up: Approaches to Scaling Up: Push, pull, plant, probe: Scaling up pathways: Drivers and spaces for scaling up; Framework and Tools for Scaling up: Planning and implementing a scaling up pathways; Scalability assessment tools; Role of policies in scaling up: Influencing policies for scaling up; Innovation Management for scaling up knowledge and implications for Extension and Advisory Services.

VII. Practical

- Identify one crop/commodity sector and use AIS framework to diagnose actors and their roles, patterns of interaction, institutions determining interaction and the enabling policy environment and develop a AIS Diagnosis Report (Review and Key informant interviews)
- Undertake a case study on a successful case of scaling up knowledge and identify factors that contributed to its success
- Identify one specific knowledge (a technology, an approach) that has been recently introduced and develop an Up scaling Strategy

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Appreciate and apply AIS framework in different contexts
– Enhance their knowledge and skills related to enabling innovation
– Diagnose AIS and design interventions for improvement and
– Design scaling up strategies to achieve innovation and impact

X. Suggested Reading

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FAO- Food and Agricultural Organisation (Research and Extension)– http://www.fao.org/research-and-extension/en/

GFRAS- Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

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WUR-Wageningen University and Research Research [Knowledge, Technology and Innovation Group (KTI)]– https://www.wur.nl/en/Research-Results/Chair-groups/Social-Sciences/KnowledgeTechnology-and-Innovation-Group.htm

I. Course Title : Gender Mainstreaming

II. Course Code : EXT 510

III. Credit Hours : 2+1

IV. Why this course?

Gender as a concept has gained well deserved attention globally. Development planners and policy makers have realized that gender implications need to be considered while planning and implementing programmes and projects for their desired impacts. Conversely, the impacts of programmes on men and women also vary due to their different socially ascribed roles and responsibilities. Extension professionals need to understand the concept of gender and its implications on agricultural and rural development and their skills need to be built for critically identifying and analysing gender implications. This course is designed to meet these requirements.

V. Aim of the course

- To orient students on the importance of "Gender mainstreaming" as well as the other concepts related to gender. The students will be able to understand the gender roles and responsibilities and how in the present times, the roles may be shifting
- To discuss ways and various techniques for conducting gender analysis theoretically and practically as well as the prerequisites for gender analysis
- To develop capacities for identifying and addressing gender implications in all development programmes related to agriculture and allied sectors, climate change adaptation and livelihood security, as well as addressing gender issues through application of extension methods including PRA and PLA

The course is organized as follows:

No	Blocks	Units
1.	Why Gender Matters	1. Historical Perspective of Gender 2. Agrarian Importance of Gender
2.	Gender Related Concepts, Analysis, Gender and Technology	1. Gender Related Concepts and Divides 2. Gender Analysis 3. Gender and Technology
3.	Gender Mainstreaming and Women Empowerment	1. Gender Mainstreaming 2. Women Empowerment 3. Global Best Practices, Policies and Frameworks 4. Entrepreneurship Development for Women

VI. Theory

Block 1: Why Gender Matters?

Unit 1: Historical Perspective of Gender

Historical perspective of gender: Feminism and emergence of gender as a concept, Scope of gender studies in agriculture and rural development

Unit 2: Agrarian Importance of Gender

Agrarian Importance of Gender: Understanding the importance of gender in national and global agriculture-Key gender issues and challenges in agriculture - Gender and value chain- Global actions to address gender-needs and strategies to address gender and women empowerment.

Block 2: Gender Related Concepts, Analysis, Gender and Technology

Unit 1: Gender Related Concepts and Divides

Gender related concepts and divides: Understanding of the concepts of gender, gender equality and equity, gender balance, gender blindness, gender relations, gender neutrality, gender bias and discrimination, gender rights, gender roles and responsibilities. Gender budgeting, Gender divides and their implications such as gender digital divide, gender access to resources and inputs divide, gender mobility divide, gender wage divide, Gender needs: practical and strategic.

Unit 2: Gender Analysis

Gender analysis: Importance, usage, prerequisites, techniques of gender analysis-Tools for gender analysis.

Unit 3: Gender and Technology

Gender and technology: How gender and technology impact each other, Gender neutral technology, Gender sensitive technology, Gender supportive assistance in technology adoption-Gender in agricultural research and extension.

Block 3: Gender Mainstreaming and Women Empowerment

Unit 1: Gender Mainstreaming

Gender mainstreaming: Importance of gender mainstreaming in agriculture, Extension strategies to address gender issues such as gender and health, nutrition, gender in agricultural value chains, gender and climate change adaptation, gender and globalization& liberalization for mainstreaming gender concerns into the national programmes and policies.

Unit 2: Women Empowerment

Women Empowerment: Importance of women empowerment, Current national women empowerment and gender indices. Women empowerment approaches (technological, organizational, political, financial, social, legal and psychological), Case studies based on experiences and learning from various development and rural development programmes.

Unit 3: Global Best Practices, Policies and Frameworks

Global Best Practices, Policies and Frameworks: Global best practices, women empowerment and gender mainstreaming models and frameworks for addressing gender concerns in agriculture, approaches of various organizations: gender mainstreaming and special women focused programmes in agriculture and rural development.

Unit 4: Entrepreneurship Development for Women

Entrepreneurship development for women: Women entrepreneurship development in agriculture and agro processing: current status, women led enterprises, supporting organizations and schemes, Govt. policies, entrepreneurship development programme and process for women in agriculture.

VII. Practicals

- Visit to a village for understanding rural gender roles and responsibilities as groups, followed by class presentation by groups
- Exercise for capturing shifts in gender roles and responsibilities
- Conducting gender analysis in a village using gender analysis techniques
- Visit to agencies supporting women empowerment followed by report presentation. Each student to visit a different organization such as State Rural Livelihood Mission, Women Development Corporation, Department of Agriculture, Important NGOs working for women empowerment
- Exercise for identification and prioritization of issues affecting/needs for women empowerment
- Interaction with a successful women entrepreneur/ SHG

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Student's interview of key policy makers
- Case Analysis
- Guest Lectures
- Review of policy documents
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of addressing agrarian gender concerns in the context of sustainable livelihoods and national development
- Understand the various concepts related to gender and the application of these concepts for women empowerment and gender mainstreaming
- Critically evaluate the various agricultural development, rural development programmes, schemes, policies and strategies for women empowerment within the context of achieving gender equity
- How to engage in gender analysis and collect and analyse sex-disaggregated data for developing strategies for women empowerment and gender mainstreaming

X. Suggested Reading

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Liz P. 2018. *Implementing Gender Transformative Approaches (GTAs) in Agricultural Initiatives.* IGENAES and USAID. https://ingenaes.illinois.edu/wp-content/uploads/ING-DP-2018_06-Gender-Transformative-Approaches-in-Agricultural-Initiatives-Poulsen.pdf

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GFRAS- Global Forum for Rural Advisory Services– http://www.g-fras.org/en/
INGENAES- Integrating Gender and Nutrition within Agricultural Extension Services– https://www.agrilinks.org/activities/ingenaes-integrating-gender-and-nutrition-within-agricultural-extension-services
RRW- Reaching Rural Women– http://www.reachingruralwomen.org/
UN WOMEN– http://www.unwomen.org/en

Course Title with Credit Load
Ph.D. in Agricultural Extension Education

Major Courses 12

Course Code	Title of Course	Credit Hours
EXT-601*	Policy Engagement and Extension	2+1
EXT-602*	Methodologies for Social and Behavioural Sciences	2+1
EXT-603*	Technology Commercialization and Incubation	2+1
EXT-604*	Educational Technology and Instructional Design	2+1

Minor Courses 06

a. It is suggested the student may choose at least one out of three courses listed below as part of minor courses as these are related to policy advocacy and bring in global perspectives with an aim to build a larger understanding of the subject to the student.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agrl. Economics/ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HOD.

EXT-605	Risk Management and Climate Change Adaptation	2+1
EXT-606	Livelihood Development	1+1
EXT-607	Facilitation for People centric Development	2+1

Supporting Courses 05

STAT	Multivariate Statistical Methods for Extension Research	2+1
COM	Multimedia and Applications	1+1

It is suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HOD".

Seminars 2

EXT-691	Doctoral Seminar-I	1+0
EXT-692	Doctoral Seminar-II	1+0
	ii. Thesis / Research	75
	Total	100

Course Contents
Ph.D. in Agricultural Extension Education

I. Course Title : Policy Engagement and Extension

II. Course Code : EXT 601

III. Credit Hours : 2+1

IV. Why this course?

Extension's performance in any country to a large extent is dependent on the wider policy and institutional context prevailing at the national level. At the organizational level, extension should have capacities to influence policies that affect their performance. To effectively influence policies, extension professionals need to generate not only sound evidence of its impact, but also capacities to engage with policy relevant actors especially at various levels. While few countries have developed specific extension policies, there has been very limited success in translating these policies into programmes and operational guidelines. Lack of policy relevant research to generate evidence on extension's impact; poor documentation of successful initiatives, and lack of training on engaging with policy relevant actors have all contributed to this. Extension professionals, often encounter situations where existing policy constraints development interventions or where new policies could better support development. This course is aimed at developing these capacities to successfully engage with policy actors and bringing about desirable policy changes to strengthen extension.

V. Aim of the course

- To orient students on the importance of policies in shaping extension's performance
- To discuss ways of generating policy relevant evidence to influence policies
- To develop capacities to engage with policy actors and the policy development process

The course is organized as follows:

No	Blocks	Units
1.	Why policies matter?	1. Understanding Policy 2. Policy Advocacy and Tools 3. Policy Analysis 4. Policy Development Process
2.	Using evidence to influence Policy Change	1. Influencing Policy Change 2. Global Experience with Extension Policy

VI. Theory

Block 1: Why Policies Matter?

Unit 1: Understanding Policy

Why policies are important for extension? Role in providing structure, ensure funding and framework for providing functions-examples; Policy: definitions and types: Is policy a product or a process or both? Policies and institutions-How these influence defining organisational roles and performance in extension organizations-Role of policies in upscaling knowledge-Role of extension in influencing policies to enable innovation.

Unit 2: Policy Advocacy and Tools

Definition of advocacy, Approaches to policy advocacy-Advising, Media campaigning, Lobbying, Activism, Information Education Communication (IEC) and Behavior Change Communication (BCC); Advocacy for Rural Advisory Services (RAS); Policy advocacy strategy

Unit 3: Policy Analysis

Explain the meaning and use of policy analysis in decision- making; Describe different types of policy analysis- empirical, evaluative or normative policy analysis, retrospective/ prospective policy analysis, predictive/prescriptive/descriptive policy analysis; How to do policy analysis? - understand the process of policy analysis, highlight the different methods and techniques used in policy analysis, doing ethical policy analysis; Tools for policy impact- research tools, context assessment tools, communication tools, policy influence tools

Unit 4: Policy Development Process

Policy development process: Who drives policy change?: National Governments, Donors, Civil Society-varied experiences: Understanding the environment and key actors in policy space- problem identification-policy adoption, implementation and evaluation; stakeholder mapping, identifying opportunities and barriers, mobilising financial resources; Dealing with policy incoherence: identifying contradictions and challenges in policy implementation

Block 2: Using Evidence to Influence Policy Change

Unit 1: Influencing Policy Change

Generating evidence: Role of policy research; analyzing the usefulness and appropriateness of the evidence; Using evidence in policy advocacy; Understanding your audience: analyzing channels of influence; creating alliances; identifying policy champions; Defining goals and objectives; Developing advocacy messages: Policy papers, Policy briefs, good practice notes, *etc*.: Good practices in influencing policies Organising policy dialogues: Policy engagement strategy-Engaging with policy makers: GO and NGO experiences; Policy working groups; advisory panels; use of committees: Use of media including ICTs and social media for influencing policies.

Unit 2: Global Experience with Extension Policy

Extension policy in different countries: Explicit extension policy Vs extension as part of Agriculture Policy, Challenges in policy implementation: lack of capacities, financial resources, ownership, lack of stakeholder consultations: Strengthening capacities in extension to influence policies: Global Forum for Rural Advisory Services (GFRAS)'s efforts in strengthening extension policy advocacy: policy compendium, training modules, training for strengthening capacities to influence policies.

VII. Practicals

- Analysis of country/state level agricultural/extension policy to understand the policy intentions from strengthening EAS

- Analysis of extension policy of other countries: policy intentions, processes adopted in development of the policy and mechanisms of policy implementation
- Interview key policy actors in EAS arena at the state/national level (eg: Director of Agriculture, Director of Extension in SAU, Chairman/Managing Director of Commodity Board. Member Agriculture, State Planning Board) to explore policy level challenges in EAS
- Identify what evidence policy makers look for from extension research? Is the evidence available? If so what form? (Reports, Briefs etc), If not, develop a plan
- Explore how different stakeholders influence policies (eg: policy advocacy of prominent NGOs, private sector and public sector) -What mechanisms and tools they use
- Identify policy level bottlenecks that constrain effective EAS delivery at the district level- Eg: Issues around linkages between KVK and ATMA; inter-departmental collaboration; public private partnerships; joint action etc.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student’s Book/Publication Review
- Student presentation
- Group Work
- Student’s interview of key policy makers
- Case Analysis
- Guest Lectures
- Review of policy documents
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the role of policies in shaping performance of extension
- Understand how to generate and communicate policy relevant evidence
- Critically evaluate extension policies in different countries
- How to engage in policy advocacy.

X. Suggested Reading

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I. Course Title : Methodologies for Social and Behavioural Research

II. Course Code : EXT 602

III. Credit Hours : 2+1

IV. Why this course?

In general, social and behavioural science research plays a crucial role in the professional development in a subject domain, through advancing knowledge and developing working modalities and standards. Precisely, the empirical research helps to develop robust and outcome focused working strategies, processes and models to enable the professionals to maximise their efficiency. This course on advanced social science research caters to the need to equipping the scholars with essential skills in conducting high quality research which helps them to design working strategies, processes and models for professional development.

V. Aim of the course

This course aims to equip the doctoral students to conduct outcome-oriented social and behavioural science research and to develop sound field focused extension strategies and models with adequate replicability, while advancing knowledge on processes governing success of those strategies. The focus of the course is on equipping the scholars with advanced capacities in conducting systematic, objective and outcome oriented research by applying state-of-art methods and tools at every stage of research from planning to publishing.

The course is organized as follows:

No	Blocks	Units
1.	Advanced methods for improving quality of research data	1. Measurement Properties of Research Instruments 2. Threats to Data Quality
2.	Scales, indexes and tests	1. Scales, Indexes and Tests-1 2. Scales, Indexes and Tests-2

No	Blocks	Units
3.	Emerging research approaches and designs	1. Qualitative Research Methods 2. Emerging Approaches
4.	Utilising research outputs	1. Publishing Research 2. Ethics in Extension Research

VI. Theory

Block 1: Advanced Methods for Improving Quality of Research Data

Unit 1: Measurement Properties of Research Instruments

Measurement properties – Dimensionality, reliability and validity; Dimensionality – Unidimensionality and multidimensionality, Methods of assessing dimensionality, Formative and reflective constructs; Validity - Importance, Internal validity - face validity; content validity, Substantive Validity, Structural Validity; External validity - Convergent and Discriminant Validity, known-group validity, Criterion-Related Validity, Consequential Validity, nomological validity; Methods of assessing various forms of validities – Judges rating, Lawshe's Content Validity Ratio, Item-objective congruence index; latent variable method; Reliability - Internal consistency reliability – Split-Half, Cronbach alpha; Temporal Stability reliability - test-retest method; Interrater Consistency and Consensus – inter rater reliability and interrater agreement; Alternative Forms or parallel forms reliability – Reliability of difference - Factors Affecting the Validity and Reliability of Test Scores; Generalizability Theory

Unit 2: Threats to Data Quality

Errors and biases; Errors – Meaning and sources; Types - Sampling error, Non-sampling or measurement error and Processing error – Meaning, causes; Effects of errors and biases on data quality; Bias in behavioural research – Meaning, causes, Types – Respondent and researcher biases; Methods of reducing errors and biases in surveys, questionnaires, personal interviews, focus groups and online methods

Block 2: Scales, Indexes and Tests

Unit 1: Scales, Indexes and Tests-1

Approaches to measurement and scale development - Classical test theory. Formative or index models, The C–OAR–SE approach and Item Response Theory; Item analysis in Classical test theory – item difficulty and item discrimination; Scoring performance in scales and tests – meaning, types and methods; Scale development strategies – deductive and empirical; Stimulus-centred scales – method of equally appearing intervals, paired comparison, Person scaling – Q methodology; Subject-centre scales – The Likert scale and Semantic Differential

Unit 2: Scales, Indexes and Tests-2

Steps in constructing a multi-dimensional scale using confirmatory factor analysis,; Response scales - Guttman's scalogram analysis and The Rasch method; Indexes –Meaning, types, importance; Similarities and differences with scales, Methods of constructing indexes; Common indexes used in extension. Measurement invariance –Meaning, types, methods of assessing measurement invariance. Tests – meaning, types, importance; steps in conducting various tests – knowledge test

Block 3: Emerging Research Approaches and Designs

Unit 1: Qualitative Research Methods

Qualitative methods – Meaning; Types – Ethnography, Grounded theory, Phenomenology, Ecological psychology, Discourse Analysis; Observational research; Case study research – Sampling and sample size; Data collection methods - In-depth interviews, Focus groups, Direct observation, Record review; Content analysis; Unobtrusive Measures; Projective and semi-projective techniques; Selecting right qualitative method – Strengths and limitations of qualitative research; Analysis and interpretation of qualitative research data; Research synthesis – meaning, importance, methods; Systematic reviews and meta analysis – meaning, steps, and applications; Policy research

Unit 2: Emerging Approaches

Mixed methods research – meaning, purpose, types and applications; Participatory research – Meaning, importance, types, methods and tools and applications; Action research – Meaning, importance, Principles, Types, Steps in conducting action research, application in behavioural sciences. Social Network Analysis – Meaning, importance, types, steps in social network analysis, applications; Advanced methods of measuring perception and beliefs. Multi criteria decision making, analytical hierarchy approach

Block 4: Utilising Research Outputs

Unit 1: Publishing Research

Scholarly communication process; Research reports – Meaning, types, contents; Presentations – Meaning, types, principles of good presentation - Tell 'Em" and KISS 'Em" principles; Research publications – meaning, importance, types; Guidelines for preparing research papers - Peer review process, citation styles; Open access publishing; Publishing in social media. Software in academic writing

Unit 2: Ethics in Extension Research

Ethics in conducting behavioural research; Human subject research – Meaning, history, and ethical guidelines; Ethical aspects of collecting and using Indigenous knowledge and farmers technologies; Ethical practices in publishing; Plagiarism – meaning, sources, Identifying and correcting plagiarism in a research paper using anti-plagiarism software

VII. Practicals

- Practice in developing research instruments
- Methods of assessing measurement properties of research instruments - dimensionality, reliability and validity
- Hands-on exercise in minimising errors and biases
- Hands-on experience in constructing tests, scale and indexes
- Practice in summated scale development using confirmatory factor analysis
- Hands on experience in assessing measurement invariance
- Practicing and collecting data using participatory tools and techniques, analyzing and interpreting qualitative data
- Hands-on experience in writing systematic review using meta-analysis
- Field practice in conducting action research
- Practical experience in writing research paper
- Hands on exercises using software for qualitative data analysis
- Practice in detecting and correcting plagiarism using software

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work
- Guest Lectures
- Research Report (Writing)

IX. Learning outcome

- The scholars should develop critical skills in conducting systematic and objective research by using robust methods while minimising biases and errors
- The students should intelligently choose and apply advanced methods and tools at every stage of research and execute them in a objective way by managing the actors and processes effectively
- The students should develop expertise in designing tests, scales and indexes along with other tools to measure the socio-psychological processes at individual, group and community levels

X. Suggested Reading

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I. Course Title : Technology Commercialisation And Incubation

II. Course Code : EXT 603

III. Credit Hours : 2+1

IV. Why this course?

The technology commercialisation and incubation is an emerging area which links technology development, transfer and commercialisation processes with entrepreneurship development. Technology commercialisation aims to realize the value of agricultural technologies developed at the research establishments, by maximising their utility to stakeholders. With the increasing awareness of protecting and commercialising the Intellectual Property Resources (IPR) in the free market economy, there is a need to understand the organic relationship between protection and commercialisation IPR, and entrepreneurship development.

V. Aim of the course

This course is aimed to develop a critical understanding among extension students about how the technology commercialisation process is linked to IPR management and entrepreneurship development.

The course is organized as follows:

No	Blocks	Units
1.	Technology commercialisation and the modern context	1. Basics of Technology Commercialisation 2. Nature of Agricultural Technology 3. Basics of Technology Transfer and Commercialisation
2.	Intellectual Property Resources (IPR) Management	1. Overview of Intellectual Property Resources 2. Systems for protecting IP 3. Management of IPR 4. Protection and Management of Biological Resources 5. Protection, Management and Commercialisation of Grass root and Farmers Innovations, Traditional and Indigenous Knowledge 6. Geographical Indications (GI) and Appellation of Origin 7. Genetically Modified Organisms (GMO), Agriculture and Biosafety
3.	Technology commercialisation	1. Technology Assessment and Refinement 2. Technology Valuation 3. Technology Commercialisation Strategies 4. Scaling up of Technologies 5. Technology Licensing 6. Technology Takers and Entrepreneurship 7. Policy Support for Technology Commercialisation and Entrepreneurship Development
4.	Technology Incubation	1. Basics of Technology Incubation 2. Technology Incubation in India
5.	Technology promotion and essential skills for technology commercialisation	1. Technology Promotion 2. Dealing with Entrepreneurs, Agripreneurs and Other Stakeholders
6.	Emerging approaches in technology commercialisation and incubation	1. Technology Scouting

VI. Theory

Block 1: Technology Commercialisation and the Modern Context

Unit 1: Basics of technology commercialisation

Technology - Definition, functions, process of technological advancement – invention, discovery, innovation and technology; types of innovation - Basic research, Breakthrough innovation, Disruptive Innovation and Sustaining Innovation; Technology transfer and commercialisation

Unit 2: Nature of Agricultural Technology

Agricultural technology – meaning, types; technology generation system; technology life cycle

Unit 3: Basics of Technology transfer and commercialisation

Technology transfer Vs Commercialisation; Technology commercialisation process – elements, models, systems and processes; Technology transfer model – research, disclosure, development and commercialisation

Block 2: Intellectual Property Resources (Ipr) Management

Unit 1: Overview of Intellectual Property Resources

Introduction to IPR; Overview & Importance; Genesis; IPR in India and IPR abroad; Patents, copyrights, trademarks & trade secrets, geographical indication, industrial design; Emergence of IPR Regimes and Governance Frameworks - Trade-Related Aspects of Intellectual Property Rights (TRIPS), Convention on Biological Diversity (CBD), Cartagena Protocol, International Union for Protection of New Plant Varieties (UPOV), and BIMSTEC.

Unit 2: Systems for Protecting IP

IPR protection laws and systems – National IPR Policy; and IPR laws; procedures for filing IP protection; Systems of IP protection and management in agricultural universities and research institutions and also by stakeholders

Unit 3: Management of IPR

Mechanisms of IPR Management – Institutional arrangement, IP Management processes – invention disclosure; IP portfolio management; Infringement management

Unit 4: Protection and Management of Biological Resources

Introduction; National Biodiversity Act (2002); Protection of Plant Varieties and Farmers Rights Act (2001); Guidelines for registration and transfer of biological resources; Farmers rights; Mechanisms of documenting/ collecting, protecting and commercialising farmers varieties and other biological resources; National Biodiversity Authority, PPVFRA and other agencies involved in management of biological resources in India. Access to Genetic Resources and Sharing of Benefits

Unit 5: Protection, Management and Commercialisation of Grassrootand Farmers Innovations, Traditional and Indigenous Knowledge

Traditional and Indigenous Knowledge, Grassroot and Farmers Innovations – Meaning, forms and importance; Systems of documentation, registration, protection and commercialisation. Documentation of traditional indigenous knowledge - Traditional Knowledge Digital Library (TKDL), Community Biodiversity Registers

(CBRs), People's Biodiversity Registers (PBRs), Plant Biodiversity Register, and Honeybee Network.

Unit 6: Geographical Indications (GI) and Appellation of Origin

Geographical indications and appellation of origin – meaning, origin; Geographical Indications of Goods (Registration and Protection) Act (1999); Documentation, registration and commercialisation of GI protected materials and processes.

Unit 7: Genetically Modified Organisms (GMO), Agriculture and Biosafety

The Global Concerns on Use of Genetically Modified Organisms in Food and Agriculture; The Cartagena Protocol on Bio-safety; Regulation of GMO in India - Recombinant DNA Advisory Committee (RDAC), Institutional Bio-safety Committee (IBSC), Review Committee on Genetic Manipulation (RCGM), Genetic Engineering Approval Committee (GEAC), State Bio-safety Coordination Committee (SBCC) and District Level Committee (DLC). Laws and Acts for regulation of GMO - Guidelines for Research in Transgenic Plants, 1998; Seed Policy, 2002; Plant Quarantine Order, 2003; Regulation for Import of GM Products Under Foreign Trade Policy, 2006; National Environment Policy, 2006

Block 3: Technology Commercialisation

Unit 1: Technology Assessment and Refinement

Meaning; Importance; Approaches and methods of assessment and refinement of various technologies – stakeholder oriented approaches including participatory technology assessment and refinement; assessment and refinement of traditional and indigenous knowledge and grassroot innovations

Unit 2: Technology Valuation

Returns to investment; IP Valuation-Oxford context, IP Valuation methods - Cost approach; Income approach - Discounted Cash Flow, Risk-Adjusted Net Present Value, Net Present Value with Monte Carlo Simulation and Real Options Theory; Market approach - Industry Standards Method, Rating/Ranking Method, Rules of Thumb Approach and Auction Method; Hybrid approaches; Royalty rate method

Unit 3: Technology Commercialisation Strategies

Meaning- approaches for technology commercialisation – technology scaling up, technology licensing, handholding, agripreneur development, technology business incubation

Unit 4: Scaling up of Technologies

Meaning, types and stages of technology scaling up; mechanisms

Unit 5: Technology Licensing

Meaning and types - Procedures of licensing, preparing licensing documents; Management of technology licensing process

Unit 6: Technology Takers and Entrepreneurship

Meaning; types of technology takers; Technology Taking as a Strategy; Types of entrepreneurship – agripreneurs, startups, small businesses, Producer Organizations, Self Help Groups, Clusters and other forms of entrepreneurship

Unit 7: Policy support for Technology Commercialisation and Entrepreneurship Development

Policy support for entrepreneurship development in India - National Policy on Skill

Development and Entrepreneurship and other polices; Government of India Support for Innovation and Entrepreneurship – Startup India, Make in India, Digital India, Atal Innovation Mission and others; Entrepreneurship policy and schemes at different states of India; Organisations promoting entrepreneurship in India

Block 4: Technology Incubation

Unit 1: Basics of Technology Incubation

Meaning, functions and types; stakeholder oriented incubation process – Livelihood incubation, village incubators

Unit 2: Technology Incubation in India

System of technology incubation- incubation process; its effectiveness; Managing profit oriented and non-profit incubators; Schemes for promoting incubators in India

Block 5: Technology Promotion And Essential Skills For Technology Commercialisation

Unit 1: Technology Promotion

Technology promotion – meaning, types, business meetings, scientist-industry/ entrepreneur meets, technology conclave, business plan competition, farmers fairs, technology shows

Unit 2: Dealing with Entrepreneurs, Agripreneurs and Other Stakeholders

Business communication; Business Etiquette; business networking

Block 6: Emerging Approaches in Technology Commercialisation and Incubation

Unit 1: Technology Scouting

Technology Scouting and Innovations in technology incubation

VII. Practicals

- Understanding the technology commercialisation process – Visit to Technology Commercialisation Unit of ICAR Institute/ Agricultural University
- Understanding the IPR protection practices – Visit to Patent Attorney office
- Hands-on experience in drafting IPR application – Patent/Copyright/ Trademark
- Understanding protection of biological resources including plant varieties – Visit to PPVFRA Branch office/ ICAR Institute or Agricultural University involved in plant variety protection
- Documenting Traditional and indigenous knowledge – Field experience in using various protocols of using traditional and indigenous knowledge
- Protecting unique local goods through Geographical Indications – Hands on experiences in documenting and registering Geographical indications
- Technology assessment/ validation of traditional and indigenous knowledge – QuIK and other methods
- Hands on experience in technology valuation
- Hands on experience in technology licensing process including drafting agreements
- Understanding the Technology Business Incubation – Visit to Agri Business Incubator or Technology Business incubator
- Hands on experience in planning and organising technology promotion events

- Hands on experience in various techniques in business communication and Business etiquette

VIII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Group Presentation

IX. Learning outcome

At the end of the course the students are expected to develop competencies in:

- Enabling stakeholders to protect and manage their IPR
- Managing IPR to maximise their value realisation through commercialisation, and
- Providing mentoring and handholding support to agripreneurs, rural entrepreneurs, start-ups, Farmer Organisations and other forms of entrepreneurs through incubation

X. Suggested Reading

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I. Course Title : Educational Technology and Instructional Design

II. Course Code : EXT 604

III. Credit Hours : 2+1

IV. Why this course?

Technology, digital media and mobile access have drastically changed how people learn. And the field of education is rapidly becoming a dynamic opportunity for interactive instruction. Today's curriculum developers and instruction designers, especially in the extension and RAS ecosystem, need to equip themselves with the continuous developments in both theory and practice of instructional design so as to create satisfying learning experiences. Similarly, knowledge and skilful use of social media and disruptive technologies like internet of things (IOT), augmented reality, artificial intelligence, etc. makes this course essential for extension professionals who are expected to act as harbingers of change.

V. Aim of the course

The aim is to develop knowledgeable, responsive and effective teachers committed to educating diverse group of learners in a dynamic extension landscape. This course will help the learners to appreciate the role of technology in learning and how it can be integrated into instructional design to create engaging learning experience in both classroom and online learning environment. The course also aims to prepare the students as competent professionals employable in the extension and RAS providers both as specialised researchers as well as designers.

The course is organized as follows:

No	Blocks	Units
1.	Educational Technology	1. The Landscape of Educational Technology and Instructional Design 2. Theories of learning 3. Technology Enabled Learning
2	Instructional Design	1. Theories of Instruction 2. Creating Instruction 3. Instructional Strategies 4. Evaluating Instruction 5. Trends in Instructional Design

VI. Theory

Block 1: Educational Technology

Unit 1: The Landscape of Educational Technology and Instructional Design

Understanding various terms - educational technology, instructional design, instructional systems design, curriculum design, pedagogy, andragogy; Brief overview of the origin and evolution of ET and ID as theory and practice; what is the relevance of ET and ID relevant in extension and rural advisory services? Extensional professionals as instructional designers and architects of the learning experience

Unit 2: Theories of Learning

What is learning? Critical overview of Behaviorism, Cognitivism, Constructivism and Complex learning theories; instructional designers and learning theories; Types of learning or learning domains- Bloom's taxonomy of the cognitive domain, Krathwohl and Bloom's affective domain and Simpson's psychomotor domain

Unit 3: Technology Enabled Learning

What is the role of technology in education? Digital media, new tools and technology; Open and distance Learning (ODL); Online Education - Synchronous and Asynchronous learning models; eLearning, Massive Open Online Courses - SWAYAM, Open Education Resources (OERs), Course CERA, EduEx, CoL, RLOs; digital education and its applications in higher agricultural education; Smart classrooms and Campuses, Web-based remote laboratory (WBRL); Integrating media and digital tools into ID; types and implications of disruptive technologies for higher education and extension; Augmented learning; Adaptive learning; meaning, features and good practices in using open source Learning Management Systems (Moodle); Quality assurance and certification in e-learning.

Block 2: Instructional Design

Unit 1: Theories and Models of Instruction

Howard Gardner's Theory of Multiple Intelligences, David Kolb's Experiential Learning Cycle, Albert Bandura's Social Learning Theory, Rand Spiro's Cognitive Flexibility Theory and Its Application In eLearning, Wlodkowski's Motivational Framework for Culturally Responsive Adult Learning; ADDIE Model, Dick and Carey Model, SAM Model, Bloom's Taxonomy; integrating the theories of instruction into the practice of ID in extension and RAS ecosystem.

Unit 2: Creating Instruction

Overview of planning, designing and implementing the curricula and learning experiences; Needs Analysis - meaning, approaches and steps; Task and content analysis - meaning, approaches, steps and techniques (topic analysis, procedural analysis, and the critical incident method); Learner analysis – meaning, importance and approaches, relevance of Maslow's Hierarchy of Needs and learning styles, Captive Audience vs. Willing Volunteers, Universal vs. user-centered design, Learner Analysis Procedures; Writing learning objectives: Meaning of Learning Goal and Learning Objectives; ABCDs of well-stated objectives; Setting goals, translating goals into objectives; Contextualising ADDIE process within the Extension learning environment

Unit 3: Instructional Strategies

Organizing content and learning activities - scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, programmed instruction, synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies

Unit 4: Evaluating Instruction

Meaning of Assessment, Measurement and Evaluation; Developing learner evaluations and their reliability & validity; assessment techniques for measuring change in knowledge, skill and attitude of learners - Objective Test Items, Constructed-Response Tests, Direct Testing, Performance Ratings, Observations and Anecdotal Records, Rubrics, Portfolios, Surveys and Questionnaires, Self-Reporting Inventories, Interviews; Conducting learner evaluation pre-, during and post-instruction; Formative and Summative Evaluation- meaning, approaches and steps; Evaluating Learner Achievement and the Instructional Design Process; Evaluating the success of instruction; Performance appraisal of teachers

Unit 5: Trends in Instructional Design

Alternatives to ADDIE model - Rapid prototyping and constructivist ID, reflections on instructional design as science and as an art; Relating ID models and process in extension learning environment; political economy of higher education in developed and developing countries; University assessment and rating methods, returns from agricultural higher education; research in education and instructional design.

VII. Practicals

- Exercises on preparation of the Analysis Report that includes the task/content

analysis and learner analysis and the Design Plan includes learning objectives and corresponding instructional strategies and assessment items
- Prepare course outline and lesson plan with an appreciation for diverse learning styles based on temperament, gender, and cultural/ethnic differences and deliver a lecture for UG/PG students
- Assessing learning styles through Barsch and Kolb inventories
- Development and testing of survey instruments for evaluating learning outcomes/ competencies of students
- Development and testing of survey instruments for performance appraisal / competency assessment of teachers.
- Design an online e-learning module on a topic of interest as a capstone project - integrate and apply the knowledge and skills gained from the course for creating an effective learning experience for a target audience
- Designing and developing a theme based knowledge portals
- Exercises on designing an online course using open source LMS like moodle or EdX
- Select and evaluate or design for social al media
- Prepare a short research paper on recent theories and models of instructional design
- Interview an instructional designer of your choice and prepare a synthesis report about what job roles he/she perform, What ID processes does he or she use, challenges faced
- Develop a prototype for one of the lessons in your design plan using PowerPoint or a website builder such as Weebly to create the screens integrating multimedia content and various functionalities
- Field visit to a virtual learning / augmented learning labs, e-learning labs, distance learning centres, etc.
- Hands-on practice with video-editing software, web conferencing and video conferencing solutions

VIII. Teaching methods/activities

– Lectures & Videos
– Individual and group assignments
– Group discussion and debating
– Enactive learning exercises
– Case studies / Case analysis
– Storyboarding
– Guest Lectures
– Field Visits
– Capstone Project
– Prototype development

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop a critical understanding of concepts of learning and education within the context of agricultural development
– Relate and apply learning theories and models to the development, design and evaluation of courses utilizing educational technology and instructional design
– Hone their skills to take up research work in analysing and evaluating different

learning systems, teaching-learning environments, competencies and learning outcomes
- Find placement opportunities in the industry for job profiles such as e-learning specialist, training officer, curriculum developer, instructional designer, education consultant, etc.

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GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. Course Title : Risk Management and Climate Change Adaptation

II. Course Code : EXT 605

III. Credit Hours : 2+1

IV. Why this course?

Present agriculture and allied sectors India face tremendous challenges on multiple fronts. Agrarian distress and the climate change impacts together pose grave dangers to food, nutritional and ecological security. As change agents, extensional professionals in particular and agricultural graduates in general need to quip themselves with knowledge and skill sets required to navigate the climate change scenario so as to help reduce risk and vulnerability. Hence, this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of risks management and climate change adaptation with reference to Indian agriculture. This course will approach the subjects from a multidisciplinary

perspective - technical, socio-economic, political, financial, and regulatory. It aims to equip students to identify, evaluate and evolve ways to address (mitigate and manage) risks and climate change.
The course is organized as follows:

No	Blocks	Units
1	Risk Management in Agriculture	1. Understanding Risk and Distress 2. Managing Risk and Distress in Agriculture 3. Extension Professionals and Risk management
2	Adapting to Climate Change	1. Introduction to Climate Change Science 2. Introduction to Climate Change Adaptation and Mitigation 3. Climate Smart Agriculture and Extension Advisory Services

VI. Thory

Block 1: Risk Management in Agriculture

Unit 1: Understanding Risk and Distress

Introduction to risk, risk management, uncertainty, sensitivity and distress, General risk theory, Risk analysis methods, Risk perception and decision making, Indicators of risk and distress in agriculture – identification, selection and assessment, Understanding the agrarian distress in Indian agriculture, Sources of distress in Indian farming -changing farm size, land use, cropping patterns, pricing policy, markets and terms of trade, Typology of crisis in agriculture; Droughts, floods and Indian agriculture, Distress and farmer suicides - causes and socio-economic consequences

Unit 2: Managing Risk and Distress

Ways to reducing/managing risk and distress in Indian agriculture; crop and life insurance; Developing support systems; Planning, implementation and evaluation of risk/distress management programs; Institutional frameworks for risk and disaster management - NDMA & SDMAs; Developing District Agriculture Contingency Plans; Risk management by diversification; Good practices and lessons from other countries; Responses of government, non-government and extension system to agrarian crisis; National Farmers Policy.

Unit 3: Extension Professionals and Risk management

Understanding social-psychological and behavioural dimensions of farmers under risk/distress; Risk perception and communication; Helping farmers manage farm level risks - mobilising resources, linking with markets, strengthening capacities; Working with village level risk management committees; Operational skills for preparing contingency and disaster management plans; Institutional and extension innovations in managing risk and distress; Policy and technological preferences for dealing with drought and flood.

Block 2: Adapting to Climate Change

Unit 1: Introduction to Climate Change Science

Basic concepts of and terms in climate change science; impacts of climate change;

anthropogenic drivers of climate change, Climate change and Indian agriculture; climate adaptation vs. disaster risk reduction; anticipated costs of adaptation; climate change and poor; Overview of UNFCCC framework and institutions, Kyoto Protocol and beyond; India's National Action Plan on Climate Change and National Mission on Strategic Knowledge on Climate Change; National Coastal Mission, Institutional arrangements for managing climate change agenda.

Unit 2: Introduction to Climate Change Adaptation and Mitigation

Introduction to Climate Change Adaptation, Conducting a vulnerability assessment (CVI and SEVI frameworks), Identifying and selecting adaptation options; Global, national and state level initiatives and plans to support climate change adaptation, private sector and civil society initiatives and activities; Mainstreaming climate change adaptation into development planning, Financing climate adaptation and budgetary allocations for programmes, Gender and climate change adaptation, Agricultural development programmes and strategies towards climate change adaptation and mitigation, Community based and Ecosystem based adaptation strategies, preparing evidence based intervention plans for vulnerability reduction at micro and macro-levels.

Unit3: Climate Smart Agriculture (CSA) and Extension &Advisory Services

Climate smart agriculture; Developing climate smart and climate resilient villages; Stakeholders and determinants involved in climate smart agriculture; Climate smart agriculture and EAS; Innovative extension approaches used in CSA; Climate information services, Farmers perceptions about climate change; Farm and household level manifestations and adaptation strategies; Barriers and limits to adaptation; Farmers feedback on performance of extension methods; Skills, competencies and tools required for extension professionals at different levels and development departments in up scaling CSA.

VII. Practicals

- Hands-on practice in using risk assessment/analysis tools
- Case studies on risk / distress assessment in agriculture -Indian and global
- Lessons / Experiences from NICRA Project in agriculture and allied sectors
- Developing criteria, indicators and indices for assessment of risk, vulnerability and resilience
- Hands on practice on use of vulnerability and risk assessment tools and techniques
- Case studies on success stories of climate change adaptation and community based initiatives
- Developing district and village level intervention plans for climate change adaptation
- Field Visits to State Disaster Management Authority
- Case studies on climate smart agriculture / villages from India and world
- Case studies on impact assessment of crop insurance programs, disaster management programs
- Capstone project on documenting ITKs and local practices related to reducing risk / climate resilience agriculture

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review

– Student presentation
– Group Work
– Student's interview of key policy makers
– Case Analysis and case studies Guest Lectures
– Review of policy documents

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Appreciate the scientific foundation of risk management and climate change science and relate the key learning to the job of an extension professional
– Utilise methods and tools for risk and climate related vulnerability assessments and adaptation strategies in the context of Indian agriculture / farming scenario
– Utilise material in scientific publications relevant for risk management and climate change adaptation and critically reflect on their benefits and limitations for decision making

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http://siteresources.worldbank.org/Globalenvironmentfacilitygefoperations/Resources/Publications-Presentations/GEFAdaptationAug06.pdf

Websites

CSA-Centre for Sustainable Agriculture– http://csa-india.org/

GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

AESA-Agricultural Extension in South Asia– http://www.aesanetwork.org/

NICRA-National Innovations in Climate Resilient Agriculture–
http://www.nicra-icar.in/nicrarevised/

CRIDA-Central Research Institute for Dryland Agriculture– http://www.crida.in/

UNCC: Learn- UN Climate Change Learning Partnership– https://www.uncclearn.org/

DST- Department of Science and Technology- Climate Change Programme, GoI–
http://www.dst.gov.in/climate-change-programme

I. Course Title : Livelihood Development

II. Course Code : EXT 606

III. Credit Hours : 1+1

IV. Why this course?

One of the aims of extension work is to enhance and expand the sustainable livelihood opportunities for individuals in a society. For this a thorough understanding of the different aspects of livelihood and its interface with nature becomes imperative. Resource poor farmers and the socially and politically weaker sections of the society currently face several challenges in expanding their livelihoods. Keeping these in view, the course has been designed to provide a theoretical framework for understanding of the basic concepts, definitions and approaches related to 'livelihood', 'vulnerability' 'institutional processes', and 'development and policies' pertaining to livelihood development in India.

V. Aim of the course

- To develop an understanding on the concept of livelihood and its various forms
- To acquaint the students regarding the various alternative approaches that has been adopted to support livelihoods
- To familiarize the students to some of the methods, tools and techniques they can utilize to design livelihood interventions
- To expose the students to the context, especially the economic models and policy environment that guides the livelihood choices
- To equip students to work in multidisciplinary teams and engage at multiple levels on livelihood issues

The course is organized as follows:

No	Blocks	Units
1.	Understanding of Livelihood	1. Concept of Livelihoods 2. Livelihood Challenges
2.	Livelihood Analysis	1. Livelihood Frameworks 2. Designing Livelihood Intervention and Promotion
3.	Livelihood Augmentation	1. Pathways for LA

VI. Theory

Block 1: Understanding of Livelihood

Unit 1: Concept of Livelihoods

Basic concepts of livelihood and Development, Types of development-Immanent/ inherent and interventionist/ intentional; Why promote livelihood; Livelihood intervention: definition, types-Spatial, segmental, sector –sub-sector; Systemic view of Livelihoods, Understanding Rural Livelihoods-Farm, Non-Farm, and off farm; Linkages with Farm and Off-farm Livelihoods; Economic Models

Unit 2: Livelihood Challenges

Livelihood Challenge- Political economy of Livelihoods, Issues of access to farm and non-farm livelihoods; Livelihoods from a Gender Perspective-Feminization of agriculture/ poverty, women in the unorganized sector, the issue of unpaid and informal work; Livelihood Coping Mechanism- Climate Change and Livelihoods; Livelihoods and Disasters

Block 2: Livelihood Analysis

Unit 1: Livelihood Frameworks

Sustainable Livelihoods Approaches (SLAs)-Definition and origins of SLA; Assets or capitals and capabilities in SLA and its linkage to the other capitals: Physical, Social, Economic, Human, Natural; Vulnerability Assessment- Shocks, trends, seasonality; Policies, institutional context and processes; Conceptual Frameworks-DFID, CARE, UNDP, OXFAM, BASIX livelihood triad, Nine square Mandala or Rural Livelihood System's Framework, etc.; Past, Present and possibilities for the future of the SLA, critiques of the approach

Unit 2: Designing Livelihood Intervention and Promotion

Designing a suitable livelihood intervention-Observing and Understanding the Local Economy; Selecting livelihood activities suitable for the poor in the area; Deciding on the interventions. Livelihood promotion approaches-Poverty and livelihood: Approaches and programs in India; Livelihood and a Rights Based Approach-MGNREGA and its critique; Livelihood and a Social Capital based approach: NRLM

Block 3: Livelihood Augmentation (LA)

Unit 1: Pathways for LA

Basic concepts; Pathways: a) Entrepreneurial strategies for LA; b) NRM based intervention; c) Market based interventions including Value-chain analysis; d) ICT based interventions; e) Livelihood and allied agriculture (dairy, poultry, Goatery, etc.) based livelihood; f) Forest based Livelihoods vis a vis Livelihood Protection and Promotion: Contribution of NTFP in supporting rural livelihoods
Note: Block 'A' and 'B' is theoretical; Block 'C' should be covered in the form practical's supported by few classroom discussion through cases

VII. Practicals

- Village stays to understand the livelihood pattern of villagers and how the other socio-economic factors affect the livelihood of people
- Visit to institutes/ universities adopted and/or nearby villages to experience the life and natural resources in rural communities-understanding of village culture, evolution, social structure, livelihood pattern, trends, governance arrangements, and the natural context (landscape layout, land use, vegetation types etc)
- Application of participatory rural appraisal skills for understanding village context; Engagement of working with rural communities and their grass-root institutions, understanding dynamics of working in a group
- Visit to different agri-business models as mentioned in the Block 'C'. Group assignments may be given to document the field experience in the form of case study of an enterprise/ entrepreneur/ members and other related stakeholders

VIII. Teaching methods/activities

– Interactive Lectures – by sharing in advance a reading material
– Analysis of case studies
– Audio-visual of successful/ failure models of agribusiness firms
– Guest session by field practitioners, if possible

– Group presentations by the students
– Field visit and field based individual or group assignments

IX. Learning outcome

This course will equip students with perspectives, knowledge and skills to develop a comprehensive understanding of the livelihood concepts, various forms, approaches, tools and techniques to analyze existing livelihood pattern and strategies the sustainable livelihood intervention in the rural areas.

X. Suggested Reading

Anonymous. 2010. *State of India's Livelihood Report.* Edited by Sankar Datta and Vipin Sharma. Sage Publications, New Delhi.

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Desai RM and Joshi S. 2014. *Can Producer Associations Improve Rural Livelihoods? Evidence from Farmer Centres in India,* The Journal of Development Studies, 50 (1): 64-80.

Ellis F. 2012. *Rural Livelihoods and Diversity in Developing Countries*, Oxford.

Mahajan V, Datta S and Thakur G. 2009. *A Resource Book for Livelihood Promotion, The Livelihood School,* BASIX, Hyderabad.

Morse S and McNamara N. 2009. *Sustainable Livelihood Approach: A critique of theory and practice,* Springer Science. (Chapter 2)

Pastakia A and Oza S. 2011. *Livelihood Augmentation in Rainfed Areas: A Strategy Handbook for the Practitioner*, Development Support Centre, Ahmedabad.

Scoones Ian. 1998. *Sustainable Rural Livelihoods: A Framework for Analysis*, IDS Working Paper 72.

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I. Course Title : Facilitation for People Centric Development

II. Course Code : EXT 607

III. Credit Hours : 2+1

IV. Why this course?

The prime aim of the agricultural extension professionals is to influence development change among the stakeholders with whom they work. In the Agricultural Innovation Systems (AIS) context, this change will happen when good relationships, networks and partnerships are formed. A new extension approach that aims at participatory and group learning as well as networking, where the extensionist acts as a facilitator is needed. It is important to inculcate the good facilitation skills by the extension professional to increase the effectiveness and impact among the agricultural extension and advisory services stakeholders.

V. Aim of the course

- To orient students on the importance facilitation
- To inspires students to understand facilitation tools to influence change at the individual, group and organisational levels
- To develop capacities in multi-stakeholder engagement, facilitation and networking

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Facilitation for Development	1. Facilitation for Development in the AIS 2. Principles, Attributes and Skills for Facilitation for Development
2.	Facilitating change in individuals, groups and organizations	1. Realise Potential- Self-Discovery 2. Group Dynamics and Working Together 3. Organizational Change Process
3.	Facilitating operational level multi-stakeholder engagements	1. Multi-Stakeholder Interactions 2. Innovation and Policy Engagement Platforms
4.	Brokering strategic partnerships, networking and facilitation	1. Linkages, Partnerships, Alliances and Networking 2. Facilitating Capacity Development

VI. Theory

Block 1: Introduction to Facilitation for Development

Unit 1: Facilitation for development in the AIS

Facilitation for development in the AIS; Understanding facilitation for development; Importance of facilitation as a core function of extension within the Agricultural Innovation Systems (AIS)

Unit 2: Principles, Attributes and Skills for Facilitation for Development

Basic principles of facilitation for development; Desired attributes of facilitator for development- Cognitive attributes, Emotional attributes (Emotional intelligence), Social, behavioural and attitudinal attributes; Technical skills of a facilitator for development- Design processes, Facilitation techniques and tools, the art of questioning and probing, Process observation and documentation, Visualisation

Block 2: Facilitating Change in Individuals, Groups and Organisations

Unit 1: Realise Potential- Self-Discovery

Self-discovery to realise our potentials, Tools for self-discovery, formulating a personal vision, Taking responsibility for your own development

Unit 2: Group Dynamics and Working Together

Understanding the dynamics of human interaction, Group dynamics and power relations, Managing relationships, Shared vision and collective action, Tools for team building

Unit 3: Organizational Change Process

Organizational change process, Organizational learning to adapt to changing environments, Enhancing performance of organizations, Leadership development, Tools for organizational change

Block 3: Facilitating Operational Level Multi-stakeholder Engagements

Unit 1: Multi-Stakeholder Interactions

Defining stakeholders, Development of collective and shared goals, Building trust and accountability, Tools for stakeholder identification and visioning

Unit 2: Innovation and Policy engagement Platforms

Visualising innovation platforms (IPs), Why are IPs important?, Different models of IPs for multi-stakeholder engagement, policy engagement platforms, Generating issues and evidence for policy action, Advocacy for responsive policy processes

Block 4: Brokering Strategic Partnerships, Networking And Facilitation

Unit 1: Linkages, Partnerships, Alliances and Networking

Brokering linkages and strategic partnerships, Identification of critical links, Knowledge brokering, Creating linkages with markets, Learning alliances and networking, Coordination of pluralistic service provision within the AIS, The concept of action learning and reflective practitioners, Networking

Unit 2: Facilitating Capacity Development

Facilitating Capacity Development-Facilitate participation and learning in development programs and projects. Virtual platforms- skills for strengthening dialogue, collaboration, shared commitment amongst diverse actors and stakeholders

VII. Practicals

- Practicing facilitation techniques,
- Self discovery exercises,
- Working together and interaction (task based),
- Arrangement for multi-stakeholder interactions,
- Understanding organisational change process tools and techniques,
- Case analysis on organisational change process,
- Participating with innovation platforms,
- Policy engagement platforms,
- Stakeholder analysis mapping,
- Exercise on networking skills,
- Facilitating capacity building programmes
- Facilitating virtual platforms
- Filed visit to multi-stakeholder partnership projects

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Facilitation Manual/Publication Review
- Student presentation
- Group Work
- Student's interview with facilitators
- Case Analysis
- Guest Lectures
- Review of facilitation methodologies
- Short internships

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of facilitation skills and tools
- Understand facilitation and networking techniques
- Critically evaluate strategic partnerships and linkages
- How to manage group dynamics and engage multi-stakeholders and virtual platforms

X. Suggested Reading

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Koutsouris A. 2012. *Exploring the emerging facilitation and brokerage roles for agricultural extension education.* AUA Working Paper Series No. 2012-4. Agricultural University of Athens. Department of Agricultural Economics & Rural Development.
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http://www.thepoultrysite.com/articles/3494/innovation-in-layer-housing-from-drawing-board-to-reality/

Lindy norris. *How to Develop Your Personal Vision Statement: A Step-by-Step Guide to Charting Your Future with Purpose and Passion.*
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http://documents.worldbank.org/curated/en/564521467995077219/pdf/103509-BRI-PUBLIC-ADD-series-ILAC-brief.pdf

Makini FW, Kamau GM, Makelo MN, Adekunle W, Mburathi GK, Misiko M, Pali M, and Dixon J.2015. *Operational Field Guide for Developing and Managing Local Agricultural Innovation Platforms.* Australian Centre for International Agricultural Research.
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Villet, V V. 2015. *Motivation Theory by David McClelland.* https://www.mindtools.com/pages/article/human-motivation-theory.htm

Websites

- **MSU**–Michigan State University Extension Facilitation– https://www.canr.msu.edu/facilitation/
- **TAPipedia**– Tropical Agriculture Platform– https://www.tapipedia.org/
- **CGSpace**- A Repository of Agricultural Research Outputs by CGIAR– https://cgspace.cgiar.org/handle/10568/33667
- **UMaine**– The University of Maine– https://extension.umaine.edu/community/strengthening-your-facilitation-skills/
- **GFRAS**– Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. Course Title : Multivariate Statistical Methods For Extension Research

II. Course Code : STAT

III. Credit Hours : 2+1

IV. Why this course?

With increasing complexity in agricultural systems, research problems in extension are becoming multi-dimensional and often influenced by the composite of biological, social and economical factors. Such complex problems require advanced analytical methods and tools derived from statistical and other decision sciences.

V. Aim of the course

This course aims to equip the students with critical skills in choosing appropriate analytical tools and interpreting the results for solving complex and multidimensional extension research problems.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Multivariate Statistical Methods	1. Basics of Multivariate Statistical Methods (MVSM) 2. Classification and Types of MVSM 3. Selecting Appropriate MVSM 4. A structured Approach for Building Multivariate Statistical Models 5. Basic Econometric Methods-1 6. Basic Econometric Methods-2
2.	Data preparation and cleaning	1. Missing Data Analysis and Outlier Management 2. Testing Assumptions of MVSM and Data Transformation
3.	Methods for assessing human choice/ preferences and decision-making	1. Assessing Human Preference Structures Using Conjoint Analysis 2. Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models 3. Multidimensional Scaling 4. Multi-criteria Decision-making
4.	Methods of assessing association and causality	1. Multiple Correlation and Multiple Regression 2. Discriminant Analysis
5	Methods of grouping objects/ variables based on latent variables	1. Principal Component Analysis (PCA) and Common Factor Analysis 2. Structural Equation Modeling (SEM)–Two units 3. Cluster Analysis
6	Emerging MV statistical methods	1. Emerging MV Statistical Methods

VI. Learning outcome

At the end of this course, the students will be able – To choose appropriate multivariate statistical methods based on research problem/ situation – To design, implement and interpret in a skilful way using SPSS

VII. Theory

Block 1: Overview of Multivariate Statistical Methods

Unit 1: Basics of Multivariate Statistical Methods (MVSM)

What is multivariate data analysis; Basic concepts in MV – variate, measurement error; Power analysis and effect size; SPSS software

Unit 2: Classification and Types of MVSM

Independence and dependence techniques; Factor analysis – principal component, exploratory factor analysis; Multiple correlation and multiple regression; Discriminant analysis; Logistic regression; Cluster analysis; Conjoint analysis; Multi Dimensional Scaling/ Perceptual mapping; Correspondence analysis; Structural equation model

Unit 3: Selecting Appropriate MVSM

Selection based on purpose - Dimension reduction, identifying latent variables, strength of relationship among multiple dependent/ independent variables, identifying choice and estimating their utility; etc and type of variables – metric and non-metric

Unit 4: A Structured Approach for Building Multivariate Statistical Models

Steps in planning and conducing MVSM

Unit 5: Basic Econometric Methods-1

Nature of regression analysis; Two variable and multivariable regression models; Linear and non-linear regression models; Estimation methods

Unit 6: Basic Econometric Methods-2

Simultaneous-equation models; Panel data models; **Forecasting** - Time series and other models

Block 2: Data Preparation and Cleaning

Unit 1: Missing Data Analysis and Outlier Management

Missing data - Meaning, types, methods of missing data processing, advantages and limitations, **Outliers-** Meaning, types, methods for identifying and managing outliers

Unit 2: Testing Assumptions of MVSM and Data Transformation

Testing assumption of parametric analyses – normality, linearity, multicollinearity; Data transformation methods

Block 3: Methods for Assessing Human Choice/ Preferences and Decision-making

Unit 1: Assessing Human Preference Structures Using Conjoint Analysis

Meaning- Importance, guidelines for selecting variables, steps in designing a conjoint experiment – objectives, design, data collection and analysis. Applications in extension

Unit 2: Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models

Meaning, importance, types – logit, probit and tobit and their variations; steps in analysis and interpretation of results, applications in extension

Unit 3: Multidimensional Scaling

Meaning, importance and types, steps and applications in extension

Unit 4: Multi-criteria decision-making

Meaning, importance, methods – analytical hierarchy process, Applications in extension

Block 4: Methods of Assessing Association and Causality

Unit 1: Multiple Correlations and Multiple Regressions

Meaning, importance, types, methods of estimation, analysis and interpretation of results, application sin extension

Unit 2: Discriminant Analysis

Meaning, types, steps in conducting discriminant analysis, Applications in extension

Block 5: Methods Of Grouping Objects/ Variables Based On Latent Variables

Unit 1: Principal Component Analysis (PCA) and Common Factor Analysis

Meaning, importance, types of factor analysis, difference between types, steps in conducting PCA/ Common Factor Analysis, applications in extension

Unit 2: Structural Equation Modelling (SEM) – Two units

Meaning, importance, types – confirmatory factor analysis and structural model; steps in conducting SEM, Applications in extension

Unit 3: Cluster Analysis

Meaning, importance, types – Steps; Applications in extension

Block 6: Emerging MV Statistical Methods

Unit 1: Emerging MV Statistical Methods

Canonical correlation, partial least square (PLS)

VIII. Practicals

- Hands on experience of following methods using SPSS/ AMOS software
- Selecting appropriate MVSM
- Missing data analysis and outlier management
- Testing assumptions of MVSM and data transformation
- Assessing human preference structures using conjoint analysis
- Assessment of adoption of agricultural technologies using limited dependent variable models – logit, probit and tobit.
- Multidimensional scaling
- Multiple correlation and multiple regression
- Discriminant analysis
- Principal Component Analysis (PCA) and Common Factor Analysis
- Structural Equation Modeling (SEM)
- Cluster analysis

IX. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work
- Guest Lectures

X. Suggested Reading

Agresti, A. 2002. *Categorical data analysis*. Second edition. New York, NY: John Wiley & Sons.

Belsley, D. A. 1991. *Conditioning diagnostics: Collinearity and weak data in regression*. New York, NY: Wiley.

Bollen, K.A. 1989. *Structural equations with latent variables*. New York: John Wiley and Sons.

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Byrne BM. 2010. *Structural equation modeling with AMOS: Basic concepts, applications, and programming*. New York: Routledge.

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Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agri-Business Management

Preface

Rapid advancement in agriculture has resulted in increased demand for qualified managers to manage this sector. Indian agriculture is facing numerous challenges with a rapidly changing business environment, pace of technological change, globalisation, competitive environment and changing role of government. These challenges will place unparalleled demands on the capabilities of tomorrow's managers. Agribusiness Management has enormous potential to address key national and global challenges of inclusive growth, and food and nutritional security. With increasing incomes, the demand for value added agricultural products will also increase, driving the demand for Agribusiness Managers. Increasing integration of World food markets and the expansion of organized retail also imply that the scope of agribusiness is becoming increasingly global. The Agribusiness Management Education System in India is uniquely placed to meet the demand for professional agribusiness managers across the globe.

Agri business management is a specialized two-year MBA programme which focuses on business aspect of agriculture production and its international trade. The postgraduate course aims to craft professional business leaders and entrepreneurs in food, agriculture and allied sectors. The course is offered in premier business schools in and State Agricultural Universities in India and across the globe and focuses on managerial skill development in the agricultural sector. Students learn how to make sustainable business decisions and minimize risk while working in the agricultural sector. The course curriculum is designed to build and enhance a global perspective among students. The course also needs to create awareness among students about the environmental forces that impact managerial decisions.

In light of the above mentioned issues and concerns, courses and programmes in the field of agri-business management must also be reformed to increase the employability and entrepreneurship opportunities for the Post Graduates and Doctoral participants at the same time prepare them for handling global competitiveness without compromising farmers' and farming community needs and demands.

The sub-committee on Agri Business Management constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept above development in view while revising the PG and PhD Curricula in Agri Business Management. We also addressed the issue of repetitions of content, updating them with the recent trends in the industry, under-graduate curricula in agriculture. To do these, we identified first the core competencies that are required at the different levels and worked backwards based on the areas and organising them into courses.

We are also recommending summer internship-2 at the Master's level (each for 4-6 weeks with agri based organisations) and we propose a credit load of 10 and 4 for each of these internships/ attachments at PG level. We believe this will help the students to have more relevant practical experience and this will boost their job prospects.

We have organised the curriculum under different block and units and each course has an introduction explicitly stating the purpose of this course (why this course), aim of the course (what it tries to provide) and learning outcomes. Several new reading references are also provided at the end of each course. The committee recognised the need for organising training of teachers to impart some of the new courses and this could be further elaborated in consultation with ICAR and other organisations that can support or even lead this exercise.

The committee organised a stakeholders meeting with agri based industry executives, academicians from reputed institutions, alumni from different ABM programmes of the SAUs, teachers involved in ABM teaching in selected SAUs at Bikaner on September 17, 2018 for development of curricula.

Our heartfelt gratitude to all the core committee members and stakeholders for their specific contributions to development of this revised curricula especially Mr Kamal Kumar, Advisor, Dhanuka Agritech Ltd; Dr Vikram Singh, Dean, NIAM, Jaipur; Dr Ranjit Singh, Professor, NAARM; Dr Seema Nath, Associate Dean, College of Agriculture, PJTSAU; Dr Radhika, Associate Professor, PJTSAU; Dr Madhu Sharma, Professor, SKRAU, Bikaner, Dr Swati Sharma, Assistant Professor, Navsari Agricultural University, Navsari; Dr Dinesh Jain, Associate Professor, RAJUVAS, Bikaner and Dr Amita Sharma, Assistant Professor, IABM, Bikaner.

Finally, we thank Dr NS Rathore, Deputy Director General (Education), ICAR for organising the BSMA for undertaking curricula revision and for his valuable guidance and support in this regard.

Dr Samarendra Mahapatra, Member
Dr Aditi Mathur, Member
Dr Lipi Das, Convener
Dr Kalpana Sastry, Chairperson

May 31, 2019

Course Title with Credit Load
MBA in Agri-Business Management

Major Courses 20 Credits

Course Code	Course Title	Credit Hours
ABM 501	Principles of Management and Organisational Behaviour	3
ABM 502	Managerial Accounting and Control	3
ABM 503	Applied Agribusiness Economics	2
ABM 504	Human Resource Management for Agricultural Organizations	2
ABM 505	Production and Operations Management	2
ABM 506	Agricultural and Food Marketing Management- I	2
ABM 507	Agricultural and Food Marketing Management- II	2
ABM 508	Agri Supply Chain Management	2
ABM 509	International Trade for Agricultural Products	2

Minor Courses 8 Credits

It is suggested the student may choose at least four courses out of the courses listed below as part of minor courses as these are related to specific areas of agri business and aim to build larger understanding of the subject. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HoD.

Course Code	Course Title	Credit Hours
ABM 510	Food Technology and Processing Management	3
ABM 511	Rural Marketing	3
ABM 512	Fertiliser Technology and Management	3
ABM 513	Management of Agro-Chemical Industry	3
ABM 514	Seed Production Technology Management	3
ABM 515	Technology Management for Livestock Products	3
ABM 516	Fruit Production & Post Harvest Management	3
ABM 517	Farm Power & Machinery Management	2
ABM 518	Food Retail Management	2
ABM 519	Management of Agricultural Input Marketing	2
ABM 520	Feed Business Management	2
ABM 521	Management of Veterinary Hospitals	2
ABM 522	Poultry And Hatchery Management	2
ABM 523	Management Of Floriculture And Landscaping	2
ABM 524	Risk Management In Agri Business	2
ABM 525	Management Of Agri-Business Co-Operatives	2

Course Code	Course Title	Credit Hours
ABM 526	Business Analytics for Agriculture	2
ABM 527	Dairy Business Management	1
ABM 528	Agri Extension Management	1
ABM 529	Renewable Energy Sources Management	1
ABM 530	Quality Management for Agri Business	1
ABM 531	Advertising And Brand Management	1
ABM 532	Agri Infrastructure and Warehousing Management	1
ABM 533	Contract Farming	1
ABM 534	Human Resource Competence And CapacityBuilding Systems	1
ABM 535	Agri Commodity Markets And Futures Trading	1

Supporting Courses 6 Credits

Course Code	Course Title	Credit Hours
ABM 536	Strategic Management for Agri Business Enterprises	2
ABM 537	Operations Research	2
ABM 538	Financial Management in Agri Business	2

Common Courses 5 Credits

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approvalof the HoD/BoS.

Master's Seminar 01 Credit

Course Code	Course Title	Credit Hours
	Research (Summer Internship + Research Project)	**30 (10+20)**
	Summer Internship/ Industrial Attachment	4
	Basic Courses mandatory for Summer Internship	6
ABM 539	Communication for Management and Agri Business	3
ABM 540	Research Methodology for Agri Business Mgmt	3
	Research Project	**20**
	Project work	**10**
	Basic courses mandatory for Project	10

Course Code	Course Title	Credit Hours
ABM 541	Computer Applications for Agri Business	3
ABM 542	Project Management and Agri Business Entrepreneurship	3
ABM 543	Agribusiness Environment and Policy	2
ABM 544	Agri Business Laws and Ethics	2

Course Contents
MBA in Agri-Business Management

I. Course Title : Principles of Management and Organizational Behaviour

II. Course Code : ABM 501

III. Credit Hours : 3+0

IV. Aim of the course

Provide students with opportunities to understand a wide variety of topics related to business management, focusing on fundamental management principles and concepts that apply to agribusiness, traditional management skills, and new competencies needed to succeed in a fast-paced environment that demands ongoing innovations.

The course is organized as follows:

No	Blocks	Units
1.	Basic Concepts of Management	1. Introduction to Management 2. Planning, Organising, Directing and Controlling
2.	Insights about Organisational Behaviour	1. Foundations of Individual behaviour 2. Group Dynamics
3.	Organisational Dynamics	1. Understanding and managing organisational culture 2. Concept of Organisational Development

V. Theory

Block 1: Basic Concepts of Management

Unit-I: Introduction to Management: Nature, Scope and Significance of Management, Evolution of Management Thought, Approaches to Management, functions and skills of a manager

Unit-II: Management functions: Planning – Types, Steps, Objective, Process, Strategies, Policies, MBO, Organizing – Structure & Process, Line, Staff, Authority & Responsibility, Staffing – Recruitment and Selection, Directing – Training, Communication & Motivation, Controlling- Significance, Process, Techniques, Standards & Benchmarks, Management Audit

Block 2: Insights About Organizational Behavior

Unit III: Nature, Scope and Significance of Organizational Behavior; Foundations ofIndividual behaviour – Emotions, Personality, Values, Attitudes, Perception, Learning and individual decision making, Motivation- Types of motivation, theories of motivation, motivational practices at workplace, managing stress and work life balance

Unit IV: Group dynamics- types of groups, group formation, Group decision making, teambuilding and developing collaboration, leadership styles and influence process;

leadership theories, leadership styles and effective leader

Block 3: Organisational Dynamics

Unit V: Understanding and managing organisational culture, power and political behavior inorganisations, conflict Management, negotiation, managing organizational change, concept of organisational development

VI. Teaching methods/activities

- Interactive Lectures
- Assignment (Reading/Writing)
- Student presentations
- Case study related to basics of management and organizational behaviour

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic concepts of management and organizational behaviour
– Develop a overall view about the various management functions, managerial skills and approaches
– Get insights about the fundamentals of individual and group behavior in the orgnisational setting
– Analyse the organisational level challenges in managing the resources optimally

VIII. Suggested Reading

- Robbins SP, Coulter M and Vohra N. 2010. *Management*. Pearson Edu.
- Weihrich H, Cannice MV and Koontz H. 2015*, Management, A Global, Innovative and Entrepreneurial Perspective,* 14th Edition, McGraw Hill Education Pvt Ltd.
- Beierlein JG, Schneeberger KC, Osburn DD. 2014. *Principles ofAgribusiness Management*. Fifth edition. Waveland Press
- Neck CP, Houghton JD and Murray EL. 2017, *Organizational behavior*, Sage Publication India Private Limited.
- Greenberg J. 2013, *Behavior in Organisations*, PHI Learning Private Limited, New Delhi.
- John A, Wagner III JA and Hollenbeck JR. 2015. *Organizational Behaviour*, Routledge Taylor & Francis Group, New York.
- Koontz H and Weighhrich K. 2010. *Essentials of Management*. Tata McGraw Hill

I. Course Title : Managerial Accounting and Control

II. Course Code : ABM 502

III. Credit Hours : 3+0

IV. Aim of the course

The objective of this course is to expose the learner to the concept and methods of financial and management accounting. Focus will be on understanding techniques, uses and applications of financial and management accounting.

No	Blocks	Units
1.	Financial Accounting	1. Introduction to financial accounting 2. Accounting standards 3. Double Entry system 4. Use of accounting softwares
2.	Managerial Accounting	1. Meaning of Managerial accounting 2. Analysis of financial statements 3. Cash flow and fund flow analysis

No	Blocks	Units
3.	Cost Accounting	1. Introduction to cost accounting 2. Standard costing 3. Variance Analysis 4. Budget and budgetary control

V. Theory

Block 1: Financial Accounting

Unit I: Financial Accounting- Meaning, Need, Accounting principles: Accounting Conceptsand Conventions; Branches of Accounting, Users of Accounting information, Advantages and Limitations of Financial Accounting, Accounting Standards

Unit II: The Double Entry System- Its Meaning and Scope, The Journal, Cash Book, Ledger, Trial Balance, Trading Account Profit and Loss Account, Balance Sheet, entries and adjustments of different heads in different Books and Accounts, Introduction of Company Accounts, Use of Accounting Software

Block 2: Managerial Accounting

Unit III: Management Accounting-Meaning, Functions, Scope, Utility, Limitations and Toolsof Management Accounting, Analysis of Financial Statements- Ratio, time series, common size and Du pont Analysis, Comparative and Common Size Statements, Cash Flow and Fund Flow Analysis

Block 3: Cost Accounting

Unit IV: Cost Accounting–Nature, Course, Significance of Cost Accounting; Classification ofCost, Costing for Material; Labour and overheads; Marginal Costing and cost volume profit Analysis- Its Significance, Uses and Limitations; Standard Costing – Its Meaning, Uses and Limitations, Determination of Standard Cost, Variance Analysis-Material, Labour and Overhead.

Unit V: Budget and Budgetary Control- Meaning, Uses and Limitations, Budgeting and Profitplanning, Different Types of Budgets and their Preparations: Sales Budget, Purchase Budget, Production Budget, Cash Budget, Flexible Budget, Master Budget, Zero Based Budgeting. Mergers and Acquisition, Tax System- GST

VI. Teaching methods/activities

- Lecture
- Case studies for making the participants get a clear idea about the real life budgeting and accounting practices
- Live project in the firms finance departments for getting the first hand experience

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop a clear understanding about the concepts of financial and managerial accounting
– Understand the basics of cost accounting through various tools and techniques available
– Get a insight about the budget and budgetary control methods

VIII. Suggested Reading

- Jain SP and Narang KL. 2014. *Financial Accounting*. 12th Edition. Kalyani publisher

- Sharma and Gupta. 2018. *Management Accounting* 13th Edition, Kalyani Publisher
- Maheshwari SN and Maheshwari SK. 2018. *Financial Accounting*. 6th Ed. Vikas Publ. House.

I. Course Title : Applied Agribusiness Economics

II. Course Code : ABM-503

III. Credit Hours : 2+0

IV. Aim of the course

This course applies basic economic tools and models to problems involving supply, demand, individual consumer and firm behavior, and market structure. Basic market structure models covered include perfect competition, monopolistic competition, oligopoly, and monopoly. Economic tools and models are related to business strategies throughout the course.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Managerial Economics	1. Basic managerial economics principles 2. Mathematical concepts used in managerial economics 3. Introduction to behavioral economics
2.	Production, cost and supply analysis	1. Production Function 2. Cost Concepts 3. Determinants of price
3.	Macroeconomics	1. The national income 2. Flow of money in the market and economy 3. Business decisions under certain and uncertain situations

V. Theory

Block 1: Overview of Managerial Economics

Unit I: Scope of managerial economics, objective of the firm and basic economic principles; mathematical concepts used in managerial economics. Introduction to behavioral economics

Unit II: Indifference curves and budget sets - Demand analysis - meaning, types and determinants of demand; demand function; demand elasticity; demand forecasting-need and techniques.

Block 2: Production, Cost and Supply Analysis

Unit III: Production, cost and supply analysis- production function, Multi period productionand cost least-cost input combination, factor productivities and returns to scale, cost concepts, cost-output relationship, short and long-run supply functions.

Unit IV: Pricing-determinants of price - pricing under different market structures, pricing ofjoint products, pricing methods in practice, government policies and pricing. Price discrimination (First, Second and Third level)

Block 3: Macroeconomics

Unit V: The national income; circular flow of income: consumption, investment and saving: money-functions, factors influencing demand for money & supply of money; inflation; economic growth; business cycles and business policies; business decisions under certain and uncertain situations

VI. Teaching methods/activities

- Interactive Lectures
- Assignment (Reading and Writing)
- Cases on recent developments in economic environment
- Live projects to understand the principles of economics for an organisation
- Group analysis of newspapers covering national level economic trends

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concepts of managerial economics and its implications on the agri business environment
– Develop a clearer overview on the macroeconomic environment that exists for a agri business enterprise to understand and adapt for optimizing the output

VIII. Suggested Reading

- Dwivedi DN. 2015. *Managerial Economics*. 8th Edition, Vikash Publishing
- Gupta GS. 2015. *Managerial Economics*. Tata McGraw Hill
- Savatore D. Srivastav R. 2012. *Managerial Economics*. 7th Edition, Oxford University Press
- Suma Damodaran. 2010. *Managerial Economics*. Oxford

I. Course Title : Human Resource Management for Agricultural Organisations

II. Course Code : ABM 504

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to the field of human resource management. The focus will be on human resource practices and their utility for managers in agri based organizations.

The course is organized as follows:

No	Blocks	Units
1	Overview of Human Resource Management	1. Meaning and scope of Human Resource Management 2. Human Resource Planning 3. Recruitment, Selection and Training 4. Performance Appraisal 5. Compensation Management
2	Industrial Relations	1. Trade Union 2. Grievance Management 3. Health and Safety of HR
3	Ethical and Global issues in HRM	1. Global HRM 2. HR Metrics, HRIS and workplace analystics

V. Theory

Block 1: Introduction to Human Resource Management

Unit I: Strategic Human Resource Management, Human Resource Planning-Nature andSignificance, Job Analysis and talent management process, Job Description, job Specification, Job enlargement, Job enrichment, Job rotation

Unit II: Recruitment and Selection Process, Induction, Training and Human Resource Development-Nature, Significance, Process and Techniques, e- recruitment, use of Big Data for recruitment, use of Artificial Intelligence and machine learning tools in recruitment practices Career planning and Development Internal mobility including Transfers, Promotions, employee separation.

Unit III: Performance Appraisal–Significance and methods, Compensation management, Strategic pay plans, Job Evaluation, Wage and Salary Administration; Wage Fixation; Fringe Benefits, Incentive Payment, bonus, and Profit Sharing

Block 2: Industrial Relations

Unit IV: Role and Status of Trade Unions; Collective Bargaining; Worker's Participation inManagement, employee retention. Quality of work life, employee welfare measure, work life balance, Disputes and Grievance Handling Procedures; Arbitration and Adjudication; Health and Safety of Human Resources;

Block 3: Ethical And Global Issues In Hrm

Unit V: Ethical issues in HRM**,** Managing Global Human Resources, Managing Human Resources in Small and Entrepreneurial firms, Human Resources accounting, Human Resources outsourcing. HR Information System, Human Resource Metrics and Workforce Analytics, Future trends in workforce technologies.

VI. Teaching methods/activities

- Lectures
- Videos showing trends and practices of innovative human resource management
- Live project for understanding the application of concepts in the real life situation
- Interaction with the HR managers of the agri based organsiations to understand the intricacies involved in the managing the human resource
- Group tasks to study the policy framework and regulatory environment that exists in India and globally to manage human resource

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic concept of HRM and SHRM
– Develop an insight into important human resource management functions like job analysis, job planning, recruitment, selection, performance appraisal, training, development, compensation management etc with major reference to the agri based organisations
– Get a clearer view about the status of employee – employer relationship in Indian agri enterprises and global agri based organizations
– Understand the ethical and recent trends in managing human resource effectively

VIII. Suggested Reading

- Gary Dessler & Biju Varkkey 2016, *Human Resource Management*, XIV Edition, Pearson India
- VSP Rao. 2010, *Human Resource Management, Text and Cases,* 3rd Edition, Excel Books
- Ashwathapa K. 2016. *Human Resource Management, Text and Caes*. Tata McGraw Hill
- Michael J. Kavanagh, Mohan Thite & Richard D. Johnson. 2016, *Human ResourceInformation Systems*, Sage Publications
- Subba Rao P. 2004. *Essentials of Human Resource Management and Industrial Relations*. Himalaya Publ. House.

I. Course Title : Production and Operations Management

II. Course Code : ABM 505

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to the field of production and operations management. The focus will be on imparting knowledge of the basic concepts, tools, and functions of production management.

The course is organized as follows:

No	Blocks	Units
1	Introduction to Production and Operations Management	1. Concept and scope of production and operations management 2. Operations strategy 3. Productivity variables and measurement
2	Inventory management	1. Determination of material requirement 2. Industrial safety 3. Cloud operations management
3	Overview of Quality Management	1. Statistical process control 2. Reengineering and Value engineering

V. Theory

Block 1: Introduction to Production and Operations Management

Unit I: Nature Concept and Scope of Production and Operations Management; FactorsAffecting System; Facility location, Types of Manufacturing Systems and Layouts, Process Selection and Facility Layout, Layout Planning and Analysis, Forecasting

Unit II: Operations Strategy: Operations Strategy, Competitive Capabilities and CoreCompetencies, Operations Strategy as a Competitive Weapon, Linkage Between Corporate, Business, and Operations Strategy, Developing Operations Strategy, Elements or Components of Operations Strategy, Competitive Priorities, Manufacturing Strategies, Service Strategies, Global Strategies and Role of Operations Strategy.

Unit III: Productivity Variables and Productivity Measurement, Production Planning andControl, Mass Production, Batch Production, Job Order Manufacturing, Product Selection, Product Design and Development, Process Selection, Capacity planning.

Block 2: Inventory Management

Unit IV: An Overview of Inventory Management Fundamentals, Determination of MaterialRequirement, Safety Management Scheduling, Maintenance Management Concepts, Work Study, Method Study, Work Measurement, Work Sampling, Work Environment, Production Planning and Control (PPC) Industrial Safety, human-machine interface, types of interface designs. Cloud operations management

Block 3: Quality Management

Unit V: Quality Assurance, Accepting Sampling, Statistical Process Control, Total QualityManagement, ISO standards and their Importance, Introduction to re-engineering, value engineering, check sheets, Pareto charts, Ishikawa charts, JIT Pre-requisites for implementation Six Sigma, Lean Management, Reliability

Engineering, Safety Engineering, Fault Tree Analysis.

VI. Teaching methods/activities

- Interactive sessions
- Live projects
- Assignments (reading and writing)
- Presentations of quality management practices by leading agri and food organizations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic concepts of production and operations management including manufacturing systems, layout planning and analysis
– Develop a understanding about the operations strategy, productivity variables, and their measurement along with product design and development
– Get an insight about fundamentals of inventory management, safety management, quality assurance practices and techniques with major emphasis on agri and food based industries

VIII. Suggested Reading

- William J. Stevenson. 2014. *Operations Management*, 12th Edition, McGraw-Hill
- Panneerselvam K. 2012. *Production and Operations Management* 3rd Edition, Prentice Hall India Learning Private Limited
- S. N Chary, 2017. *Production and Operations Management*, McGraw Hill Education; 5 edition

I. Course Title : Agricultural And Food Marketing Management-I

II. Course Code : ABM 506

III. Credit Hours : 2+0

IV. Aim of the course

To develop the understanding the concept of marketing system with specific inputs of product, pricing, availability and promotional details

The course is organized as follows:

No	Blocks	Units
1.	Marketing concept	1. Overview of Marketing Management 2. Developing the product mix 3. Branding decisions 4. Packaging technology
2	Pricing decisions	1. Pricing Objectives 2. Types of pricing
3	Channel Management and Physical Distribution	1. Distribution channels 2. Warehouse management, Inventory management 3. Transport management
4	Marketing Communications	1. Marketing communications mix 2. Digital Marketing, Mobile Marketing, Social Marketing and Social Media Marketing 3. Marketing efficiency and effectiveness

V. Theory

Block 1: Overview Of Marketing Management

Unit 1: Introduction and Concept/ philosophies of Marketing Management; Product Management: The product, The product mix, Product line extensions, Product linedeletions, Branding products, The advantages and disadvantages of branding, Branding decisions Brand loyalty models, Homogenous first-order markov models, Higher-order markov models Packaging, The functions of packaging, Packaging technology, Recent developments in packaging

Block 2: Pricing Decisions

Unit 2: Pricing objectives, The laws of supply and demand, Elasticity of demand Cross-price elasticity of demand, Practical problems of price theory, Cost - revenue - supply relationships, The meaning of price to consumers, Price as an indicator of quality, Pricing strategies, Cost-plus methods of price determination, Breakeven analysis, Market-oriented pricing, Psychological pricing, Geographical pricing, Administered pricing

Block 3: Channel Management and Physical Distribution

Unit 3: Channel decisions in relation to marketing strategy, The value of middlemen, Key decisions in channel management, Types of distribution system, Marketing to middlemen, Power and conflict in distribution channels, Physical distribution, Customer service levels, Developing a customer service policy, The total distribution concept, Warehouse management, Inventory management, Calculating the economic order quantity, Transport management, Technological advances in physical distribution, Vehicle scheduling and routing, Fixed and variable routing systems, Vehicle scheduling tools, Vehicle scheduling models, Computer-based vehicle scheduling

Block 4: Marketing Communications

Unit 4: The nature of marketing communications, Setting marketing communication objectives, Factors influencing the communications mix, The marketing communications mix, Advertising, Sales promotion, Public relations, Personal selling, Digital Marketing, Mobile Marketing, Social Marketing and Social Media Marketing, Training the sales force, Change agents, Selecting the media, Establishing the promotional budget, Monitoring the effectiveness of marketing communications

Unit 5: Marketing Costs And Margins: Assessing the performance of a marketing system, Marketing efficiency and effectiveness, Operational efficiency, Pricing efficiency, Identifying marketing costs and margins, The reference products concept, Handling costs, Packaging costs, Transport costs, Storage costs, Processing costs, Capital costs

VI. Teaching methods/activities

- Lectures
- Cases studies from recent marketing trends from the agri and food organisations
- Assignments (Group/ Individual)
- Live project based upon marketing practices adopted by various organizations
- Group discussions on contemporary marketing practices

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basics of marketing with specific emphasis on managing the product details
– Get detailed insight on the pricing techniques and managing the demand and supply relationship profitably
– Develop the understanding about the marketing channels and intermediaries involved
– Understand the promotional strategies and communication development tools and methods

VIII. Suggested Reading

- Kotler P, Keller K, Koshy A and Jha M. 2013. *Marketing Management–Analysis, Planning, Implementation and Control*. Pearson Education.
- Ramaswamy VS. 2017. *Marketing Management: A Strategic Decision Making Approach*
- McGraw Hill Education
- Saxena R. 2009. *Marketing Management*. Mc Graw Hill.4th Edition
- William Perreault Jr., Mccarthy E. Jerome., 2006, *Basic Marketing: A Global Marketing Approach,* Tata McGraw Hill
- Gay R, Cjarlesworth A, Esen R. 2014, *Online Marketing*, Oxford University Press
- Mohammed, Fisher, Jaworski and Cahill: *Internet Marketing – Building Advantage in a networked economy* Tata McGraw-Hill
- Strauss J and Frost R. 2013. *E-Marketing*, Prentice-Hall
- Roberts M. 2018. *Internet Marketing*, Cengage Learning
- Vassos: *Strategic Internet Marketing – Practical e-commerce and branding Tactics*, Que Books
- Chaffey, Meyer, Johnston and Ellis – Chadwick. 2009. *Internet Marketing*, Prentice-Hall/ Financial Times

I. Course Title : Agricultural and Food Marketing Management-II
II. Course Code : ABM 507
III. Credit Hours : 2+0

IV. Aim of the course

To develop learning about the basic concept of marketing with major emphasis on agri and food marketing by equipping the students with the understanding of ecosystem in which the agri organization functions to meet the requirements of the customer profitably

The course is organized as follows:

No	Blocks	Units
1.	Agricultural and Food Marketing	1. Marketing concept and marketing systems 2. Market Liberalisation
2.	Marketing Strategy, Planning and Control	1. Marketing planning 2. New Product Development:
3.	Commodity Marketing	1. Grain marketing, 2. Livestock and meat marketing, 3. Poultry and eggs marketing, marketing of fresh milk

V. Theory

Block 1: Agricultural and Food Marketing

Unit 1: The importance of agricultural and food marketing to developing countries,

the marketing concept and marketing systems, Marketing sub-systems
Marketing functions, Links between agriculture and the food industry, Agricultural and food marketing enterprises, Marketing boards in developing countries, Co-operatives in the agriculture and food sectors, Control and management of secondary co-operatives, The weaknesses of co-operatives, Selling arrangements between co-operatives and their members

Unit 2: Market Liberalisation: Economic structural adjustment programmes, Macro-economicstabilisation, The role of the state in liberalised markets, Strategies for reforming agricultural marketing, Obstacles to be overcome in commercialisation and Privatisation of agricultural marketing, Dealing with accumulated deficits, Encouraging private sector involvement in agricultural marketing, Impediments to private sector participation in agricultural markets, impact of the macro-economic environment on private traders, Government action to improve private sector performance

Block 2: Marketing Strategy, Planning and Control

Unit 3: Marketing Strategy, Planning and Control: Strategy, policy and planning, Strategic businessunits, The need for marketing planning, The process of marketing planning, Contents of the marketing plan, Monitoring, evaluating and controlling the marketing planning, Marketing controls, Marketing plan control, Efficiency control

Unit 4: New Product Development: The impetus to innovation, New product development process
The adoption process, The effect of products characteristics on the rate of adoption, Buyer behavior: The influences on buyer behaviour, Exogenous influences on buyer behaviour Endogenous influences on buyer behaviour, The consumer buying decision process, Buyer behaviour and market segmentation, Lifestyle segmentation, Organisational markets Industrial markets, Industrial buyer characteristics

Block 3: Commodity Marketing

Unit 5: Stages in a commodity marketing system, Grain marketing, Challenges for grain marketing systems, fruits and vegetables, Livestock and meat marketing, Poultry and eggs marketing, marketing of fresh milk

VI. Teaching methods/activities

- Lectures
- Cases studies from recent marketing trends from the agri and food organisations
- Assignments (Group/ Individual)
- Live project based upon marketing practices adopted by various organizations
- Group discussions on contemporary marketing practices

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Understand the agricultural and food marketing concepts and systems
– Get an insight about the marketing planning and strategies for developing products for meeting the specific needs of the final customers
– Develop a clear view about the commodity marketing practices in India and in International markets

VIII. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural Marketing in India*. 4th Ed. Oxford and IBH.

- Kohls RL and Uhj JN. 2005. *Marketing of Agricultural Products*. 9th Ed. Prentice Hall.
- Mohan J. *Agri-Marketing Strategies in India*, NIPA
- Sharma Premjit. 2010. *Agri-Marketing Management*, Daya Publishing House

I. Course Title : Agri Supply Chain Management

II. Course Code : ABM 508

III. Credit Hours : 2+0

IV. Aim of the course

To introduce the students to the concepts, processes and framework of agricultural supply chain management.

The course is organized as follows:

No	Blocks	Units
1	Overview of Supply Chain Management	1. Introduction to Agri Supply Chain Management 2. Demand Management in Supply Chain 3. Manufacturing Management
2	Procurement Management	1. Purchasing Cycle 2. Material Requirement Planning
3	Logistics Management	1. Distribution Strategies and Management 2. Warehouse Management 3. IT application in ASCM

V. Theory

Block 1: Overview Of Supply Chain Management

Unit I: Supply Chain: Changing Business Environment; SCM: Present Need; ConceptualModel of Supply Chain Management; Evolution of SCM; SCM Approach; Traditional Agri. Supply Chain Management Approach; Modern Supply Chain Management Approach; Elements in SCM. Innovations in Global Agri-SCM

Unit II: Demand Management in Supply Chain: Types of Demand, Demand Planning andForecasting; Operations Management in Supply Chain, Basic Principles of Manufacturing Management. SCM Metrics/Drivers and Obstacles.

Block 2: Procurement Management in Agri. Supply Chain

Unit III: Purchasing Cycle, Types of Purchases, Contract/Corporate Farming, Classification ofPurchases Goods or Services, Traditional Inventory Management, Material Requirements Planning, Just in Time (JIT), Vendor Managed Inventory (VMI).

Block 3: Logistics Management

Unit IV: History and Evolution of Logistics; Elements of Logistics; Management; Distribution Management, Distribution Strategies; Pool Distribution; Transportation Management; Fleet Management; Service Innovation; Warehousing; Packaging for Logistics, Third-Party Logistics (TPL/3PL); GPS Technology.

Unit V: Concept of Information Technology: IT Application in SCM; Advanced Planning andScheduling; SCM in Electronic Business; Role of Knowledge in SCM; Performance Measurement and Controls in Agri. Supply Chain Management-Benchmarking: introduction, concept and forms of Benchmarking. Case Studies on the following: (a) Green Supply Chains (b) Global Supply Chains (c) Coordination in a SC. Value of and distortion of information: Bullwhip effect (d) Sourcing and contracts in SC (e) Product availability with uncertain demand (f) Inventory planning with known/ unknown demand (g) Cases from FAO/IFPRI, etc.

VI. Teaching methods/activities

- Lectures
- Case study on the real life situations regarding the supply chain management practices
- Assignments (Group and individual)
- Live projects
- Newspaper analysis
- Presentations of best practices in the industry
- Videos and guest lectures by the eminent and successful organizations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the various elements involved in managing agri supply chain from farm to fork
- Relate well with the issues and challenges involved in managing and forecasting the demand of the products
- Develop insights on the techniques of procurement management and handling inventory
- Assess the importance of managing logistics along with adequate handling and packaging intricacies
- Get a overall clarity about the use of information technology to make the agri supply chain more efficient and rewarding

VIII. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural marketing in India*. Oxford and IBH.
- Altekar RV. 2006, *Supply Chain Management: Concepts and Cases*. PHI
- Chopra S, Meindl P and Kalra DV. 2016. *Supply chain management: Strategy, Planning, and Operation*, Pearson Education India
- Mohanty RP. 2010. *Indian Case studies in Supply Chain Management & other Learning Resources*. Oxford.
- Chandrasekaran N. 2010. *Supply Chain Management: Process, system & Practice*. Oxford.
- Singh S. 2004. *Organic Produce Supply Chains in India-Organisation and governance*. Allied Publ.

I. Course Title : International Trade in Agricultural Products

II. Course Code : ABM 509

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge to the students about international trade in agriculture and various provisions under WTO in the new trade regime.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to International Trade	1. Basic concepts of International Trade 2. WTO and its implications for Indian agri business sector 3. International trade restrictions and support systems
2.	Regulations and policy measures for International trade	1. India's foreign trade policy framework 2. Market entry methods 3. Export procedures & documentations

V. Theory

Block 1: Introduction To International Trade

Unit I: International trade–basic concepts, WTO and its implications for Indian economy ingeneral and agriculture sector in particular.

Unit II: TRIPS, TRIMS quotas, anti dumping duties, quantitative and qualitative restrictions, tariff and non-tariff measures, trade liberalization, subsidies, green and red boxes, issues for negotiations in future in WTO; CDMs and carbon trade.

Unit III: Importance of foreign trade for developing economy; absolute and comparativeadvantage, foreign trade of India. Cases on agri business commodity trade practices

Block 2: Regulations and Policy Measures for International TRADE

Unit IV: India's balance of payments; inter regional Vs international trade; tariffs andtradecontrol; exchange rate; the foreign trade multiplier.

Unit V: Foreign demand, supply side analysis, opportunity cost, trade and factor prices, implications for developing countries, market entry methods, export procedures & documentations.

VI. Teaching methods/activities

- Lectures
- Cases on contemporary issues
- Group assignments
- Live projects
- Policy discussions
- Guest lectures
- Industrial visits to firms exporting agri commodities

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic concepts of International trade with reference to WTO and International agreements on Agriculture
- Assess the practices of trade of agri business commodities
- Develop a clear understanding about the significant regulations and policy measures for International Trade

VIII. Suggested Reading

- Study materials by the Center for WTO Studies, ITPO, New Delhi, *The Future of Indian Agriculture*

• Brouwer F and Joshi PK. 2016. *International Trade and Food Security*, LEI - Wageningen UR, The Netherlands.

I. Course Title : Food Technology and Processing Management
II. Course Code : ABM 510
III. Credit Hours : 3+0

IV. Why this course?

As a discipline, Food Technology is the combination of engineering, food science, hotel management, and home science. It is an advanced study of the technology and processing methods used to develop, research, manufacture, produce, preserve and process food with related substances.

V. Aim of the course

Food Technology is the application of food science to the selection, preservation, processing, packaging, distribution and use of safe, wholesome and nutritious food. The food processing industry covers a range of food products.

The Course is organized as follows:

No	Blocks	Units
1.	Food Technology	1. Food Industry in India
2.	Processing Management	1. Basics of Food Processing 2. Food Safety and Costs Analysis 3. Case studies on project formulation in various types of food industries

VI. Theory

Block 1: Food Technology

Unit 1: Food Industry in India: Present status of food industry in India; Organization in food industry; Introduction to operations of food industry; Deteriorative factors and hazards during processing, storage, handling and distribution.

Block 2: Processing Management

Unit 2: Basics of Food Processing: Basic principles of food processing and food preservation through technology interventions; Application of energy, radiations, chemicals and other agents for food preservation; aseptic modes of processing-freezing, quick, cryogenic, high pressure, membrane technology; Packaging of foods, labelling techniques, advanced technologies for packaging.

Unit 3: Food Safety and Costs Analysis: Analysis of costs; risk management; Laws and regulations w.r.t to food industry including production, processing and marketing; Food Safety and Quality Standards-AGMARK, BIS/ISO, FPO, FSSAI, TQM, HACCP etc.

Unit 4: Case studies on project formulation in various types of foodindustries: Discussion sessions and analysis of Case studies related to dairy, cereal milling, sugarcane production; baking/confectionary, vegetable storage, handling, egg processing, fish and meat products; Cases related HACCP.

VII. Learning outcome

After completion of this course, the students are expected to be able to acquaint the students with different food processing techniques and their management.

VIII. Suggested Reading

- Acharya SS and Aggarwal NL. 2004. *Agricultural Marketing in India*. Oxford & IBH.
- Early R. 1995. *Guide to Quality Management Systems for Food Industries*. Springer
- Jelen P. 1985. *Introduction to Food Processing*. Reston Publishing.
- Potly VH and Mulky MJ. 1993. *Food Processing*. Oxford & IBH
- Fellows PJ. 2016. *Food Processing Technology Principles and Practice,* Woodhead Publishing, 4th Edition
- Potter NN. 2018. *Food science*. McGraw-Hill Education, 6th Edition
- Singh RP, Heldman DR. 2013. *Introduction to Food Engineering.* Elsevier Inc., 5th Edition
- Smith JS, Hui YH. 2013. *Food Processing: Principles and Applications*, Wiley

I. Course Title : Rural Marketing

II. Course Code : ABM 511

III. Credit Hours : 3+0

IV. Aim of the course

To explore the possibilities and potential of the rural market. It aims at critically analysing the market opportunities, consumer trends and patterns and development of better marketing strategies for the rural areas.

The Course is organized as follows:

No	Blocks	Units
1	Rural MarketingEnvironment	1. Rural Market Concept & Scope 2. Environmental factors 3. Rural finance 4. Rural consumer's behavior
2	Rural Marketing Strategy	1. Rural Product strategy 2. Pricing for rural markets 3. Promotion and communication strategy

V. Theory

Block 1: Rural Marketing Environment

Unit 1: Rural Market Concept & Scope: Concept, Definition and Scope of rural marketing, nature and characteristics of rural markets, potential of rural markets in India, rural V/S urban market.

Unit 2: Environmental factors: Socio-cultural, economic, demographic, technological and other environmental factors affecting rural marketing.

Unit 3: Rural finance: Concept, demand, banking model; Finance Schemes of NABARD, Other Schemes of State Govt, Central Govt.

Unit 4: Rural consumer's behavior: Behavior of rural consumers and farmers; buyer characteristics and buying behavior; customer relationship management, rural market research.

Block 2: Rural Marketing Strategy

Unit 1: Rural Product strategy: Marketing of consumer durable and non-durable goods and services in the rural markets with special reference toproduct planning; marketing mix, product mix.

Unit 2: Pricing for rural markets: Pricing policy and pricing strategy, distribution strategy, Rural retailing and modern store formats in rural areas.

Unit 3: Promotion and communication strategy: Media Planning, Distribution channels, personal selling strategies in rural markets, innovations in rural marketing

Teaching methods/activities

- Lectures
- Discussion
- Case Studies
- Student-led presentations

V. Learning outcome

After completion of this course, the students are expected to be able to develop understanding regarding issues in rural markets like marketing environment, consumer behaviour, distribution channels, marketing strategies, etc.

VI. Suggested Reading

- Krishnamacharyulu and Ramakrishnan. 2010. *Rural Marketing: Text and Cases*: Pearson Education. 2nd edition
- Singh S. 2004. *Rural Marketing: Focus on Agricultural Inputs,* Vikas Publishing
- Kashyap P. 2011. *Rural Marketing*. Pearson Education
- Kumar D and Gupta P. 2017. *Rural Marketing: Challenges andOpportunities*. Sage Publications.

I. Course Title : Fertilizer Technology and Management

II. Course Code : ABM 512

III. Credit Hours : 3+0

IV. Why this course?

Provide exposure to most recent Nitrogenous and Complex fertilizer production technologies. Improve participants' technical knowledge over a varied range of fertilizer production techniques

V. Aim of the course

Enhance the participants' analytical and trouble-shooting skills by generating awareness to identify and resolve operational inefficiencies, if any, of their facilities. The Course is organized as follows:

No	Blocks	Units
1	Fertilizer Production	1. Fertilizer development 2. Raw material 3. Production efficiency
2	Testing and Field Trials	1. Testing 2. Field trials

VI. Theory

Block 1: Fertilizer Production

Unit 1: Fertilizer development: Concept, scope, need, resource availability; import and export avenues for fertilizer; types of fertilizers, grading and chemical constituents, role of fertilizers in agricultural production, production and consumption of fertilizer in India.

Unit 2: Raw material Supply; Principles of manufacturing-potassic fertilizers, secondary and micro-nutrient formulations

Unit 3: Production efficiency: Production efficiency and capacity utilization; quality control and legal aspects fertilizer control order

Block 2: Testing and Field Trials

Unit 1: Testing facilities; constraints in fertilizer use; assessment of demand and supply of different fertilizers, fertilizer distribution, fertilizer storage.

Unit 2: Field trialsand demonstrations; environmental pollution due to fertilizers

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Provide a platform to exchange ideas on a varied range of production topics, opportunity for active interaction with leading technology experts and to acquaint the students in latest advances in fertilizer technologymanagement.

IX. Suggested Reading

- Brady NC & Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- *Fertilizer Control Order* (different years). Fertilizer Association of India, New Delhi.
- *Fertilizer Statistics* (different years). Fertilizer Association of India, New Delhi
- *Indian Journal of Fertilizers* (different years). Fertilizer Association of India, New Delhi.
- San Chilli V. 1960. *Chemistry and Technology of Fertilizers*. American Chemical Soc. Monograph Series. Reinhold Publ. Corp.
- Tisdale SL, Nelson WL, Beaton JD & Havlin JL. 2002. *Soil Fertility and Fertilizers*. 5th Ed. Prentice Hall

I. Course Title : Management of Agro Chemical Industry

II. Course Code : ABM 513

III. Credit Hours : 3+0

IV. Why this course?

The agrochemicals (pesticides, hydrogels, plant growth regulators etc.) have played a pivotal role in the past in increasing agricultural productivity and production, and in protecting and preserving the human and animal food, feed, health and the belongings.

V. Aim of the course

Plant protection chemicals have and will continue to play a crucial role in meeting the food, feed and fiber needs of the mankind.

The Course is organized as follows:

No	Blocks	Units
1.	Agro Chemicals	1. Agro Chemicals 2. Insecticides 3. Fungicides
2.	Insecticide Act and Plant Protection	1. Insecticide Act. 2. Plant Protection

VI. Theory

Block 1: Agro Chemicals

Unit 1: Introduction: Agro-chemicals: Definition and classification; Basic knowledge of agro- chemicals; role andstatus of agro-chemical industry in India; Pesticides – Classification and Introduction, knowledge of different pesticides.

Unit 2: Insecticides: Insecticides – Definition and classification based on (a)Mode of Entry (b) Mode of Action and(c) ChemicalStructure with example; Insecticidal formulation; preliminary knowledge of mode of action of insecticides; knowledge of plant protection equipments.

Unit 3: Fungicides: Fungicides – Classification and preliminary knowledge of commonly used fungicides; Biomagnifications ofpesticides and pesticidal pollution.

Block 2: Insecticide Act and Plant Protection

Unit 1: Insecticide Act: Introductory knowledge about development of agro-chemicals; Insecticidal poisoning, symptoms and treatment; Main features of Insecticide Act.

Unit 2: Plant Protection: Directorate of Plant Protection, Quarantine and Storage– A brief account of its organizational set up and functions; IPM Concept – Bio-pesticides – Plant products.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To familiarize the students with the agrochemicals, their structure, classification and development and management of agro-chemical industry.

IX. Suggested Reading

- Dhaliwal GS, Singh R and Chhillar BS. 2014. *Essentials of Agricultural Entomology*. Kalyani Publishers.
- Hayes WT and Laws ET. 1991. *Hand Book of Pesticides*. Academic Press.
- Matsumura F. 1985. *Toxicology of Insecticides*. 2nd Ed. Plenum Publ.
- Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

I. Course Title : Seed Production Technology Management

II. Course code : ABM 514

III. Credit Hours : 3+0

IV. Aim of the course

The course covers a wide range of seed science and technology issues related to production of high quality seeds, processing, testing, certification, quality control, seed policies and regulations, variety release and registration, seed quality management in *seed* multiplication systems, seed storage, marketing.

The Course is organized as follows:

No	Blocks	Units
1.	Seed Technology	1. Seed Technology
2.	Seed Management Programmes	1. Development and Management of Seed

No	Blocks	Units
		2. Maintenance of genetic purity 3. Management of seed processing plant 4. Seed Marketing

V. Theory

Block 1: Seed Technology

Unit 1: Seed Technology: Role of Seed Technology, its Course Objective and goal, Seed Industry in India, National Seed Corporation – Tarai Seed Development, Corporation, State Seed Corporations, National Seed Project and State Farms and their role.

Block 2: Seed Management

Unit 1: Development and Management of Seed Programmes: Seed Village Concept, Basic Strategy of Seed Production and Planning and Organization of Seed Programme; Types of Seed Programme–Nucleus seed, Breeders seed, Foundation seed and Certified seed etc.

Unit 2: Maintenance of genetic purity: Minimum seed certification standard and Management of breeders & Nucleus seed; Management of seed testing laboratory and research and development.

Unit 3: Management of seed processing plant seed storage management; seed packaging and handling.

Unit 4: Seed Marketing: GM Crop seed, IPR, PBR, Patents and related issues and their impact on developing countries; Statutory intervention in the seed industry; Seed legislation and seed law enforcement, Seed act; Orientation and visit to seed production farms, seed processing Units, NSC, RSSC, RSSCA and seed testing laboratories.

VI. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VII. Learning outcome

To apprise students regarding principles and efficient management of seed production technology.

VIII. Suggested Reading

- Agrawal RL. 2017. *Seed Technology*. Oxford & IBH.
- Desai BB, Katecha PM and Salunkhe DK. 2009. *Seed Handbook: Biology, Production, Processing and Storage*. Marcel Dekker.
- Kelly A. 1988. *Seed Production of Agricultural Crops*. Longman.
- McDonald MB Jr. and Copeland LO. 2012. *Seed Production: Principles and Practices.* Chapman & Hall.

I. Course Title : Technology Management for Livestock Products

II. Course code : ABM 515

III. Credit Hours : 3+0

IV. Why this course?

Students may study two major topics include meat technology and dairy technology.

They may also do research activities on product development, development of functional meat, an extension of shelf life, and development of milk products.

V. Aim of the course

The main aim of this course is to disseminating knowledge about hygienic milk production, hygienic slaughter, utilization of slaughterhouse by-products, preparation of value-added meat products, preparing of value-added indigenous as well as milk products, and dressing of food animals.

The Course is organized as follows:

No	Blocks	Units
1.	Livestock product & Technology	1. Status of livestock product and technology 2. Manufacturing technologies
2.	TQM and Marketing of Livestock Products	1. TQM in processing 2. Marketing livestock products

VI. Theory

Block 1: Livestock Product and Technology

Unit 1: Present status of livestock products industry in India: Dairy, meat, skin and hides, wool, etc; SWOT analysis of livestock product industry, importance of value addition of livestock products, Concept of organic milk and meat. New techniques of biotechnology for improving food value.

Unit 2: Manufacturing technologies: Dairy-Manufacturing technologies of various dairy products and byproduct utilization. Meat- Manufacturingtechnologies of meat and its products, industrial processing and utilization of wool and animal by-products, valueadded egg product development.

Unit 3: Milk and meat processing plant: Layout and designing of milk and meat processing plant, abattoir design, sanitation and basic slaughterhouse practices, Plant Management- Production, planning and control, packaging, preservation and storage system for livestock products; transportation system for domestic markets and international markets.

Block 2: TQM and Marketing of Livestock Products

Unit1: Total quality management in processingTotal quality management in processing of milk and its byproduct, meat and byproduct, value added eggduct and wool, Quality control measures during storage transit; extent of losses during storage and transport, management measures to minimize the loss.

Unit 2: Marketing livestock products

Milk, meat, wool, fish etc and its byproduct, Marketing and distribution system of animal products; National and international specifications and quality standards for various products; environmental and legal issues involved.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To impart knowledge about management of livestock products, product development, quality control, preservation and marketing strategies for livestock products.

IX. Suggested Reading

- Mandal PK and Biswas AK. 2014. *Animal Products Technology,* Studium Press India Pvt. Ltd.; 1st Edition
- Bishwas AK and Mandal PK. 2014. *Textbook of Poultry, Egg and FishProcessing Technology,* Studium Press (India) Pvt. Ltd.

I. Course Title : Fruit Production and Post-Harvest Management

II. Course Code : ABM 516

III. Credit Hours : 3+0

IV. Why this course?

Postharvest management of fruits and vegetable: A potential for reducing a minimum postharvest losses as well as can potentially reduce production cost .

V. Aim of the course

A dual purpose of preventing losses that occur due to harvest losses of fruits and vegetables vary from 25% to 40%, depending on the kind of produce and the pre and post-harvest practices they are put through. The Course is organized as follows:

No	Blocks	Units
1.	Fruit Production	1. Introduction 2. Management of horticultural crops
2.	Post-Harvest Management	1. Post harvest management in horticulture-procurement 2. Post harvest management in horticulture process 3. Marketing of fruits

VI. Theory

Block 1: Fruit Production

Unit 1: Introduction: Global and National Status of Horticultural production in India and emerging scenario

Unit 2: Management of horticultural crops: Establishing an orchard, basic cultural practices, regulation of flowering, fruiting and thinning, protection against insect-pest, weeds: Maturity indices, Harvesting and its relationship with quality, sorting and grading, pre-harvest crop management practices and their influence on quality during storage and marketing.

Block 2: Post-Harvest Management

Unit 1: Post-harvest management in horticulture-procurement: Procurement management, important factors for marketing, standardization and quality control, packaging. Physiology of ripening and senescence. Storage system: on-farm storage-evaporatively cooled stores, ventilated storage, pit storage etc. Refrigerated storage refrigeration cycle, controlled/modified atmosphere, hypobaric storage.

Unit 2: Post harvest management in horticulture process: Application of growth regulators for quality assurance, post-harvest treatments: pre cooling, heat treatments (hot water, hot air and vapor heat), fungicides & biologically safe chemicals, irradiation, curing, pulsing *etc*. Packingline operations, packaging of horticultural produce. Transportation rail, road, sea, air. Codex norms for export ofperishables. Development of fruit-based carbonated drinks, development of dehydrated products from someimportant fruits, storage of pulp in pouches, essential oils from fruit waste, dehydrated fruits. Market structure andexport potential of fruits.

Unit 3: Marketing of fruits: Problems in marketing of fruits, and government policy; quality standards for domestic and international trade.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To impart knowledge about management of horticultural crops and post-harvest technologies

IX. Suggested Reading

- Rathore NS, Mathur GK and Chasta SS. 2013. *Post-Harvest Management and Processing of Fruits and Vegetables*, ICAR.
- Chadha KL and Pareek OP. 1993. *Advances in Horticulture*. Vols. I-IV. Malhotra Publ. House.
- Kader AA. 1992. *Post-harvest Technology of Horticultural Crops*. Univ. of California. Div. of Agri. & Natural Resources.
- Jacob JP. 2012. Handbook on Post Harvest Management of Fruits and Vegetables, ASTRAL Publishing.
- NIIR Board of Consultants & Engineers. 2016. *The Complete Technology Book on Processing, Dehydration, Canning, Preservation of Fruits & Vegetables*, NIIR PROJECT CONSULTANCY SERVICES; 3rd Revised Edition
- Thompson K. 2003. *Fruit and Vegetables: Harvesting, Handling and Storage*, Wiley-Blackwell; 2nd Edition

I. Course Title : Farm Power and Machinery Management

II. Course Code : ABM 517

III. Credit Hours : 2+0

IV. Why this course?

The role of mechanization and its relationship to productivity, employment, social and technological change; performance and *power* analysis(Various sources of *farm power*, their availability and utilization) cost analysis of mechanized agriculture.

V. Aim of the course

Agricultural machinery management is the section of farm management that deals with the optimization ofthe equipment phases of agricultural production. It is concerned with the efficient selection, operation, repair and maintenance, and replacement of machinery.

The Course is organized as follows:

No	Blocks	Units
1.	Farm Power and Machinery	1. Farm power and tractors 2. Tillage and Tillage machinery 3. Sowing, Planting and Intercultural Equipment
2.	Agricultural equipments industry and Cost analysis of operations	1. Agricultural equipments industry 2. Cost analysis of operations

VI. Theory

Block 1: Farm Power And Machinery

Unit 1: Farm power and tractors: Farm power in India - sources, IC engines – working principles, two stoke and four stoke engines, IC engine terminology, different systems of IC engine. Tractors – types and utilities.

Unit 2: Tillage and Tillage machinery: Tillage – ploughing methods – primary tillage implements – mould board, disc plough and chisel plough – secondary tillage implements –cultivators, harrows and rotovators – wetland equipment – puddlers, tramplers and cage wheels.

Unit 3: Sowing, Planting and Intercultural Equipment: Sowing methods – seed drills, seed cum fertilizer drills – Paddy transplanters – nursery requirements – implements for intercultural operations – wet land, dry land and garden land intercultural tools. **P**lant Protection Gadgets, Harvesting Machinery and Horticulture tools: Plant protection equipment, tools for horticultural crops.

Block 2: Agricultural Equipments Industry and Cost Analysis Of Operations

Unit 1: Agricultural equipments industry: Agricultural equipments production, marketing and constraints; establishment of agricultural engineering enterprises (agro service centers, etc.). Equipment for land development and farm machinery selection: Equipment for land development and soil conservation.

Unit 2: Cost analysis of operations: Cost analysis ofoperations using different implements, economic performance of machines, optimization of tractor implements system and transport of farm produce. Cost of operation of farm machinery – Tractor and implement selection

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To equip the students with sufficient theoretical knowledge and practical skills about farm power and tractor power, implement resources used in agriculture, their cost of operation and selection.

IX. Suggested Reading

- Senthilkumar T, Kavitha R and Duraisamy VM. 2015. *A text book of farm machinery*, Thannambikkai Publications, Coimbatore.
- Jagadishwar S. 2010. *Elements of agricultural engineering*. Standard Publishers Distributors, New Delhi.

I. Course Title : Food Retail Management

II. Course Code : ABM 518

III. Credit Hours : 2+0

IV. Why this course?

Study a short *course* in *Retail Management* to learn how to run a retail store or department efficiently and to introduce you to key issues and concepts associated with the *retail* environment. Topics covered in the *course* typically include business administration, visual merchandising, and marketing.

V. Aim of the course

Identify the most dramatic change in food retailing today; Assess the variety and Define a target market; Explain why a retailer would want to meet the needs of a Customer. Describe the steps to recruiting top talent; Identify selection and training.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to Food market 2. Value Chain in Food Retailing
2.	Retail Marketing Strategy	1. Marketing Mix in Food Retail Management 2. Managing Retail Operations 3. Retail Sales Management

VI. Theory

Block 1: Introduction

Unit 1: Introduction to Food market: Introduction to International Food market, India's Competitive Position in World Food Trade, Foreign Investment in Global Food Industry, Retail management and Food Retailing, The Nature of Change in Retailing, Organized Retailing in India, E-tailing and Understanding food preference of Indian Consumer, Food consumption and Expenditure pattern, Demographic and Psychographic factors affecting Food Pattern of Indian Consumer.

Unit 2: Value Chain in Food Retailing: Value chain and value additions across the chain in food retail, Principal trends in food wholesaling and retailing, Competition and pricing in food retailing, various retailing formats, the changing nature of food stores, market implications of new retail developments, food service marketing.

Block 2: Retail Marketing Strategy

Unit 1: Marketing Mix in Food Retail Management: Merchandise Management, Pricing Strategies used in conventional and non-conventional food retailing, Public distribution system, Promotion mix for food retailing, Management of sales promotion and Publicity, Advertisement Strategies for food retailers & Brand Management in Retailing.

Unit 2: Managing Retail Operations: Managing Retailers' Finances, Merchandise buying and handling, Logistics, procurement of Food products and Handling Transportation of Food Products.

Unit 3: Retail Sales Management: Types of Retail Selling, Salesperson selection, Salesperson training, Evaluation and Monitoring, Customer Relationship Management, Managing Human Resources in retailing, Legal and Ethical issues in Retailing.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

It will equip the students with desired knowledge and skills for managing food retail operations.

IX. Suggested Reading

- Singh S. 2011. *Fresh food retails in India: Organisation and impacts,* Allied publishers Pvt. Ltd., New Delhi
- Mahapatra. S, *Food Retail Management*, Kalyani Publishers
- Zentes, Joachim, Morschett, Dirk, Schramm-Klein, Hanna 2017. *Strategic Retail Management: Text and International Cases,* Springer Gabler.
- Agrawal N and Smith SA. 2015. *Retail Supply chain Management: Quantitative Models and Empirical Studies,* Springer; 2nd revised edition.

I. Course Title : Management of Agricultrual Input Marketing

II. Course Code : ABM 519

III. Credit Hours : 2+0

IV. Why this course?

It will help in gaining a deeper understanding of the four P's of marketing as applied to agricultural input marketing and an exposure to social and ethical issues is oriented in the course.

V. Aim of the course

The present course aims at familiarizing the participants with various aspects of agricultural input marketing in India.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Market for agricultural inputs
2.	Marketing of Agricultural Inputs	1. Marketing of seeds 2. Marketing of fertilizers 3. Marketing of pesticides 4. Marketing of tractors

VI. Theory

Block 1: Introduction

Unit 1: Market for agricultural inputs: Nature of demand, promotional media, nature of competition, a framework for understanding the markets for inputs, agronomic potential, agro economic potential, effective demand, actual consumption.

Block 2: Marketing of Agricultural Inputs

Unit 1: Marketing of seeds: Government policy, product, trade practices in seed production, seed pricing, input costs, distribution system, management of seed distribution. proper storage of seeds, promotion, problems faced by seed industry, strategy for a seed enterprise, source of seeds, terms of transaction for seed procurements.

Unit 2: Marketing of fertilizers: Nature of Indian fertilizer market, product, fertilizer distribution, marketing cost and margins, credit, dealer selection and management, fertilizer promotion and extension, promotional program, advertising in fertilizers, emerging marketing mix in fertilizer, extension strategy for the future, marketing of biofertilizers, strategies for fertilizer marketing.

Unit 3: Marketing of pesticides: Market profile, structure of industry, farmer behaviour, problems of farmers in pesticide purchase and usage, marketing mix, bio pesticides market development and promotion activities, problems in marketing of bio pesticides. Integrated pest management.

Unit 4: Marketing of tractors: Segments in tractor market, market share, nature of demand, buyer behaviour, role of distribution, promotion, MNC's. Marketing of credit-Nature of market, market segment, market players, marketing mix, marketing options. Strategies for input marketing-Client and location specific promotion, joint promotion, interdependence of input markets, management of demands, developmental marketing, usp, extension services, ethics in business, sustainability.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To enhance the understanding and analytical capabilities with respect to products, market environment, and operational issues in marketing of agricultural inputs.

IX. Suggested Reading

- Mahapatra. S. *Management of Agricultural Inputs*, NIPA Publishers
- Seetharaman SP.: *Agricultural Input Marketing,* Oxford & IBH Pub. Co.
- Krishnamacharyulu CSG. : *Rural Marketing: Text and Cases*, Pearson Education India Venugopal P. 2014. *Agri-input Marketing in India,* SAGE Publication; 1st Edition.

I. Course Title : Feed Business Management

II. Course Code : ABM 520

III. Credit Hours : 2+0

IV. Why this course?

It will help in gaining a deeper understanding of the production, processing and marketing of cattle feed, poultry feed and fish feed.

V. Aim of the course

The present course aims at familiarizing the participants with various aspects feed for livestock and poultry.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Feed resources 2. Nutrients requirements of livestock and poultry
2.	Feed Preparation and Distribution	1. Feed preparation 2. Importance of mineral mixture 3. Feed Distribution

VI. Theory

Block 1: Introduction

Unit 1: Feed resources: Gap between demand and availability of nutrients; status of feed industry in India and world, constraints in the development of Indian feed industry.

Unit 2: Nutrients requirements of livestock and poultry: Knowledge about the quality of feed ingredients used in feed manufacturing. Procurement procedure of feed ingredients, scientific storage of feeds and feed ingredients. BIS, CLAFMA and all other commercial standards of all class of livestock and poultry feeds.

Block 2: Feed Preparation and Distribution

Unit 1: Feed preparation: Layout and design of feed plants, feed plant management; Basic principles of processing of feeds, Feed preparation for cattle and poultry and as specialty feeds for aqua and pet animals.

Unit 2: Importance of mineral mixture: Feed additives, supplements and pass feed, to know the new technology regarding improving the feeding value of poor quality roughages. To acquaint the concept of silage technology, complete feed block technology, hydroponics technology and UMMB technology.

Unit 3: Feed Distribution: Distribution channels, regulations relating to manufacture and sale of feed stuffs.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To acquaint the students with the role and importance of feed industry and the production of feed for livestock and poultry.

IX. Suggested Reading

- Morrison FB. 1961. *Feeds and Feeding*, Abridged, Morrison Publishing; 9th edition John.
- Moran. 2005. Tropical Dairy Farming: Feeding Management for Small Holder Dairy Farmers in the Humid Tropics, Csiro Publishing.
- Moran J and McDonald S. 2010. *Feedpads for Grazing Dairy Cows,* Csiro Publishing.
- Kellems RO and Church DC. 2009. *Livestock Feeds and Feeding*, Pearson; 6th Edition

I. Course Title : Managmement of Veterinary Hospitals

II. Course Code : ABM 521

III. Credit Hours : 2+0

IV. Aim of the course

It will help in gaining a deeper understanding of the Veterinary Science is the science of *treating* and curing the diverse types of Animals.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Feed resources 2. Nutrients requirements of livestock and poultry
2.	Feed Preparation and Distribution	1. Feed preparation 2. Importance of mineral mixture 3. Feed Distribution

V. Theory

Block 1: Veterinary Hospital Administration

Unit 1: Needs, aims and objectives: Objectives of Veterinary hospitals; the existing and simulated situations under which veterinary hospitals work or are to work.
Unit 2: Designing and planning an ideal hospital: Optimizing the use of resources - human, space, equipment, drugs, time, capital, etc.; Materials management and problems Normal purchase procedure. Receipt; storage and distribution of materials Cost reduction & scientific inventory control. Information system and materials management performance. Equipment maintenance, condemnation & disposal.
Unit 3: Authority, responsibility: Accountability of management for optimizing the use of skill, developing and upgrading skills and technology; efficient system of record keeping and accounting; Concept of quality & Total quality management (TQM) Introduction to Veterinary audit, Statistical quality control (SQC), Quality control Circle (QCC).

Block 2: Information System & Quality Control

Unit 1: Hospital information system: Hospital information system as an aid to efficient controlling and monitoring; need for financial resources - investment and working capital; Records: Types & Methodology, Reports and Reporting system. Contemporary and need-based methods of accounting; General consideration. Need based information system. Applicability in surveillance & monitoring; planning & policy making; cost control.
Unit 2: Quality control system: Economic functions and quality control system; Animal health Economics: An introduction Need for financial resources (type and need). Investment planning and working capital; Budgeting and cost cutting (cost control). legal aspects in the functioning of the hospital.

VI. Learning outcome

The objective of this course is to acquaint the students about the designing, planning, organizing, and controlling the veterinary hospitals for optimizing the use of space, capital, skill and other resources.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

I. Course Title : Poutlry and Hatchery Management
II. Course Code : ABM 522
III. Credit Hours : 2+0

IV. Why this course?

This course introduces about updated production standards achievable under field conditions and financial viability of poultry operations. This specialized course is designed to train persons in Incubation and Hatchery Management and is meant for those engaged in or scheduled to take up Hatchery operations.

V. Aim of the course

To give the opportunity for trainees to learn about raising chickens for their meat and eggs in order to manage a small-scale, commercial poultry enterprise that will be profitable

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Poultry and hatchery Business 2. Poultry and hatchery unit
2	Hatcheries and Risk Management	1. Incubation and hatching 2. Franchise hatcheries management 3. Personal management and insurance

VI. Theory

Block 1: Introduction to Poultry and Hatchery Industry

Unit 1: Poultry and hatchery Business: Poultry and hatchery industry; Present scenario of Poultry industry, Integration in poultry farming, Scope and future perspective, role of management in poultry industry.

Unit 2: Poultry and hatchery unit: Planning and establishing a poultry and hatchery unit- location, size and construction; farm and hatchery equipments and physical facilities; organizing and managing a poultry farm and hatchery.

Block 2: Hatcheries and Risk Management

Unit 1: Incubation and hatching Production of quality chicks and eggs; factors affecting hatchability; bio-securityand hatchery sanitation; handling of hatching eggs; maintaining chick quality-chick grading, sexing, packing, dispatch, transportation and chick delivery.

Unit 2: Franchise hatcheries management: Custom hatching; brooding; growing and laying management; crisis management; industrial breeding, feeding, housing and disease management; waste management; Record management; cost accounting and budgetary control.

Unit 3: Personal management and insurance: Labour relations including wages and salaries, job evaluation and employee appraisal; marketing management direct sale and sale through franchisees/ agents, advertisement, sale and after sale services, other innovative sales strategies.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

The course provides an insight into the importance of management in poultry industry, managing a poultry and hatchery enterprise, planning production of poultry products, financial, personnel and marketing management.

IX. Suggested Reading

- Handbook of Poultry Science.
- Rathinam GK. 2015. *Manual of Hatchery Management: For Poultry Professionals* Hardcover.

I. Course Title : Management of Floriculture and Landscaping

II. Course Code : ABM 523

III. Credit Hours : 2+0

IV. Why this course?

It deals with the cultivation of flowers and ornamental crops from the time of planting to the time of harvesting. It also includes production of planting materials through seeds, cuttings, budding, grafting, etc, up to the marketing of the flower and flower produce.

V. Aim of the course

The objective of this course is to expose the students with floriculture and landscaping technologies and their Agri-business implications including international trade.

The Course is organized as follows:

No	Blocks	Units
1.	Management of Floriculture	1. Introduction 2. Indoor and ornamental plants
2.	Landscaping and Trading	1. Introduction 2. Landscape gardening 3. Value-addition in floriculture

VI. Theory

Block 1: Management Offloriculture

Unit 1: Introduction: Introduction, importance and scope of floriculture industry and landscaping; Recent advances in floriculture industry.

Unit 2: Indoor and ornamental plants: Raising of foliage plants in pots, production technology of ornamental plants, commercial cultivation of flower crops (rose, jasmine gladiolus, tuberose, marigold, aster, carnation, gerbera, cilium chrysanthemum; special techniques for forcing of flowers for export.

Block 2: Landscaping and Trading

Unit 1: Introduction: Drying and dehydration of flowers; bonsai; scope of landscaping, response of flowering plants to environmental stresses;

Unit 2: Landscape gardening: Styles of gardening; modern and traditional garden planning; Socio-aesthetic planning; use of computers in designing gardens; planning towns

Unit 3: Value Addition in floriculture: Extraction, purification and storage of essential oils and perfumes; post-harvest storage changes; packing techniques of produce harvesting of flowers for export and home use, Export-Import trade in flowers and their specifications along major trading countries.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Students are suitable for it working independently and apply the latest trends to their work. They should be able to understand about floriculture and landscaping.

IX. Suggested Reading

- Banker N. 2011. *Landscape gardening*, IBDC publishers, Lucknow
- Misra RL and Misra S. 2012. *Landscape gardening*, Westville Publishing House, New Delhi
- Chadha KL and Choudhary B. 2006, *Ornamental Horticulture in India*. ICAR. New Delhi
- Grindal EW. *Every Day Gardening in India*. DB Tarporevala Sons.
- Randhawa GS and Mukhopadhyay A. 1998, *Floriculture in India*. Allied Publ., New Delhi

I. Course Title : Risk Management in Agri Business

II. Course Code : ABM 524

III. Credit Hours : 2+0

IV. Why this course?

Risk and uncertainities is involved in food and Agribusiness industries. Government to formulate policy that will encourage investors adopt the highlighted risk keeping in view priority of food security for rising population. The focus is to foster profitability in agri-allied sector.

V. Aim of the course

Identification, mitigation and management of risk is unique to agriculture-production, markets, finance, Institutions and HR. Policy implications at local, regional, national as well as international level. Data analysis and research findings to help in decision making at firm and industry levels using history to guide future events/projection, Degree of risk varies in agri-business compared to other sectors.

The Course is organized as follows:

No	Blocks	Units
1.	Risk Management process	1. Financial intermediation 2. Strategic Issues in Bank Marketing 3. Credit policy in banks
2.	Introduction to banking Operations and Risk Management	1. Banking operations 2. Definition of Risk and risk management techniques

VI. Theory

Block 1: Risk Management Process

Unit 1. Financial Intermediation, Indian Financial system, Origin and Growth of Banking. RBI and its functions. Principles of Banking, Banking Law and Practice. Nationalization of Banks in India, Deposit Products, Lending Activities, Retail Banking, Wealth Management, Financing SMEs, Corporate Banking, Forex Management, Fee-Based & Subsidiary Services, Plastic Money, Role of Central Banks, Emerging Trends in Banking, Fundamentals of International Banking.

Unit 2: Strategic Issues in Bank Marketing, Positioning Bank Services in the Market, New Product Development, Pricing and Launching, New Distribution Channels for Bank Marketing, Communicating and Promoting Bank Services, Improving Quality and Productivity, Customer Relationship Management in Banks, Globalizing Bank Services, Opportunities and Challenges in Bank Marketing.

Unit 3: Credit Policy in Banks, Principles of Credit Management, Objectives of Credit Management, Credit Disbursal and Monitoring, Credit Deployment and

Types of Borrowers, Follow up and Recovery Management, Treasury Operations, Introduction to Risk Management in Banks, Rural Banking in India, Security Considerations, Control System in Banks, Corporate Governance in Banks, Annual Reports and Statutory Audit.

Block 2: Introduction to Banking Operations and Risk Management

Unit 1: Introduction to Banking Operations, Front Office and Back Office Operations, Operational Controls, Demand Forecasting and Resource Allocation, Policy Framing – Deposits, Advances and Investments, Services Design and Delivery Strategies in Banks, Service Quality Metrics, Work Measurement and Quality Assurance, Payment and Settlement Systems, RTGS and Clearing House, Cash Management Services, Facilities Planning, ERP in Banks, BPR in Banks, IT Enabled Supply Chain Management, Disaster and Recovery Management.

Unit 2. Introduction to Risk, Risk Management Essentials, Measurement of Risk, Loss Exposure, Risk Management – Non-insurance Techniques, Introduction to Insurance, Principles of Insurance, Insurance Industry, Insurance Market, Insurance as Risk Management Techniques, Selection and Implementation of Risk Management Techniques.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Developing an understanding of the different types of risk in general to agriculture sector and with special reference to agriculture business.

IX. Suggested Reading

- Sethi J and Bhatia N. 2012. *Elements of Banking and Insurance*. PHI Learning
- Jian W and Rehman A. 2016. *Risk Management in Agriculture: Theories and Methods.* Science Publishing group
- Hardaker JB, Huirne RBM, Anderson JR and Lien G. 2004. *Coping With Risk in Agriculture,* CABI Publishing, 2nd Edition
- Rose PS and Hudgins SC. 2006. *Bank Management & Financial Services.* Mcgraw-Hill College; 7th edition

I. Course Title : Management of Agribusiness Cooperatives

II. Course Code : ABM 525

III. Credit Hours : 2+0

IV. Why this course?

Proper management enables **c**ooperatives to offer high quality, efficient and effective services to their members. Moreover, well managed agricultural cooperatives can also contribute to wider development issues such as food security, sustainable use of natural resources and inclusive employment creation.

V. Aim of the course

These cooperatives were usually initiated by small scale farmers, as a response to their weak position in the market. By joining forces they could improve this position and obtain better prices and services for the purchase of inputs and the marketing of produce.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Cooperative administration 2. Cooperative management
2.	Cooperative Movement and Management	1. Cooperative Movement 2. Human resource management 3. Overview of agribusiness cooperative

VI. Theory

Block 1: Introduction

Unit 1: Cooperative administration: Global perspective, ecology of cooperative administration, cooperative sector and economic development.

Unit 2: Cooperative management: Nature, functions and purpose of cooperatives –procurement, storage, processing, marketing, process of cooperative formation, role of leadership in cooperative management.

Block 2: Cooperative Movement and Management

Unit 1: Cooperative Movement: The state and cooperative movement, effects of cooperative law in management, long range planning for cooperative expansion, policy making.

Unit 2: Human resource management: Placement and role of board of directors in cooperative management.

Unit 3: Overview of agribusiness cooperative: Credit cooperatives, cooperative marketing, dairy cooperative; financing agribusiness cooperative.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide the students an understanding about the agribusiness cooperative organizations and their management.

IX. Suggested Reading

- Kamat GS. 2011. *New Dimensions of Cooperative Management*. Himalaya Publ. House.
- Ansari AA. 1990. *Cooperative Management Patterns*. Anmol Publ.
- Ravichandran and Nakkiran. 2009. *Cooperation* (*Theory & Practice*) Neha Publishers & Distributors;
- Sah AK. 1984. *Professional Management for the Cooperatives*. Vikas Publ. House.
- Anwar SA. *HRM Practise in Cooperative Sector*. Idea Publishing.

I. Course Title : Business Analytics for Agriculture

II. Course Code : ABM 526

III. Credit Hours : 1+1

IV. Why this course?

Analytics can enble farmers to make data-based decisions like which crops to plant for their next harvest. Reality as actionable insights to make decisions on data and information to improve agronomic opportunities, such as timing of applications, product decisions, amounts of products, and profitability of decision making.

V. Aim of the course

To make the students understand the concepts of data science tools and techniques and develop the skills for using it strategically and for the developing of the agri business sector.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction 2. Fundamentals of Research
2.	Machine and Deep Learning	1. Supervised machine learning-1 2. Supervised machine learning-2 3. Deep learning

VI. Theory

Block 1: Introduction

Unit 1: Introduction to data science, evolution of data science, work profile of a data scientist, career in data science, nature of data science, typical working day of a data scientist, importance of data science in agribusiness; defining algorithm, big data, business analytics, statistical learning, defining machine learning, defining artificial intelligence, data mining; difference between analysis and analytics, business intelligence and business analytics, typical process of business analytics cycle.

Unit 2: Fundamental of Research

Fundamentals of R and RStudio, fundamentals of packages of RStudio, data manipulations, data transformations, normalization, standardization, missing values imputation, dummy variables, data visualization (2D and 3D), basic architecture of machine learning analytical cycle, descriptive analytics-case study covering data manipulation, measures of central tendency, measures of dispersion, measures of distribution, measures of associations, t-test, f-test, ANOVA, Chi-square test, basic statistical modeling framework.

Block 2: Machine and Deep Learning

Unit 1: Supervised machine learning: Basic framework, regression models and classification models. Linear regression, nonlinear regression, multiple regression, polynomial regression, lasso regression, ridge regression, stepwise regression, quantile regression, logistic regression.

Unit 2: Supervised machine learning: Linear discriminant analysis, principal component analysis, factor analysis, support vector machines, naïve Bayes, nearest neighbors, decision trees, random forest, ensemble methods, *k*-fold cross validation, X gradient boosting. Unsupervised machine learning—basic framework, concept of clustering, k-means, c-means, hierarchical clustering, hidden markov models, forecasting models (AR, MA, ARMA and ARIMA).

Unit 3: Deep learning: Basic framework of neural nets, types of neural nets, computer vision, object detection and localization, gradient descent optimization for loss function, regularization L1 and L2, feed forward neural nets, back propagation, recurrent neural nets, convolutional neural nets, reinforcement neural net, concurrent net, introduction to IoT. All the illustrations used in the syllabus of Data Science in Agribusiness will be primarily from agribusiness domains and RStudio will be used for practical purposes.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To equip students of agribusiness with knowledge, skills and attitude for using data science tools and techniques so that agribusiness get competent professionals who can strategically and successfully implement data science applications.

IX. Suggested Reading

- *Deep Learning with R*. MEAP Edition, Manning Early Access Program. Version 1, © 2017, Manning Publication.
- James RG, Witten D, Hastie T and Tibshirani R. 2017. *An Introduction to Statistical Learning with Application.* Springer Publication
- Millstein F. 2018. *Machine Learning With Tensorflow: A Deeper Look At Machine Learning With Tensor Flow* Frank Millstein
- Stanton J. 2012. *Introduction to Data Science.* Version 3, SAGE Publications, Inc.

I. Course Title : Dairy Business Management

II. Course Code : ABM 527

III. Credit Hours : 1+0

IV. Why this course?

The main objective of dairy management course is to provide basic input to students about production, planning and management of dairy farms, entrepreneurship development in milk preservation, entrepreneurship development in dairy processing and management of dairy farm, co-operative and industry.

V. Aim of the course

To emphasize on the application of Principles of Management in dairy business with special emphasis on co-operative dairy units. The emphasis shall be on main functional areas like Finance, Marketing, Human Resources, Production and Information Technology.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to commodity derivatives 2. Dairy Plant Management System
2.	Dairy Business Strategy:	1. Marketing Management, Supply Chain and International Trade in Dairy sector 2. Strategic, HR Management and Entrepreneurship in Dairy Sector 3. Financial Management and Financial Analysis in dairy sector

VI. Theory

Block 1: Introduction

Unit 1: Dairy Development in India: Dairy organizations: functioning, Challenges and Opportunities, Anand pattern dairy Cooperatives: features and impact; Public sector dairy schemes, Dairy Development schemes, Dairy problems and policies, National Dairy Plan-I, Rise of Producer Companies. Policy Frameworks in context to dairying.

Unit 2: Dairy Plant Management System: Production Planning and control in dairy plants, milk procurement from the rural milk producer, milk processing and products manufacturing. Pricing and marketing of milk and milk products. Survey on milk production potential and marketed surplus of milk for setting up of milk plants, energy utilization, Conventional and nonconventional sources of energy used in dairy sector. Concept of Quality; TQM concept and Kaizen in Dairy Industry, new concepts in quality assurance (HACCP; ISO certification); patent laws, pollution control laws in relation to dairy plants. Guidelines for obtaining ISO/HACCP certification for dairy plants. SQC in dairy operations.

Block 2: Dairy Business Strategy:

Unit 1: Marketing Management, Supply Chain and International Trade in Dairy sector: Marketing- mix in relation to dairy sector, marketing environment,. Marketing Opportunities Analysis in Milk and Milk Products: Demand status of Milk and milk products in the country, growth rates, Marketing research and marketing information systems; Market measurement present and future demand; Market forecasting. Market segmentation, Product-mix; Promotion mix decisions. Advertising; Sales Promotion. Food and Dairy Products Marketing, Consumer Buying Behaviour; New product development processPrice determination and pricing policyInternational Marketing Marketing; Composition & direction of Indian exportsExports- Direct exports, indirect exports; WTO and its Implications; SPS/TBT; Supply chain Management in Dairy sectorLogistics Management: Primary and Secondary Markets; Distribution channels; chilling points

Unit 2: Strategic, HR Management and Entrepreneurship in Dairy Sector: PESTLE analysis, BCG matrix, Strategic Management in dairy industry, Governance Structure in Dairy Sector, Management control System. Organisational Performance parameters – Quantitative and Financial, Use of Balanced Score card and other strategy control tools. HR management practices in dairy sector, Promotions, transfers employee remuneration and other HR benefits and problems. Motivation, turnover, employee capacity building, Training and orientation etc. social and business economics; industrial relations and human values; labour laws; trade unionism Business Plan Preparation; TIDP plant setting; Compliances Systems in Dairy Industry

Unit 3: Financial Management and Financial Analysis in dairy sector: Nature and uses of financial analysis, Liquidity ratios, Leverage ratios, Activity ratios, Profitability ratios, Utility of Ratio analysis. Sources of long term capital in dairy Industry: Grants from NDDB, Grants from NABARD, Government and Other Schemes, cost of debt, debentures, preference share capital, equity share capital & retained earnings, overall cost of capital. Capital budgeting in dairy Industry. Various techniques: NPV, IRR, etc. Financial Planning and control in dairy Industry: Budgeting process, Problems and practices in Budgeting and evaluation. Cost Volume

– Profit analysis and operating leverage, Break-even analysis, Profit analysis and operating analysis, Utility of CVP analysis. Costing in Dairy sector: Costing Techniques and Costing of various dairy products – Milk costing based on Fat and SNF, Ice cream, milk, Paneer, etc. Essentials of sound costing system. Different methods of costing, elements of cost: Labour- recording of time, idle time, methods of remunerating labour, Premium & Bonus Plans, Materials, Overheads.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

- To understand the overall scenario of dairy and develop insights in managing dairy as a entrepreneurial venture.
- To enhance the Decision making, Critical thinking and the problem solving capabilities of the students.
- To bring out the hidden potential and entrepreneurship aptitude of the students and also to encourage team building activities.

IX. Suggested Reading

- Acharya R M and Kumar P. *Dairy Production & Business Management* EIRI, Dairy Darming
- Rao Venkateswara, *Dairy Farm Busines Management*
- Singh Umashankar, *Dairy Farming*

I. Course Title : Agri Extension Management

II. Course Code : ABM 528

III. Credit Hours : 1+0

IV. Why this course?

To enhance the techno-managerial competence of extension functionaries and to acquaint the extension functionaries on the latest developments in the field of agricultural extension

V. Aim of the course

To equip the extension functionaries in latest tools and techniques for participatory decision making and to develop an insight into various extension models to enrich the agri - value chain

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Approaches of Agricultural Extension 2. Cyber Extension
2.	Implications and contemporary issues	1. Implications of WTO 2. Extension and contemporary issues

VI. Theory

Block 1: Introduction

Unit 1: Approaches of Agricultural Extension: A critical analysis of different approaches of agricultural extension. Importance and relevance of indigenous knowledge system, identification and documentation of ITK, Integration of ITK system in research formulation, Concept of Agricultural Knowledge and Information System, Training of Stakeholders of AKIS.

Unit 2: Cyber Extension: Concept of cyber extension, national and international cases of extension projects using ICT and their impact of agricultural extension, alternative methods of financing agricultural extension - Scope, limitations and experience and cases. Research -Extension -Farmer - Market linkage: Importance, Scope, Implications etc., Market – Led Extension, Farmer - Led Extension, Concept of Farm Field School, Farm School, Public - Private Partnership: Meaning, Models, Identification of various areas for partnership. Stakeholder's analysis in Extension. Main streaming gender in Extension - Issues and Prospects

Block 2: Implications and Contemporary Issues

Unit 1: Implications of WTO: OA for extension services, re-orientation of extension services for agri-business and marketing activities, GOI- NGO collaboration to improve efficiency of extension.

Unit 2: Extension and contemporary issues: Extension and issues related to rural poverty. Privatization of Extension. Intellectual Property Rights (IPRs). Extension Reforms in India –Decentralized decision making, Bottom up planning, Farming System and Situation based Extension Delivery System, Extension delivery through Commodity Interest Groups. Organization innovations in Extension - ATIC, IVLP, Kisan Call Centres.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

By the end of the course student will be able to critically analyze different Agricultural Extension approaches, understand Agricultural Knowledge Information System (AKISs) ITK, Understand Advances in Extension - Cyber extension, ICT enabled extension services; Market Led Extension, Public Private Partnership, Mainstreaming gender in extension organizational Innovations.

IX. Suggested Reading

- Bagchi J. 2007. *Agriculture and WTO Opportunity for India*.
- Sanskruti Chambers R, Pacy A and Thrupp LA. 1989. *FarmersFirst*. Intermediate Technology Publ.
- Crouch BR and Chamala S. 1981. *Extension Education and Rural Development*. Macmillan.
- John KC, Sharma DK, Rajan CS and Singh C. 1997. *Farmers Participation in Agricultural Research and Extension Systems*. MANAGE, Concept Publ. Co.
- Khan PM. 2002. *Text Book of Extension Education*. Himanshu Publ.
- Narasaiah ML. 2005. *Agricultural Development and World Trade Organization*. Discovery Publ.
- Talwar S. 2007. *WTO Intellectual Property Rights*. Serials Publ.
- Van den Ban BW and Hawkins BS. 1998. *Agricultural Extension*. S.K. Jain Publ.
- Venkaiah S. 2001. *New Dimensions of Extension Education*. Anmol Publ.

I. Course Title : Renewable Energy Sources Management

II. Course Code : ABM 529

III. Credit Hours : 1+0

IV. Why this course?

Renewable Energy Management will contribute to the promotion of renewable energy sources in countries, especially developing nations.

V. Aim of the course

The course aims to provide fundamental clarity regarding various renewable&alternative energy sources/ technologies options available today, its usage potential & related aspects like cost, impact on environment, etc.

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Introduction 2. Commercial application
2	Implications and contemporary issues	1. Institutional Framework 2. Devices for renewable energy development

VI. Theory

Block 1: Introduction

Unit 1: Introduction: Concept on alternate and non-conventional energy sources. Biofuels, Geothermal, Ocean, Hydropower, Biogas, Solar and Wind energy.

Unit 2: Commercial application: Commercial application of renewable energy sources and its benefits. Government Policy towards promoting renewable energy.

Block 2: Institutional Framework and Types

Unit 1: Institutional Framework: MNRE, CREDA-Renewable Energy Development Authority, State level Renewable Energy Development Agency, Society of Renewable Energy.

Unit 2: Devices for renewable energy development: Biogas plant, Wind Mills, Solar Cells – Solar Pumps, Solar Dryers, Solar water heating system, etc.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide an insight to the meaning and concepts of Renewable energy resources development and Institutional support as well as Government policy framework.

IX. Suggested Reading

- Sorensen B. 2010. *Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning*, Elsevier Publishing; 4th Edition
- Armaroli N, Balzani V and Serpone N. 2013. *Powering Planet Earth–Energy Solutions for the Future*, Wiley
- Boyle G. 2012. *Renewable Energy: Power for a Sustainable Future*, Oxford; 3rd Edition
- Twidell J, Weir T. 2013. *Renewable Energy Resources,* CRC Press; 3rd Edition
- Ahmed AI. *Renewable Energy Sources* by Jain Brothers

I. Course Title : Quality Management for Agribusienss

II. Course Code : ABM 530

III. Credit Hours : 1+0

IV. Why this course?

The focus of the process is to improve the quality of organizations outputs, including goods and services, through continual improvement of internal practices

V. Aim of the course

The course will help the students to have an understanding of the quality standards in agribusiness.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Basic concepts of quality management 2. TQM
2.	Quality grades, standards and Control	1. Quality grades and standards 2. Statistical to quality control 3. Food quality standards

VI. Theory

Block 1: Introduction

Unit 1: Basic concepts of quality management: importance of quality and the role of quality assurance in agribusiness.

Unit 2: Total Quality Manangement: TQM and business strategy. Quality control process and its relevance.

Block 2: Quality Grades, Standards And Control

Unit 1: Quality grades and standards: Overview and relevance, benefits to consumers, producers and food processors, food grades and standards for various food commodities; cereals, fruits and vegetables, meats, poultry products.

Unit 2: Statistical to quality control: Statistics relevant to quality control, quality control charts used in the food industry, process control to assure food quality, food processing.

Unit 3: Food quality standards: Food quality standards and world food trade. HACCP, ISO9000, auditing and certification.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

The course will help the students to have an understanding of the quality standards in agribusiness.

IX. Suggested Reading

- Luning PA, Marcelis WJ. 2009. *Food Quality Management: Technological and Managerial Principles and Practices*. Wageningen Academic Publishers
- Dale BG. 2004. *Managing Quality*. Blackwell Resources

I. Course Title : Advertising and Brand Management

II. Course Code : ABM 531

III. Credit Hours : 1+0

IV. Why this course?

To impart basic understanding among the candidates about the advertising along with detailed aspects of brand management practices and techniques.

V. Aim of the course

It aims to ensure consistency of message and the complementary use of media. ... measurable, persuasive brand communication programs with consumers.
The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to Advertising Management 2. Message Strategy 3. Consumer Promotions and Trade Promotions
2.	Branding Decision	1. Major Brand Concepts and branding Decision 2. Managing Brand Equity and Loyalty

VI. Theory

Block 1: Introduction

Unit 1: Introduction to Advertising Management: Integrated Marketing Communications, Setting Goals and Objectives, How advertising works: Segmentation and Positioning Assess the strengths, weaknesses, opportunities and threats (SWOT) of different kinds of promotional campaigns

Unit 2: Message Strategy: Attention and comprehension, Advertising appeals, Associating Feelings with the Brand, Brand Equity, Image and Personality and Group Influence and word of month advertising, Media Planning and Media Strategy, Media Strategy and Tactics, Legal, Ethical and Social concerns of Advertising.

Unit 3: Consumer Promotions and Trade Promotions: Their purpose and types How to plan and evaluate a successful promotion, The relationship between advertising and promotions, Introduction to Global Marketing, Advertising and sales promotion.

Block 2: Branding Decision

Unit 1: Major Brand Concepts and branding Decision: Identifying and selecting brand name Building brand personality, image and identity; Brand positioning and re-launch; Brand extension; Brand portfolio; communication for branding Enhancing brand image through sponsorship and even management.

Unit 2: Managing Brand Equity and Loyalty: Brand Building in Different Sectors - Customers, industrial, retail and service brands. Building brands through Internet, social Media. Building Indian brands for global markets.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

This course investigates various promotional tools used in the communication mix, such as advertising, sales promotion, and publicity, to sell products and services. Concepts include: advertising planning processes, determining advertising and promotional goals and objectives, control and evaluation of advertising and promotional programs, and regulatory issues. Students will develop a comprehensive advertising campaign for a real or imaginary product.

IX. Suggested Reading

- Keller KL. *Strategic Brand Management;* Pearson education, New Delhi Verma, Harsha*: Brand Management;* Excel Books; New Delhi
- Kapferer JN. *Strategic Brand Management;* Kogan Page; NewDelhi
- Kumar S. Ramesh; *Marketing and Branding–The Indian Scenario;* Pearson Education; New Delhi Kapoor, Jagdeep; *24 Brand Mantras*, Sage Publications; New Delhi
- Sengupta S. *Brand Positioning: Strategies for competitive advantage*; Tata McGrawHill; New Delhi.
- Clifton R and Simmons J. *Brands and Branding*; The Economist; Delhi

I. Course Title : Agri Infrastructure and Waregousing Management

II. Course Code : ABM 532

III. Credit Hours : 1+0

IV. Why this course?

To create a pool of Agricultural storage infrastructure, logistics and warehouse professionals with capacity to manage agri-warehouse operations efficiently includes the overall inventory turnover and working capital management.

V. Aim of the course

The course provides an introduction to the key principles and activities related to the warehousing function in a modern organization designed for receiving, shipping, picking, packing etc. It also includes cold chain project, logistics awareness & training programs.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Agricultural Infrastructure in India 2. Warehouse Functions: 3. Warehouse Types, Characteristics
2.	Warehouse Management	1. IT for Warehouse Management (WM): 2. Agri-warehousing Management in India

VI. Theory

Block 1: Introduction

Unit 1: Agricultural Infrastructure in India: Incentive schemes, Agri-infra fund, Agri-market Infrastructure, Agri-technological infrastructure fund, Central Government policy on Infrastructure promotion for the development of primary sector such as Irrigation, Watershed development, Rural electrification, Connectivity, Communication and Markets in coordination with the Institutional framework.

Unit 2: Warehouse Functions: Meaning of Warehousing - Importance –Functions:

Receiving: Logistics support for Inward Transportation, Unloading, Inspection, Acceptance and Recording; Storing: Space allocation, Facilitation to stocking, Guarding &Recording; Risk bearing- Processing- Grading and branding – Disinfecting services -Issuing: Order preparation, Picking, Dispatching/ Delivery & Recording- Handling, Transportation & Storage of ISO Containers– Utility and Advantages of warehouses- Problems and issues in receiving processes.

Unit 3: Warehouse Types, Characteristics: Warehouse Types, Characteristics of ideal warehouses- Warehouse Layout-Principles and Facilities- Types, Internal Operations: Measures and metrics of warehouse operations, Logistics in the warehouse- Localization of materials in a warehouse, Identification and classification of Materials and products in the warehouse, Managing the material/products turns in warehouse (FIFO/LIFO) - Problems and issues in shipment processes. Warehousing Equipment, Inventory management.

Block 2: Warehouse Management

Unit 1: IT for Warehouse Management (WM): Warehouse documentation- Information flows in the warehouse- ERP-WMS - Bar code – RFID- Organization Data- Warehouse Structure- Warehouse Master Data - WM Material master view- Organization Data- Define Warehouse structure, Warehouse number - Storage type- Storage section - Storage Bin - Picking Area -Storage unit – Quantity- Creating Transfer requirement automatically/ manually – Creating Transfer requirement for storage.

Unit 2: Agri-warehousing Management in India: Agri-warehousing in India, capacity development and utilisation, Role and significance of Central Warehousing Corporation, State warehousing Corporation, Private sector in Agri-warehousing. Status of Warehousing Industry:

Agri-warehousing organisations in India, e-NAM to promote agri-warehouse.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To study the status of development of Agricultural infrastructure as well as the role of Warehouses to boost Agricultural sector.

IX. Suggested Reading

- Study materials of NABARD as well as by the Ministry of Rural development
- Edward F. 2001. *World-Class Warehousing and Material Handling,* McGrraw Hill
- Jeroen P. Van Den Berg. 2009. *Integral Warehouse Management*, Management Outlook Max Muller. 2009. *Essentials of Inventory Management*. AMACOM
- Steven M. Bragg. 2011. *Inventory Best Practices*. Wiley

I. Course Title : Contract Farming

II. Course Code : ABM 533

III. Credit Hours : 1+0

IV. Why this course?

To assess the need of Contract farming arrangement . It relates to agricultural production carried out according to an agreement between a buyer and farmers, with set conditions for production and marketing of farm products.

V. Aim of the course

The course provides an agreement between a farmer and a buyer. At the same time, the buyer also needs to provide the farmer with the necessary inputs required for the farm like land preparation, technical aspects etc. It is an effective means to develop markets and bring about crop rotation.

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Need for contract farming 2. Project formulation and management
2	Policies, prospects and global issues	1. Policies for promoting contract farming 2. Prospects of contract farming in India 3. Global issues

VI. Theory

Block 1: Introduction

Unit 1: Need for contract farming: objectives and its definition; contract farming framework, contract farming arrangement-centralized model, nucleus estate model, multipartite model, informal model, intermediary model.

Unit 2: Project formulation and management: Coordination, crop husbandry, human resource. Advantages of contract farming for farmers and sponsors and the problems faced by them.

Block 2: Policies, Prospects And Global Issues

Unit 1: Policies for promoting contract farming: Agreement for contract farming-parties, duration, produce and quality specification, delivery arrangements pricing, insurance, support services, etc.

Unit 2: Prospects of contract farming in India: Prospects of contract farming in India in view of interest for commercialization of agriculture. Active organizations in contract farming and their success stories.

Unit 3: Global issues: lobal issues in contract farming, Contract farming and WTO agreement

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide the students an understanding of concepts, policies, strategies and decisions relating to marketing that can be associated with agribusiness organizations. It involves agricultural production being carried out on the basis of an agreement between the buyer and farm producers. The farmer undertakes to supply agreed quantities of a crop or livestock product, based on the quality standards and delivery requirements of the purchaser.

IX. Suggested Reading

- Sharma P. 2007, C*ontract Farming*, Genetech Books

- Kuzilwa JA, Fold A, Henningsen A and Larsen MN. *Contractfarming and the development of smallholder* agricultural business. Routledge
- Kumaravel KS 2006. *Contract farming in India* - An Introduction.

I. Course Title : Human Resource Competence and Capacity Building Systems

II. Course Code : ABM 534

III. Credit Hours : 1+0

IV. Why this course?

Capacity development is the process by which individuals and organizations obtain, improve, and retain the skills, knowledge, tools, equipment and other resources needed for Human resource development.

V. Aim of the course

This course is designed to provide an in-depth understanding and enable the participants to manage capacity building processes and performance system for developing human resource.

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Human Resource competence 2. Competency modelling and assessment
2	Capacity building	1. Competency based training and development 2. Performance Management System 3. Capacity building systems in agriculture and agri business

VI. Theory

Block 1: Introduction

Unit 1: Human Resource competence: Concept and rationale; processes, Organization and Management of competence and competency mapping.

Unit 2: Competency modelling and assessment: Approaches, tools and techniques, competency based human resource management applications.

Block 2: Capacity Building

Unit 1: Competency based training and development: Training methods compared with objectives, learning process and facilities, Developing Group and the Climate: the social process – indicators of group development, the training climate, Trainers And Training Style: Post training support for improved performance at work.

Unit 2: Performance Management System: Establishing and operationalising performance management system; measuring performance- results and behaviour; conducting performance review discussions; harnessing performance management system for performance improvement.

Unit 3: Capacity building systems in agriculture and agri business: Capacity building of farmers and agri stakeholders through e-learning, knowledge management for agri business.

VII. Teaching methods/activities

- Lecture and Discussion

- Case Study
- PPT presentation

VIII. Learning outcome

Proactive human resources management is essential to achieve the excellence through Capability Development and Planning. A Competence Profile for Staff Supporting the formal and informal training, job-rotation, traditional class-room courses, internal vs external training.

IX. Suggested Reading

- Kandula SR. 2013. *Competency Based Human Resource Management*. PHI
- Noe RA and Kodwani AD. 2012. *Employee Training and Development*. McGraw Hill Education. Fifth Edition
- Saks AM and Haccoun RR. 2013. *Managing Performance through Training and Development*. Cengage Learning. Sixth Edition

I. Course Title : Agri-Commodity Markets and Futures Trading

II. Course Code : ABM 535

III. Credit Hours : 1+0

IV. Aim of the course

To make the students understand the marketing procedure for commodity futures through commodity exchanges

The course is organized as follows:

No	Blocks	Units
1.	Overview of Commodity Market in India	i. Price risk management in agricultural markets ii. Global Specifications of futures contracts
2.	Mechanics of futurestrading	i. Option and forward transaction ii. Clearinghouse and margin system
3.	Market surveillance and risk control	i. trading in warehouse receipts ii. Regulation of futures and trading practices in leading national and regional exchanges in India

V. Theory

Block 1: Overview Of Commodity Market In India

Unit I: Introduction to commodity derivatives and price risk management in agriculturalmarkets; organizational setup of exchanges and specifications of futures contracts in world's leading commodity exchanges

Block 2: Mechanics of Futures Trading

Unit II: Futures trading; hedging price risk using futures contracts; option transaction andforward transaction – concept and mechanism, price discovery mechanism and market efficiency

Unit III: Clearinghouse and margin system; clearing, settlement and delivery of contracts

Block 3: Market Surveillance and Risk Control

Unit IV: Market surveillance and risk control; trading in warehouse receipts (WRs):

WRs andcollateralized commodity financing

Unit V: Regulation of futures and trading practices in leading national and regional exchangesin India.

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Get an overview about the commodity markets in India
- Understand the mechanics of futures trading practices
- Know about the risk and surveillance mechanism available for agri commodity trading in India

VIII. Suggested Reading

- Hull, John C. 2017. *Fundamentals of futures and options markets*, Boston, Pearson publication.
- Ram PV and Bala SD. 2016. *Strategic Financial Management*. Snow White Publ. 80.

I. Course Title : Strategic Management for Agri Business Enterprises

II. Course Code : ABM 536

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to provide students a strategic orientation in conduct of the business and to develop a holistic perspective of an organization and to enable the students to analyse the strategic situation strategies in general and functional management areas.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Strategic Management	1. Strategic management process 2. Environment scanning and industry analysis 3. Value Chain Analysis
2.	Strategy Formulation and Choice	1. Strategy formulation 2. Types of strategies 3. Strategic analysis tools and techniques
3.	Strategy implementation and control	1. Strategy implementation and control 2. Entrepreneurial ventures and small businesses

V. Theory

Block 1: Overview Of Strategic Management

Unit I: Introduction - Concepts in Strategic Management, Strategic Management Process; Corporate Governance, Social Responsibility and Ethics in strategic management, Environment Scanning and Industry analysis

Block 2: Strategy Formulation And Choice

Unit II: Organization appraisal and strategy formulation: organizational dynamics andstructuring organizational appraisal, business models and Value chain analysis, Strategy formulation- corporate level strategies and business strategies, Generic Strategies- Types of Strategies, tools and techniques for strategic analysis.

Unit III: Turnaround and Diversification Strategies: Turnaround strategy - Management ofStrategic Change, Strategies for Mergers, Acquisitions, Takeovers and Joint Ventures - Diversification Strategy

Block 3: Strategy Implementation And Control

Unit IV: Strategy implementation and control: aspects, structures, design and change: behavioural implementation-leadership, culture, value and ethics, strategic evaluation and control-an overview and techniques of strategic evaluation and control.

Unit V: Strategic issues in managing technology & innovation, entrepreneurial ventures andsmall businesses, Cases in strategic management

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Define the strategic management process and scanning of internal and external environment
– Get a clear picture about value chain analysis
– Understand the different types of strategic choices available and the method of analysis to choose the best among them
– Learn the method of strategic implementation and evaluation for agr entrepreneurial ventures

VIII. Suggested Reading

- Wheelen TL and Hunger JD. 2012. *Strategic Management & Business Policy, towards Global Sustainability*, Pearson India Edn. Thirteenth Edition
- David FR and David FR. 2016. Strategic Management, Concept and Cases, Pearson India Edn, Fifteenth Edition
- Thompson Jr. AA, Peteraf M and Gamble JE. 2015. *Crafting and Executing Strategy*. McGraw Hill, Irwin.
- Stead JG and Stead EW. 2014, *Sustainable Strategic Management*. Routledge Taylor & Francis Group.
- Kazmi Azhar. 2015. Strategic Management. Mcgraw Higher Ed. 4th Edition
- Srinivasan R. 2014. Strategic Management. PHI Learning 5th Edition

I. Course Title : Operations Management

II. Course Code : ABM 537

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students with the applications of important operations research

techniques for better understanding to solve business problems.
The course is organized as follows:

No	Blocks	Units
1.	Introduction to Linear Programming	1. Formulation of Linear Programming problem 2. Methods of solving linear programming problem 3. Transportation and Assignment problems
2.	Inventory control and waiting line models	1. Types of inventory and inventory costs
3.	Decision making under risk and uncertainty	1. Decision problem 2. Decision trees

V. Theory

Block 1: Introduction to Linear Programming

Unit I: Linear Programming: Objective, Assumptions, Formulation of Linear Programming Problem, Data Envelopment Analysis, Graphic Method, Simplex method, Introduction to Dynamic Programming, Transportation and Assignment Problems.

Block 2: Inventory Control And Waiting Line Models

Unit II: Inventory control Models: Costs Involved in Inventory Management, Types of Inventory, Economic Order Quantity (EOQ) Model, Continuous Review (Q) System, Periodic Review (P) System, and Hybrid System.

Unit III: Waiting Line Models: Waiting Line Problem, Characteristics of a Waiting-Line System, Single- Channel Model, Multiple-Channel Model, Constant-Service Time Model, Finite Population Model, Sequencing and Replacement models.

Block 3: Decisionmaking Under Risk and Uncertainty

Unit IV: Decision making under Risk and uncertainties, Decision problem, Maximax Criterion, Maximin Criterion, Minimax Regret Criterion, Laplace Criterion, Pay off Tables, Decision Trees, Expected Value of perfect Information, stochastic models, neural networks, Markov process.

Unit V: Game Theory - Two -Person Zero-Sum Game, Simulation, Network analysis– PERT& CPM. Financial Engineering

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Knowledge and understanding about the characteristics of different types of decision-making environments and the appropriate decision making approaches and tools to be used in each type.
– Develop cognitive skills (thinking and analysis) to build and solve Transportation Models and Assignment Models

VII. Suggested Reading

- Taha HA. 2007. *Operations Research - An Introduction*. Prentice Hall.
- Vohra ND. 2017. *Quantitative Techniques in Management*. 5th Edition McGraw Hill.
- Wagner HM. 2005. *Principles of Operation Research*. Prentice Hall.

I. Course Title : Financial Management in Agribusiness

II. Course Code : ABM 538

III. Credit Hours : 2+0

IV. Aim of the course

To impart trainings to the students regarding various aspects of sources of financing agribusiness.

The course is organized as follows:

No	Blocks	Units
1.	Financial management in India	1. Agribusiness Financing in India 2. Risk and return concept and analysis 3. Money and Capital Markets 4. International financial management
2.	Capital budgeting	1. Techniques of capital budgeting decision 2. Cost of Capital 3. Sources of Long and Short term finance
3.	Current assets management	1. Management of Working Capital 2. Perspectives and operational aspects of Micro finance

V. Theory

Block 1: Financial Management In India

Unit I: Meaning, importance, nature and scope of financing in India, agribusiness financing inIndia; classification and credit need in changing agriculture scenario; finance functions, investment financing, Risk and return concept & analysis

Unit –II: Business Financing System in India, Money and Capital Markets, Regional and All -India Financial Institutions; venture capital financing and its stages, International financial management.

Block 2: Capital Budgeting

Unit III: Features, types and Techniques of capital budgeting decision. Cost of Capital, Leverage analysis, Capital structure. Theory and Policy, Sources of Long and Short term finance, Dividend Theory, Dividend Policy.

Block 3: Current Assets Management

Unit IV: Management of Working Capital, Management of Receivables, Management of cash; Cash budget, Management of collections and disbursement, Investment of Surplus cash.

Unit V: Perspectives and operational aspects of Micro finance**:** Definition, Scope andimportance of Micro Finance, Evolution of Micro Finance in India, Micro Finance credit lending models: - Association model, Community Banking model, Credit union model, Co-operative model, SHG model, Village Banking model.

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the financial management practices in India
- Know about the concepts capital budgeting and cost of capital
- Understand the major sources of financing in India and their implications for a agri-based organization

VIII. Suggested Reading

- Nelson AG & Murrey WG. 1988. *Agricultural Finance*. Kalyani Publ.
- Gordon and Natarajan. 2016. *Financial Markets and Services*. Himalaya Publishing House; Tenth Edition
- Machiraju HR. 2010. *Indian Financial System*. Vikas Publishing House
- Pandey IM. 2015. *Essentials of Financial Management*, Vikas Publishing House
- Khan and Jain. 2014. *Financial Management*. McGraw Higher Education
- Srivastav and Misra. 2010. *Financial Management*, Oxford University Press; Second edition
- Reddy GS. 2010. Financial Management, Himalaya Publishing House

I. Course Title : Communication for Management and Business

II. Course Code : ABM 539

III. Credit Hours : 3+0

IV. Aim of the course

The course aims to make students proficient in written as well as in oral communication with focus on business related communication.
The course is organized as follows:

No	Blocks	Units
1.	Introduction to Business Communication	1. Communication process, barriers and methods 2. Types of business communication 3. Developing listening skills 4. Non verbal communication
2.	Reading and writing skills	1. Reading Comprehension and techniques 2. Business writing skills 3. Messages for electronic media
3.	Oral and visual communication Technical writing skills	1. Oral presentation skills 2. Public speaking skills
4.	Team and Interpersonal communication	1. Effective Interpersonal Communication 2. Business etiquettes 3. Problem solving skills 4. Case method of learning

V. Theory

Block 1: Introduction to Business Communication

Unit I: Communication process, barriers to communication, methods of communication, effective communication, assertive communication, types of organisational communication. Listening skills, active listening, barriers to effective listening, Non Verbal Communication

Block 2: Reading And Writing Skills

Unit II: Reading comprehension and techniques, rules of good writing, business letter writing, e-mail writing, crafting messages for electronic media, social media, business blogs, podcasts, employment messages

Block 3: Oral, Visual Communication and Technical Writing

Unit III: Visual presentation, oral presentation skills, conducting business meetings, brainstorming sessions and presentations, public speaking skills, Communicating across cultures, Various forms of scientific writings, theses, technical papers, reviews, manuals, research work, various parts of thesis and research communication Title page, authorship, contents, preface, introduction, review of literature, material and methods, experimental results and discussion, Technical Writing Style and Editing, Writing Introductions & Conclusions, Editing and Proof reading, Writing a review article and book summary

Block 4: Team And Interpersonal Communication

Unit IV: Developing interpersonal skills (transactional analysis), Business Etiquettes, essentials of business conversations. Business meeting agenda and minutes, circulars and sales letters, notices, overview of business proposals

Unit V: Developing self awareness (Johari Window), solving problems analytically andcreatively, introduction to case method of learning, case reading, approaches and analysis

VI. Teaching methods/activities

- Interactive sessions to make the participants practice communication skills
- Group and individual presentations followed by feedback
- Live projects to study the challenges faced in the organsiational communication setup
- Make the participants practice communicating on social media platforms to write blogs, make and upload videos
- Self awareness assessment based questionnaires
- Case studies to develop interest and understanding of solving real life situation analytically and creatively

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concepts of business communication
– Practice listening, reading writing and presentation skills
– Develop clarity about the method of handling team and interpersonal communication effectively

VIII. Suggested Reading

- Cardon PW. 2015. *Business Communication, Developing leaders for a networkedworld* Mc Graw Hill Edication
- Chaturvedi PD and Chaturvedi M. 2017. *Business Communication, Skills, Concepts, Cases and Applications*, Pearson India Education
- Bovee CL, Thill JV and Chaterjee A. 2013. *Business Communication Today*, Pearson Education, Tenth Edition

I. **Course Title** : **Research Methodology for Agri Business Management**
II. **Course Code** : **ABM 540**
III. **Credit Hours** : **3+0**

IV. Aim of the course

To develop an understanding of research methodology related to efficient agri business management

The course is organized as follows:

No	Blocks	Units
1.	Overview of research	1. Research methodology in management 2. Scales of measurement 3. Questionnaire designing
2.	Use of softwares for statistical analysis	1. Multivariate statistical analysis 2. Evaluation metrices 3. Forecasting Techniques
3.	Data science in agriculture	1. Introduction to data science in agriculture 2. Overview of deep learning and machine learning 3. Concept of cloud machine learning

V. Theory

Block 1: Overview of Research

Unit I: Meaning, Course Objective, types, and process of research; research methodology inmanagement- exploratory, descriptive, experimental, diagnostic, Problem formulation, setting of Course Objective, formulation of hypotheses, models, types of models, process of modeling.

Unit II: Scales of measurement - nominal, ordinal, interval, ratio, Likert scale and other scales; Primary and secondary data, sources of data, Questionnaire Designing, instruments of data collection, data editing, classification, coding, validation, tabulation, presentation, analysis, development process of scale, identification of variables, variable measurement, variable standardization and dummy variables.

Block 2: Use of Softwares for Statistical Analysis

Unit III: introduction to multivariate statistical analysis techniques, Multivariate linearregression models, principal component analysis, linear discriminant analysis, factor analysis, evaluation matrices and model diagnostics for regression models.

Unit IV: Logistic regression, decision trees, cluster analysis, random forest, GARCH, CARTmodels, support vector machines, Forecasting techniques (AR, MA, ARMA and ARIMA models)

Block 3: Introduction to Data Science

Unit V: Definition, scope and importance, machine learning, types of machine learning, linearand nonlinear models in machine learning, introduction to deep learning, basic differences in machine learning and deep learning, concept of cloud machine learning, Big data analysis.

VI. Teaching methods/activities

- Interactive lectures

- Group assignments
- Presentations
- Live projects for marketing research problems
- Case study on application of marketing research tools

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand research methodology concepts along with its application in marketing research
- Develop insights about the statistical analysis tools and techniques for better research outcomes
- Understand the concept of and usage of data science, big data analysis for agriculture

VIII. Suggested Reading

- Cooper DR and Schindler PS. 2006. *Marketing Research Concepts and Cases*. TMH
- Kumar R. 2014. *Research Methodology,* Sage publications, 4th Edition
- Glenn JC. 2010. *Hand book of Research Methods.* OXFORD.
- Kothari CR. 2018. *Research Methodology- Methods and Techniques.* New Age International Publishers; Fourth edition

I. Course Title : Computer Applications for Agri Business

II. Course Code : ABM 541

III. Credit Hours : 3+0

IV. Aim of the course

The course aims to instill the significance of computer applications in the organizations and handling recent trends in information technology and system for improved decision making

The course is organized as follows:

No	Blocks	Units
1.	Basics of computers	1. Concept of computers 2. System and application softwares 3. Data base management system
2.	Business value of internet	1. Cloud computing 2. Cyber security and ethical challenges
3.	Management Information System	1. Concept of MIS 2. Introduction to Artificial Intelligence 3. E-commerce agri business trends

V. Theory

Block 1: Basics Of Computers

Unit I: Concept of Computers- Brief History of Computers, Generation and Its Evolution, Characteristics of Computers, Main Areas of Computers and their Applications; Classification of Computers, Input-Output Devices, Memory Types (Cache, RAM, ROM), Memory Units,

Unit-II: System Software and Application Software, Open source software, introduction tocomputer languages, Introduction to Operating Systems – Functions, Features and Types., MS Windows and LINUX. Data Base Management System, MS Office (MS Word, MS Power Point, MS Excel, MS-Access and use of various management software Like SPSS, SAS etc.

Block 2: Business Value Of Internet

Unit III: The business value of internet, Intranet, extranet and Internet, Introduction to Web page design using HTML, Cloud Computing, Security and ethical challenges: Computer crime – Hacking, cyber theft, unauthorized use at work. Piracy – software and intellectual property. Health and Social Issues, Ergonomics and cyber terrorism.

Block 3: Management Information System

Unit IV: The concept of MIS–Definition, importance, Course Objective, pre-requisites, advantages and challenges; Information Needs of organization, MIS and Decision – Making. Types/Classification of Information System for organizations; Introduction to Artificial Intellignce (AI), Neural Networks, Fuzzy logical control systems.

Unit V: e-business/ e-commerce: e-business models, e-commerce processes, electronic paymentsystems, e-commerce trends with special reference to agri business. Applications of MIS in the areas of Human Resource Management, Financial Management, Production/Operations Management, Materials Management, Marketing Management.

VI. Teaching methods/activities

- Lectures
- Practicals
- Live project
- Assignments
- Presentations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the fundamentals of computers
- Get a clearer idea about the application of Information technology in agri business management
- Use of e commerce, artificial intelligence and MIS for improved decision making in management

VIII. Suggested Reading

- Laudon KC and Laudon JP. 2016. *Management Information Systems- Managingthe digital Firm,* 14h Edition, Pearson India
- Turban, Volonino, Woods. Wali OP. 2015. *Information Technology for Management, Advancing Sustainable, Profitable Business Growth*, Wiley
- Jaiswal M and Mittal M. 2005. Management Information System, Oxford.

I. Course Title : Project Management and Agribusiness Entrepreneurship

II. Course Code : ABM 542

III. Credit Hours : 2+1

IV. Why this course?

This course aims at providing student an insight into the nature of small scale industry. They will be exposed to various aspects of establishment and management of a small business unit.

The course is organized as follows:

No	Blocks	Units
1.	Concept of Project Management	1. Introduction to project management 2. Project feasibility 3. Network methods and project scheduling
2.	Introduction to Agri Entrepreneurship	1. Concept of agri entrepreneurship 2. Creativity, Innovation and Agro Entrepreneur
3.	Support System for Agri Entreprenuership	1. Sources of Financing for entrepreneurs 2. Preparation of Detail Project Report 3. Structure and Government Policy Support

V. Theory

Block 1: Concept of Project Management

Unit I: Concept, characteristics of projects, types of projects, project identification, and Project's life cycle. Project feasibility- market feasibility, technical feasibility, financial feasibility, and economic feasibility, social cost-benefit analysis, project risk analysis.

Unit II: Network Methods: Meaning, Network Analysis, Critical Path Method (CPM), Programme Evaluation and Review Technique (PERT), Project scheduling and resource allocation. Financial appraisal/evaluation techniques- discounted/non-discounted cash flows; Net present values, profitability index, Internal rate of returns; Cost benefits ratio; Accounting rate of return, Payback period, Project implementation; Cost overrun, Project control and information system.

Block 2: Introduction to Agri Entrepreneurship

Unit III: Concept of Agri Entrepreneurship**:** Objective, Introduction to agri entrepreneurship, Entrepreneurial Development Models, Successful Models in Agro Entrepreneurship Intrapreneur, Development of women entrepreneurship with reference to SHGs, Social entrepreneurship

Unit IV: Creativity, Innovation and Agro Entrepreneur: Inventions and Innovation, The Environment and Process of Creativity, Creativity and the Entrepreneur, Innovative Approaches to Agro Entrepreneurship, Business Incubation, Steps and Procedure to start a new business, Business Opportunities in different field of Agriculture and Allied Sectors.

Block 3: Support System For Agri Entreprenuership

Unit V: Sources of Financing, Structure and Government Policy Support: Estimating FinancialRequirements, Preparation of Detail Project Report, Project Appraisal, Sources of Long-Term Financing, Working Capital Financing, Venture Capitalist, Finance from Banking Institutions, Industrial Policy Resolutions in India, Incentives and Subsidies, Schemes for Incentives, Government Organisations like SIDO, DIC, KVIC, NSIC, SIDBI, NABARD and their role, Sick Industries and their Up gradation policy measures

VI. Teaching methods/activities

- Interactive lectures

- Live project in association with innovative farmers/ agri entrepreneur
- Cases related to agri entrepreneurship
- Guest lectures by bankers, entrepreneurs, academicians and venture capitalist firms
- Assignments
- Presentations of Agri Business Plans

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Understand the fundamentals of project management
– Develop a understanding of agri entrepreneurship opportunities and challenges
– Understand the method of developing a agri based venture through the support system available in the Indian scenario

VIII. Suggested Reading

- Arora R and Sood SK. *Fundamentals of Entrepreneurship and Small BusinessManagement*. Kalyani Publishers, Ludhiana.
- Desai V. 2016. *Business Planning and Entrepreneurial Management*, Himalaya Publishing House, Mumbai.
- Ramachandaran K. *Managing a New Business Successfully*. Global Business Press, New Delhi.
- Shukla MB. *Entrepreneurship and Small Business Management*. Kitab Mahal, New Delhi.
- Dandekar VM and Sharma VK. 2016. *Agri-Business and EntrepreneurshipDevelopment*. Manglam Publications, New Delhi.
- Zimmerer TW, Scarborough NM. *Essentials of Entrepreneurship and small Business Management,* 5thEdition, PHI Learning Pvt Ltd
- Panigrahi SR and Singh B. 2017. *Agro Entrepreneurship*. Scientific Publishers(India)

I. Course Title : Agribusiness Environment and Policy

II. Course Code : ABM 543

III. Credit Hours : 2+0

IV. Aim of the Course

To expose the students to the environment in which the agri-business is conducted. The course is organized as follows:

No	Blocks	Units
1.	Agribusiness in India	1. Agri business environment in India 2. Major sub sectors of agri business in India
2.	Economic reforms affecting agri-business	1. Policies and regulations affecting agri business in India 2. WTO Agreement on Agriculture and its compliances
3.	Emerging trends in agri Business	1. Reforms in agri output markets 2. International trade in agri business 3. Food safety and quality management

V. Theory

Block 1: Agribusiness in India

Unit I: Role of agriculture in Indian economy; Problems of agriculture in India;

Agribusiness–definition and nature, Structure of Agriculture and linkages among sub-sectors of the agribusiness.

Block 2: **Economic Reforms Affecting Agri Business**

Unit II: Economic reforms: liberalization, privatization and globalization specifically affectingAgri Business; WTO Agreement on Agriculture and its compliances; changes in policies and regulations related to the sub sectors of agribusiness and its impact on agribusiness in India.

Block 3: Emerging Trends in Agri Business

Unit III: Emerging trends in farm supplies, farm production, agricultural finance, agroprocessing, international trade etc.; reforms in agri output markets: private markets, contract farming, futures trading in agri commodities and e-NAM, etc. Pricing of agricultural outputs, public distribution system, imports and exports.

Unit IV: Importance of food safety and quality management in agri business; Environmentalissues and including carbon markets and Clean Development Management etc.

Unit V: Other major issues: Intellectual property rights, importance of cooperative or collectiveactions in present scenario with examples of mergers and acquisitions, Farmers Producer Organisations, etc.

VI. Teaching methods/activities

- Lectures
- Role plays
- Case studies as group assignment
- Presentations
- Assignments
- Live projects

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop an understanding about the role and problems agriculture and agri business is playing in the Indian economy
– Critically evaluate the major economic reforms that have directly or indirectly affected agri business in India
– Understand the emerging trends and challenges in the field of agri business

VIII. Suggested Reading

- Barnard FL, Akridge JT, Dooley FL, Foltz JC and Yeager EA. 2012. *Agribusiness Management*, Routledge, 4th Edition
- Aswathappa K. 2014. *Essentials of Business Environment*. Himalaya Publ.
- Francis Cherunilam 2003. *Business Environment*. Himalaya Publ.
- Kodekodi GK and Viswanathan B. 2009. *Agril. Development, Rural Institution & Economic Policy*, Oxford.

I. Course Title : Agri Business Laws and Ethics

II. Course Code : ABM 544

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to various ethical issues and laws affecting business. Focus will be on understanding provisions of various business laws with reference to agriculture and also ethical practices to conduct the business properly.

The course is organized as follows:

No	Blocks	Units
1	Indian Legal System	1. Indian Contract Act 3. Companies Act
2.	Regulatory environment for agri-business	1. Essential Commodities Act 2. Consumer Protection Act
3.	Business ethics	1. Ethics in agri business functional areas 2. Governance mechanism

V. Theory

Block 1: Indian Legal System

Unit I: Introduction to Indian legal system, The Indian Contract Act-1872: Contract meaning, types of contract, essentials of a valid contract, offer and acceptance, capacity to contract, free consent, performance of contract.

Unit-II: Law of Negotiable Instruments: Promissory Notes, Bills of Exchange, Cheques and Bank Drafts, Endorsements, Law of Sale of Goods, Sales of Goods Act-1930-: Sale and agreement to sale, types of goods, Transfer of property in goods, mode of delivery of goods, performance of contract of sales, rights of an unpaid seller.

Unit III: Companies Act-1956: incorporation, commencement of business, types of companies, management of company, Memorandum of Association and Articles of Association, prospectus, winding of companies.

Block 2: Regulatory Environment For Agri Business

Unit IV: Essential Commodities Act, Consumer Protection Act, RTI Act, MRTP Act- majorprovisions and implications. Competition Act-2002, Regulatory environment for International Business

Block 3: Business Ethics

Unit V: Nature and importance of ethics and moral standards; corporations and socialresponsibilities, scope and purpose of business ethics; Ethics in business functional areas; industrial espionage; solving ethical problems; governance mechanism. implementing business ethics in a global economy

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Learn about the Indian legal system that directly affects the agri business in India
– Know about the regulatory framework in which the agri business is to be conducted and managed
– Understand the importance of practicing business ethics

VIII. Suggested Reading

- Mathur SB. 2010. *Business Law*. Tata McGraw Hill Edn. Pvt Ltd.
- Gulshan SS and Kapoor GK. 2003. *Business Law including Company Law*. 10th Ed. New Age Publ.
- Kapoor ND. 2005. *Business Law*. S. Chand & Sons.
- Tuteja SK. 2005. *Business Law for Managers*. S. Chand & Sons.
- Tulsian PC and Tulsian B. 2015. *Business Law*. TMH, New Delhi.
- Singh Avtar. 2017. *Contract and Specific Relief,* Eastern Book Company; Twelfth edition
- Pathak A. 2015. *Legal Aspects of Business*. McGraw Hill Education. 6th Edition

Course Title with Credit Load
Ph.D. in Agri-Business Management

Course Code	Course Title	Credit Hours
	Major Courses	**12**
ABM 601	Econometrics for Agri Business	3 (2+1)
ABM 602	Research Methods I	3 (2+1)
ABM 603	Agri Input & Output Marketing	3 (2+1)
ABM 604	Research Methods II	3 (2+1)
	Minor Courses	**6**
ABM 605	Natural Resource Management	2+0
ABM 606	Knowledge Management	2+0
ABM 607	Value Chain Management in Agribusiness	2+0
	Supporting Courses	**5**
ABM 608	Agri-Entrepreneurship and Corporate Governance	1+0
ABM 609	International Food and Agri Business	2+0
ABM 610	Communication for Management Teachers	0+2
	Seminars	**2**
	Doctoral Seminar I	1(1+0)
	Doctoral Seminar II	1(1+0)
	Research	**75**
	Total	**100**

Course Contents
Ph.D. in Agri-Business Management

I. Course Title : Econometrics for Agri-Business
II. Course Code : ABM 601
III. Credit Hours : 2+1

IV. Aim of the course

The course is mainly designed to solid data base analysis of market and policy variables to back up their business strategies. The emphasis will be given on application rather than theoretical details.

The course is organized as follows:

No	Blocks	Units
1.	Formulation and specification of econometric models	1. Simple Regression Analysis 2. Properties of Regression Coefficients and Hypothesis Testing 3. Multiple Regression Analysis 4. Heteroscedasticity 5. Stochastic Regressors and Measurement Errors 6. Simultaneous Equations Estimation
2.	Estimation and testing of models	1. Modelling Dynamic Processes 2. Autocorrelation 3. Logit and Probit (binary choice models)

V. Theory

1. Introduction: Correlation theory, Basic concept of regression analysis, assumptions of regression model, theory of OLS, properties of least square estimates, maximum likelihood, hypothesis testing, interval estimation, prediction in linear regression model.
2. Heteroskedasticity and autocorrelation, multicollinearity, specification errors, selection of regressors, dummy variables, autoregressive and distributed models.
3. Set of regression equations, casuality and simultaneity: application.
4. Time series econometrics- stationarity, unit roots and co-integrassion, error-correction model, AR, MA, ARMA, ARIMA processes.
5. Qualitative dependent variables – LPM, Logit and probit models.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Acquire the basic knowledge of econometrics
– Learn the basics of econometric models and testing its application in the agri business environment

VII. Suggested Reading

- Gujarati, Damodar, *Basic Econometrics*, McGraw-Hill Company
- James H. Stock and Mark W. Watson: *Introduction to Econometrics*, Pearson Education

I. Course Title : Research Methods-I

II. Course Code : ABM 602

III. Credit Hours : 2+1

IV. Aim of the course

The objective of the course is to enable research scholars in developing the knowledge and skills required to specify, evaluate and utilise different types of unstructured and semi-unstructured information. They are required to develop competence in problem formulation, hypothesis generation and method of carrying scientific research in situations where research work plays a critical role. The course is practical in nature and students are expected to learn by doing live projects and studying the latest researches in different fields related to agri business.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Research Methodology	1. Research process 2. Problems and Hypotheses 3. Processing and analysis of data
2.	Introduction to business analytics	1. Types of Business Analytics 2. Introduction to predictive modelling/analytic

V. Theory

Block 1: Overview of Research Methodology

Unit 1: Translating problems to research issues: Selection of qualitative vs quantitative research definitions, objectives, research methodologies rationale, sample/sources of data, data collection techniques, Questionnaire designing: use of measurement and scaling techniques, reliability testing.

Unit 2: Fieldwork: Data collection, gaining access and entry, ethical considerations, identifying key informants, validation and evaluation of fieldwork, data preparation, field notes and recording

Unit 3: Hypothesis Development and Theoretical Modelling. Business Analytics, Business Intelligence,

Block 2: Introduction To Business Analytics

Unit 4: Types of Business Analytics, Introduction to predictive modelling/analytics. Linear programming, Contemporary applications of marketing research

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Learn about the basics of research methodology
– Understand the application of research for problem solving related to agri business environment

I. Course Title : Agri Input and Output Marketing

II. Course Code : ABM-603

III. Credit Hours : 2+1

IV. Aim of the course

Agricultural Input & Output marketing is a dynamic and competitive field where lot is to be done looking to the gap in technology existing and possible. Changes are taking place in manifolds ranging from farming practices to trading in domestic and international markets. Presence of private players, infrastructure development, impact on prices, concept of e mandietc are becoming more important to understand in current scenario. Scholars will also study the researches and articles to understand interesting changes going on in this field.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to agri input and out marketing environment	1. Current status of agri input and output markets in India 2. Marketing mix for agri inout and output marketing
2.	Evaluation of marketing costs and efficiencies	1. Assessment of different cost components 2. Case studies on various marketing strategies adopted by national and global players

V. Theory

Block 1: Introduction to Agri Input and Out Marketing Environment

Unit 1: Agriculture input and output marketing environment-Current status, trends, market structure, infrastructure, competition, Government intervention in agricultural inputs and outputs marketing

Unit 2: Buyers/users behavior, Market Segmentation, Product and Pricing, Promotion and advancement in promotional strategies, Marketing Channels for different agri inputs and outputs

Block 2: Evaluation of Marketing Costs and Efficiencies

Unit 3: Evaluation of marketing costs and efficiencies, WTO and Indian Agriculture, Case Studies- Competitive marketing strategies and advancements in agricultural marketing, International agri marketing practices

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop a understanding about the existing practices of agri input and output marketing in India
– Acquire a deep learning about assessing the marketing cost and related efficiencies to make the agricultural marketing profitable

I. Course Title : Research Method-II

II. Course Code : ABM 604

III. Credit Hours : 2+1

IV. Aim of the course

Once the students are equipped with the information required for interpretive research,

RM II will train the students with advanced analytical tools and their uses.
The course is organized as follows:

No	Blocks	Units
1.	Hypothesis testing	1. Analysis of variance and covariance 2. Multidimensional scaling and conjoint analysis
2.	Data Mining, Data Mining Methods	1. Data Mining Methods 2. Business Process Discovery
3.	Applications of Statistical Softwares	1. Modelling with statistical softwares, Report preparation and presentation

V. Theory

Block 1: Hypothesis Testing

Unit 1: Hypothesis testing, Analysis of variance and covariance, Correlation and regression, Discriminant and Logit analysis, Factor analysis, Cluster analysis, Multidimensional scaling and conjoint analysis.

Block 2: Data Mining

Unit 2: Data Mining, Data Mining Methods—Data Dredging, Data Fishing, Data Snooping and Process Mining—Business Process Discovery, Conformance Checking and Model Enhancement. Arena Modelling.

Block 3: Applications of Statistical Software

Unit 3: Applications of Statistical Softwares like SAS, Modelling with statistical softwares. Report preparation and presentation, International Marketing Research.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Understand the concepts of hypothesis testing
– Learn the application of statistical analysis softwares by hands on experience in agri business problem solving methods

VII. Suggested Reading

- Cohen L, Lawrence M and Morrison K. 2005. *Research Methods in Education* (5th edition). Oxford: Oxford University Press.
- Denscombes M. 2010. *The Good Research Guide: For small-scale social research projects*. Maiden-Read: Open University Press.
- Dornyei Z. 2007. *Research Methods in Applied Linguistics*. Oxford: Oxford University Press.
- Kothari CR. 1980. *Research Methodology: Research and Techniques*, New Delhi: New Age International Publishers.
- Kumar R. 2011. *Research Methodology: a step-by-step guide for beginners* (3rd edition).
- Singh YK. 2006. *Fundamental of Research Methodology and Statistics*. New International (P) Limited, Publishers, New Delhi.

I. Course Title : Natural Resource Management
II. Course Code : ABM 605
III. Credit Hours : 2+0

IV. Aim of the course

The course on Natural Resource Management will provide indepth knowledge to the participants to look for ways to make responsible natural resource management decisions which will have an impact on all stakeholders.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to natural resources	1. Types and classification of natural resource 2. Economic resource theory and applications
2.	Overview of Natural Resource Management	1. NRM sectors product marketing and their roles 2. Concept of environmental services 3. Ecotourism Policy and practices

V. Theory

Block 1: Introduction To Natural Resources

Unit-I Natural resources: Types and classification of natural resource, concept of Economic value, relevance of environmental economics, ecosystems services, direct and indirect economic benefit from – forest ecosystems, mountain ecosystems, mineral and water resources, ecotourism. Valuation and accounting: Supply and demand, conservation and management, cost/ benefit analysis, methods of costing, cost criteria, evaluating alternative projects, operational vs. total costs, determining benefiting vs. comprehensive stakeholders Application of resource accounting Methods of pricing resources- example forest and mineral resources.

Unit-II Economic resource theory and applications: Concept of CPR, open access, Ecological economics-methodology, economic valuation of non market benefits, environmental accounting, population resources and the environment, command and control vs. emission trading, emission trading vs. exposure trading, hotelling principle, future strategies for mineral resources.

Block 2: Overview of Natural Resource Management

Unit-III Natural Resource Management: Initial concept of market and marketing, NRM sectors product marketing and their roles, promoting NRM products- NTFPs, livestock, watershed, fisheries, agriculture and medicinal plants and ecotourism, Role of national and international organizations in the promotion of sustainable natural resource use and management.

Unit IV: Concept of environmental services: Definitions, ecotourism, alternative examples, development of ecotourism in India and outside. Threats due to large scale ecotourism. Payment for Ecosystem Services, the ecotourism dilemmas: High value may also be high impact, bulk ecotourism and problems, stakeholder challenges, tourist carrying capacity. Ecotourism Policy and practices, national policy frame work, example – Madhya Pradesh & Uttarakhand State case. Successful ecotourism initiative, Criteria and Indicators for sustainable Ecotourism.

VI. Suggested Reading

- Barber E. 1989. *Economics: Natural Resources Scarcity and Development*. Earthscan.
- Harris JM. 2006. *Environmental and Natural Resource Economics: A Contemporary Approach*, 2nd edition. Houghton Mifflin
- Field Barry C. 2008. *Natural Resource Economics: An Introduction*. Waveland Press.
- Honey Martha. 2008. Ecotourism and Sustainable Development: Who Owns Paradise? 2 nd edition. Island Press. 2. Seema Bhat & Syed Liyakhat 2008. Ecotourism Development in India: Communities, Capital and Conservation published by CEE, Ahmedabad

I. Course Title : Knowledge Management

II. Course Code : ABM 606

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the course is to provide the basics of the emerging area of Knowledge Management to students. This course throws light on few important concepts as Knowledge management and Information Technology, Knowledge process, etc.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to knowledge management	1. The Knowledge Economy 2. Knowledge Management and Information Technology
2.	Future of Knowledge Management and Industry perspective	1. Knowledge process 2. Implementation of Knowledge Management:

V. Theory

Block 1: Introduction to Knowledge Management

Unit 1: The Knowledge Economy: Leveraging Knowledge, Data-Information-knowledge-Wisdom relationship, organizational knowledge, characteristics and components of organizational knowledge –Building knowledge societies- Measures for meeting the challenges of implementing, KM programmes.

Unit 2: Knowledge Management and Information Technology: Role Information Technology in Knowledge Management Systems, Knowledge Management tools, Creative effective Knowledge Management Systems through Information Technology, ERP and BPR, Data Warehousing and Data Mining.

Block 2: Future of Knowledge Management and Industry Perspective

Unit 3: Future of Knowledge Management and Industry perspective: Companies on the road to knowledge management, Knowledge Management in Manufacturing and service industry, challenges and future of Knowledge Management.

Unit 4: The Knowledge Process: Universal appeal, Stages of KM Process, Knowledge Capital vs physical capital, Customer Relationship Management, Business Ethics And KM, The Promise of Internet and the Imperatives of the new age.

Unit 5: Implementation of Knowledge Management: Discussion on Roadblocks to success, Business Intelligence and Internet platforms, web Portals, Information Architecture: A three-way Balancing Act, KM, the Indian experience, Net Banking in India. –Role of knowledge Management in Organisational Restructuring. -The Mystique of a Learning Organisation.

VI. Suggested Reading

- Mattison: *Web Warehousing and Knowledge Management*, Tata McGraw-Hill,2009
- Becerra Fernandez: *Knowledge management: An Evolutionary view*, PHI, 2009
- Fernando: *Knowledge Management*, Pearson, 2009
- B. Rathan Reddy: *Knowledge management*, Himalaya, 2009
- Tapan K Panda: *Knowledge Management*, Excel, 2009.
- Barnes: *Knowledge Management systems*, Cengage, 2009.

- Tiwana: *The Knowledge Management tool kit*, 2/e, Pearson Education, 2009.
- Warier: *Knowledge Management*, Vikas Publishing House, 2009
- Sislop: *Knowledge Management*, Oxford University Press, New Delhi, 2009
- Debowski: *Knowledge Management*, Wiley Student Edition, Wiley India, 2007

I. Course Title : Value-Chain Management in Agribusiness

II. Course Code : ABM 607

III. Credit Hours : 2+0

IV. Aim of the course

To recognize the characteristics of Global Food Systems, the multiple variables impacting Global Food Systems, to identify value chain thinking and how it differs from supply chain thinking, the characteristics of agri-food markets, what influences their supply and demand, and what sets them apart from other markets, the role played by external factors such as population and income growth, globalization, climate change, technology, and international tradein global food systems, agribusiness and value chains, to recognize the role the consumer plays in the food system, markets, and value chains

V. Theory

Unit 1: Global Food Systems and Value-Chains

Characteristics of global food systems; identify the variables impacting global food systems; identify value chain thinking and how it differs from supply chain thinking; identify the role that external factors (for example, population and income growth, globalisation, climate change, technology and international trade) play on global food systems, agribusiness and value chains; and identify the actors in, and characteristics of, value chains, demonstrated with the building of a value chain model.

Unit 2: Agribusiness Market Dynamics

Characteristics of agri-food markets, what influences their supply and demand, and what sets them apart from other markets; identify the role that external factors, such as population and income growth, globalisation, climate change, technology and international trade, play on agri-food markets; interpret the key elements of supply and demand; andrecognise the basic characteristics of supply and demand curves.

Unit 3: The Role of the Consumer

Role the consumer plays in the food system, markets and value chains; recognise the consumer characteristics, trends and behaviours that influence value chains; and recognise some of the techniques used in market and consumer researchto better understand consumer behaviour.

VI. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural marketing in India*. Oxford and IBH.
- Altekar RV. 2006. *Supply Chain Management: Concepts and Cases*. PHI
- Chopra S, Meindl P and Kalra DV. 2016. *Supply chain management: Strategy, Planning, and Operation*, Pearson Education India
- Mohanty RP. 2010. *Indian Case studies in Supply Chain Management and other Learning Resources*. Oxford.
- Chandrasekaran N. 2010. *Supply Chain Management: Process, system and Practice*. Oxford.

- Singh Sukhpal. *Organic Produce Supply Chains in India-organisation and governance*. Allied Publ.

I. Course Title : Agri Entrepreneurship and Corporate Governance

II. Course Code : ABM 608

III. Credit Hours : 1+0

IV. Aim of the course

The course aims to make students understand the nature of ntrepreneurship, and acquaint the students with challenges of starting new ventures and enable then to investigate, understand and internalize the process of setting up a business. Objective is also to enlighten them with the importance of Corporate Good Governance and Business Ethics.

The course is organized as follows:

No	Blocks	Units
1.	Agri Entrepreneurship and Feasibility Studies	1. Nature of Entrepreneurship 2. Starting the venture 3. Functional plans and Sources of finance
2.	Introduction to Business Ethics and Corporate Governance	1. Business Ethics 2. Corporate Governance

V. Theory

Block 1: Agri Entrepreneurship And Feasibility Studies

Unit I: Nature of Entrepreneurship: Concept, knowledge, skills requirement and functions; characteristic of successful entrepreneurs; ; scenario in India and Abroad, entrepreneurship process; factors impacting emergence of entrepreneurship; managerial vs. entrepreneurial approach and emergence of entrepreneurship, Risk Reduction strategies

Unit 2: Starting the venture: generating business idea – sources of new ideas, methods of generating ideas, SWOT Analysis, environmental scanning, competitor and industry analysis; feasibility study – market feasibility, technical/operational feasibility, financial feasibility; drawing business plan; preparing project report; presenting business plan to investors.

Unit 3: Functional plans: marketing plan – marketing research for the new venture, steps in preparing marketing plan, contingency planning; organizational plan – form of ownership, designing organization structure, job design, manpower planning; Financial plan – cash budget, working capital, proforma income statement, proforma cash flow, proforma balance sheet, break even analysis.

Unit 4: Sources of finance: debt or equity financing, commercial banks, venture capital; financial institutions supporting entrepreneurs, Government Grants and Subsidies, Entrepreneurship Promotion Schemes of Department of Industries (DIC), KVIC, SIDBI, NABARD, NSIC, APSFC, IFCI and IDBI etc.; legal issues – intellectual property rights patents, trademarks, copy rights, trade secrets, licensing; franching.

Block 2: Introduction To Business Ethics And Corporate Governance

Unit 5: Necessity for Business Ethics- Salient Issues in Ethics and Commerce-

Shadow Economy – Basic Principles in Ethics –Corporate Climate and corporate climate audits – Political Issues – Nature and theory of Ethics, Corporate Governance- Historical perspective and issues of Corporate Governance –Corporate Governance mechanisms – Corporate Governance Models, – The confederation of Indian Industry's initiative.; Corporate Social Responsibility

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concept of agripreneurship and its application for starting a new venture
– Learn the basics of making functional plans like marketing, production and financial
– Acquire the knowledge about business ethics and corporate governance

VII. Suggested Reading

- Robert Hisrich Michael Peters Dean Shepherd Entrepreneurship 10th Ed 2016 by McGraw-Hill Education
- Vasanth Desai: *Entrepreneurship*, HPH, 2011.
- David Martin: *Corporate Governance*, Viva, 2010.
- Nandan H: *Fundamentals of Entrepreneurship*, PHI, 2013.
- Barringer: *Entrepreneurship*, Pearson, 2015.
- RK Mishra, Gitarani: *Corporate Governance*, Excel, 2012.
- V. Balachandran and V. Chandrasekaran: *Corporate Governance & Social Responsibility*, PHI, 2009.
- A.C. Fernando: *Business Ethics*, Pearson, 2009.
- Laura P Hartman and Abha Chatterjee: *Business Ethics*, TMH, 2009.
- Tripat Kaur: *Values and Ethics in Management*, 2/e, Paragon International, 2009.

I. Course Title : International Food and Agri Business
II. Course Code : ABM 609
III. Credit Hours : 2+0

IV. Aim of the course

The objective of the paper is to acquaint the students with the fundamentals of international business, its environment and complexities. The paper provides exposure to multiple dimensions of the field and imparts international perspective to business decisions.

The course is organized as follows:

No	Blocks	Units
1	Global trends in International trade	1. Structure of IB environment 2. Global financial system,
2	Global manufacturing and material management	1. International product life cycle, product and branding decisions; 2. Export assistance and incentives in India 3. Harmonizing accounting difference across countries 4. Ethical dilemmas and social responsibility issues

V. Theory

Block 1: Global Trends In International Trade

Unit I: Global trends in international trade and finance; dimensions and modes of IB; structure of IB environment; risk in IB; organizational structure for IB; world trading system and impact of WTO; exchange rate systems; global financial system; barriers to IB; international business information and communication.

Unit II: Foreign market entry strategies; country evaluation and selection; factors affecting foreign investment decisions; impact of FDI on home and host countries; types and motives for foreign collaboration; control mechanisms in IB.

Block 2: Global Manufacturing and Material Management

Unit I: Decisions concerning global manufacturing and material management; outsourcing factors; managing global supply chain; International product life cycle, product and branding decisions; managing distribution channels; international promotion mix and pricing decisions; counter trade practices; mechanism of international trade transactions. EXIM policy of India. Export costing and pricing, Export procedures and export documentation. Export assistance and incentives in India.

Unit II: Harmonizing accounting difference across countries; currency translation methods for consolidating financial statements; the LESSARD-LORANGE Model; cross cultural challenges in IB; international staffing decisions; compensation and performance appraisal of expatriate staff; ethical dilemmas and social responsibility issues.

I. Course Title : Communication for Management Teachers

II. Course Code : ABM 610

III. Credit Hours : 0+2

IV. Aim of the course

Communication in management education is not limited to classroom teaching. There are lot of innovative techniques to make teaching and learning interesting, practical and effective. There are various researches are done for methodological and effectiveness aspects. This course will be dealt understanding all the methods of communication for management teaching in learning by doing method and presenting the various researches done in this field.

The course is organized as follows:

No	Blocks	Units
1.	Management education	1. Action gaps in education and latest developments and required skills
2.	Theory and techniques of communication in management	1. Active listening, group communication 2. Emotional perspective in teaching 3. Learning in management education
3.	Case teaching and writing	1. Writing a case and teaching note, Critiquing a research article

VI. Theory

Block 1: Management Education

Unit 1: Management education: Action gaps in education and latest developments and required skills

Block 2: Theory and Techniques of Communication in Management

Unit 1: Communication: Active listening, group communication, Language process Presentation on readings- recorded and graded: Oral presentation & computer assisted presentations

Unit 2: Theory and techniques: Didacticism, Group work & discussion method, Simulation, facilitation skills and styles for experiential learning. Emotional perspective in teaching

Unit 3: Learning in management education: Experiential learning, Action Learning, Group learning, Simulation and games, Role Play, Teaching and learning through Electronic Media

Block 3: Case Teaching and Writing

Unit 1: Case method of teaching: Writing a case and teaching note, Critiquing a research article

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Basic Sciences

- Agricultural Chemicals
- Biochemistry
- Microbiology
- Plant Physiology

Contents

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Dr Anupama Singh
Dr Amitava Bhattacharya
Agricultural Chemicals

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Agricultural Chemicals

Preamble
(Agricultural Chemicals)

Agricultural chemicals, generally referred to as pesticides, play a vital role in sustaining agriculture productivity by controlling insect pests and diseases that damage field crops and food commodities during cultivation, transport and storage. In addition, they stimulate plant growth, enhance agri-input (water and fertilizer-N use) efficiency to increase farm productivity, and control pests of veterinary and public health importance. The Discipline of Agricultural Chemicals is multidisciplinary as it is linked to various agricultural and basic science disciplines like Entomology, Plant Pathology, Nematology, Toxicology, Weed Science, Environmental Science, Chemistry, Biochemistry, Microbiology, and Soil Sciences & Agricultural Chemistry. Due to the excessive use/ misuse of inherently toxic pesticides, environmental scientists and ecologists from time to time raise concerns about theirharmful effects on humans, domestic animals and the environment. However, since benefits outweigh risks,agricultural chemicals will continue to play a leading role in crop protection.

The world is witnessing huge scientific, technological, digital and socio-economical transformation necessitating nations to launch new initiatives for their development and growth. With emphasis on the holistic education, the new National Education Policy (NEP) declared by the Government of India is aimed at bringing about sea changes in higher education. It will not only transform India into a global knowledge superpower, but will also help it achieve United Nations Sustainable Development Goal-4 aimed at ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all.

Global warming and climate change has posed significant challenges to food security. Changes in crop-pest and host-pathogen complexions haveresulted in minor pests becoming major, and have increased the instances of pest resurgence and resistance development in insect pests and pathogens. In last ten years significant advances have been made globally in the field of crop protection and agricultural chemicals in particular. New molecules with novel chemistries and modes of actions are being developed and registered globally. With change in focus from pest kill to pest control, old generation highly toxic and persistent pesticides are being replaced with new generation reduced risk pesticides with novel chemistries and modes of action. These developments have necessitated restructuring of the course curriculum of the Discipline of Agricultural Chemicals at the Master's and Doctoral level to enable students undertake research in the emerging areas of agrochemical R & D, formulation technology, as well as foodand environment safety through chemical, biochemical, biotechnological and nano-technological interventions. The in-depth understanding of the subject will empower students, researchers, farmers and other stakeholders to take informed decisions about safe use of pesticides in crop and environment protection

In the discipline of Agricultural Chemicals, 20 post-graduate courses have been comprehensively restructured after modification of the existing courses. Of these, 12 are M.Sc. and 8 are Ph.D. courses. Course numbered AC-503,AC-504, AC-505, AC-506, and AC-510 (15 credits) will be compulsory for the M. Sc. students, and the courses numbered

AC-601 and AC-602 (7 credits) will be compulsory for the Ph.D. students. The coursenumbered AC-501 and AC-502 have been designed for students from outside the discipline, and courses AC-503, AC-504, AC-505 and AC-602 may be joint interdisciplinary courses. The doctoral degree level courses (AC-601 to AC-605) are advanced and research oriented.

Basic Chemistry (AC-503) course has been consolidated after clubbing Basic Chemistry I and II courses and modifying/ updating the entire course content. Natural Product Chemistry (AC-504) course has been designed as a new course with more emphasis on metabolomics, health-benefitting nutraceuticals,phytoceuticals,natural antioxidants and food colorants, polymers, enzymes and other natural products for industrial and other applications. The course on Agrochemical Regulation, Quality Control and Management (AC-505) and Pesticide Residue Chemistry (AC-510) have been completely revamped by incorporating provisions of Food Safety and Standards Act 2006 and Rules 2011, Pesticide Management Bill (2017), ecological and consumer risk assessment, and MRL fixation as per the national/ international guidelines. In view of the recent advancements, new topics on acaricides, termiticides, management of resistance in insects, fungi and weeds, NABL accreditation of *laboratories,* and national/international guidelines on good agricultural practices (GAP), and good laboratory practices (GLP) have been added in the revised syllabus. New crop protection concepts like development and use of entomopathogenic nematodes, entomopathogenic fungi, plant inhabited fungal endophytes, nanotechnology, biotechnologyand plant incorporated protectants have also been introduced in the revised syllabus,

Practical content in the designed courses requires modern equipment for extraction, separations, chemical characterization, structure determination, synthesis, and analysis of pesticide residues in food commodities and in soil and aquatic environment. For better research and teaching capabilities, obsolete equipment(s) need to be replaced with new ones like GLC, HPLC, GC-MS-MS, LC-MS-MS, particle size analyzers etc. Additional funds may be required for purchasing such equipment and their spare parts and supplies. Thus, a one-time grant of Rs. 5 crores with a recurring contingency of Rs. 20 lacs per annum will be needed to effectively run Master's and Doctoral programmes in ICAR-IARI/SAUs where the courses of Agricultural Chemicals are taught.

Course Title with Credit Load
M.Sc. (Ag) in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 501	Introduction to Agrochemicals	2+0
AC 502	Chemical Laboratory Techniques	1+2
AC 503*	Basic Chemistry	3+1
AC 504*	Natural Product Chemistry	2+1
AC 505*	Agrochemical Regulation, Quality Control and Management	2+0
AC 506*	Agrochemicals for Insect Mite and Termite Management	2+1
AC 507	Agrochemicals for Disease Management	2+1
AC 508	Agrochemicals for Weed and Crop Management	2+1
AC 509	Chromatographic and Spectroscopic Techniques	2+1
AC 510*	Pesticide Residue Chemistry	2+1
AC 591	Master's Seminar	1+0
AC 599	Master's Research	30

*Core courses

Course Contents
M.Sc. (Ag) in Agricultural Chemicals

I. Course Title : Introduction to Agrochemicals
II. Course Code : AC 501
III. Credit Hours : 2+0

IV. Why this Course?

Pesticides and allied agrochemicals are required for the management of pests of agriculture, veterinary and public health importance. Since pesticides are inherently toxic, their excessive use has led to the residues detrimental to human health and the environment. This interdisciplinary course provides introductory knowledge to students about the use of crop protection chemicals in pest control.

V. Aim of the Course

To provide basic information about crop protection chemicals, their production/ consumption and trade statistics, and adverse impact of these chemicals on human health and the environment.

The course is organized as follows:

No.	Blocks	Units
1.	Agrochemical use and Trade Statistics	1. Agrochemicals and Pest Management 2. Pesticide Production, Consumption and Trade Statistics
2.	Different Group Pesticides	1. Botanical and Biopesticides 2. Synthetic Pesticides
3.	Pesticides Formulation	1. Solid and Liquid Formulations 2. Role of Adjuvants in Pesticide Formulations
4.	Pesticide Residues, their Adverse Effects and Safe Disposal	1. Pesticide Residues in Food and the Environment 2. Adverse Effect of Pesticides on Non-target Organisms 3. Safe Disposal of Pesticides

VI. Theory

Block 1: Agrochemicals and Trade Statistics

Unit 1: Agrochemicals and Pest Management

Definition of pests and pesticides, Synthetic and natural plant protection chemicals – history and classification, House-hold pesticides, Non-pesticidal agrochemicals like nitrification inhibitors, chemical hybridizing agents, hydrogels, soil conditioners, and plant growth stimulants, Pesticide toxicity ($LD_{50,}$ $LD_{90,}$ LC_{50}, EC_{50}, I_{50}),Pesticide antidotes. Safety precautions in pesticide application, Introduction to integrated pest management (IPM).

Unit 2: Pesticide Production, Consumption and Trade Statistics

Pesticide production and consumption in India and other countries, Pesticide export and import

Block 2: Pesticide Groups

Unit 1: Botanical and Biopesticides

History of botanical and biopesticide use, Structure, properties, and use of conventional botanical insecticides - nicotine, pyrethrins, rotenones and neem limonoids. Plant allelochemicals, Biopesticides and bioagents.

Unit 2: Synthetic Pesticides

History of synthetic pesticide use, Structure, properties, and uses of insecticides- organochlorines, organophosphates, carbamates, synthetic pyrethroids, fungicides (inorganic and organic), nematicides, rodenticides, herbicides, and plant growth regulators (PGR)

Block 3: Pesticide Formulation

Unit 1: Solid and Liquid Formulations

Formulation of pesticides- objective and classification, Conventional solid and liquid formulations such as EC, WP, Dust, Granule etc. Physico-chemical properties of formulations

Unit 2: Role of Adjuvants in Pesticide Formulations

Pesticide adjuvants like synergists, stabilizers and surfactants, Pesticide carriers and diluents General methods of preparation of solid and liquid formulations

Block 4: Pesticide Residues, Their Adverse Effects And Safe Disposal

Unit 1: Pesticide Residues in Food and the Environment

Pesticide residue - definition and significance, Pesticide residues in food commodities and in water, air and in soil environment

Unit 2: Adverse Effect of Pesticides on Non-target Organisms

Adverse effect of pesticides on human health, soil health, and on non-target organisms

Unit 3: Safe Disposal of Pesticides

Various techniques for disposal of unused, obsolete, and expired pesticides and their solid and liquid formulations, Disposal of pesticide containers

VII. Teaching methods/activities

- Lectures assignments
- Review of research documents and its presentation
- Periodical quizzes
- Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire basic knowledge about agrochemicals, their formulations and safe use in crop protection. Student will also know about the adverse effects of pesticides and ways to dispose obsolete, expired and unused pesticides and pesticide containers/packaging

IX. Suggsted Reading

- DC Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Marrs TC & Bryan BT. (Eds.). 2004. *Pesticide Toxicology and International Regulation*. John Wiley & Sons.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Tomar SS and Parmar BS. 1992. *Dictionary of Agricultural Chemicals*. Academic India Publ.
- Handa SK 2004. *Principles of Pesticide Chemistry*. Publisher Agrobios (India), Jodhpur (ISBN 10: 8177542168 ISBN 13: 9788177542165)
- Pimentel D. *Encyclopedia of Pest Management* (1st Edition), CRC Press, 931 pp. ISBN 9780824706326.
- Pimentel and Lehman H (Eds.). 1993. The Pesticide Question, Environment, Economics and Ethics, pp442.DOI 10.1007/b102353, Springer US.
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- FICCI-TSMG (2016). *Next Generation Indian Agriculture: Role of Crop Protection Solution, A report on Indian Agrochemical Industry*. pp 45.

I. Course Title : Chemical Laboratory Techniques

II. Course Code : AC 502

III. Credit Hours : 1+2

IV. Why this Course?

Students desirous of pursuing research in agrochemicals and crop protectionare expected to know about the safe handling of laboratory chemicals and instruments. They need to be well versed with extraction, purification and separation techniques commonly employed in a chemical laboratory.

V. Aim of the Course

To acquaint students with laboratory hygiene, upkeep and maintenance of laboratory, handling of chemicals/solvents/glassware, as well as distillation and chromatographic techniques:

No.	Blocks	Units
1.	Laboratory Hygiene and Safe Laboratory Practices	1. Safe Storage and Handling of Chemicals 2. Safety Practices in Chemical Laboratory
2.	Distillation, Extraction and Separation Techniques	1. Theory and Practice of Distillation and Drying of Solvents 2. Theory and Practice of Extraction and Other Techniques 3. Theory and Practice of Chromatographic Techniques

VI. Theory

Block 1: Laboratory Hygiene and Safe Laboratory Practices

Unit 1: Safe Storage and Handling of Chemicals

Laboratory hygiene and safety, Handling and storage of hazardous (flammable, volatile, and corrosive) chemicals, Accurate weighing of chemicals, Maintenance of lab-wares, Maintenance of lab notebooks and records of laboratory chemicals/solvents

Unit 2: Safety Practices in Chemical Laboratory

Precautions while carrying out lab experiments, Use of safety gadgets, Safe disposal of reaction wastes and used solvents, Laboratory accidents and their management

Block 2: Distillation, Extractionand Separation Techniques

Unit 1: Theory and Practice of Distillation and Drying of Solvents

Solvent distillation, Fractional distillation, Steam distillation, Hydro-distillation, Drying of solvents,

Unit 2: Theory and Practice of Extraction and Other Techniques

Different extraction techniques, Cold extraction, Soxhlet extraction, liquid-liquid partitioning, Crystallization and sublimation, Determination of melting point, boiling point, and density of organic compounds

Unit 3: Theory and Practice of Chromatographic Techniques

Chromatography - principle and practice, Partition and adsorption chromatography (TLC, Preparative TLC, HPTLC, Paper chromatography, Column chromatography), Chromatography solvents and chromogenic reagents.

VII. Practicals

- Simple distillation, vacuum distillation, and fractional distillation of solvents/ volatile materials (e.g. essential oils)
- Determination of melting point, boiling point, density, etc.
- Purification and drying of organic solvents
- Crystallization and sublimation techniques.
- Solvent extraction techniques (cold extraction, Soxhlet extraction, percolation, accelerated solvent extraction), and refluxing a reaction
- Chromatographic separation of organic compounds by paper chromatography and thin layer chromatography (TLC)
- Separation of compounds by preparative TLC, HP-TLC and column chromatography

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutsafe handling of chemicals, lab safety and basic laboratory techniques

X. Suggested Reading

- Fessenden RJ, Fessenden JS, Feist P. 2001. *Organic Laboratory Techniques* 3rd Edition, Publisher: Cengage Learning, 256 pages
- Feist P. 2002. *Handbook for Organic Chemistry Lab*. 6th Ed. Brooks/Cole
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Prentice Hall.
- Pavia DL, Kriz GS, Engel UJF. 2006. *Organic Chemistry: A Lab Manual*, Thomson and Brooks/Cole 972 pages.
- Brown SL. 2012. *Laboratory Techniques for General Chemistry*, Hayden McNeil; 208 pages
- ICAR Institute/SAU, *Practical Manual on Chemical Laboratory Techniques*

I. Course Title : Basic Chemistry

II. Course Code : AC 503*

III. Credit Hours : 3+1

IV. Why this Course?

Basic knowledge of physical, inorganic and organic chemistry is fundamental for understanding various aspects of pesticides and allied agrochemicals, pesticide residue analysis, and dynamics in the environment. This course empower the students with important aspects of chemistry.

V. Aim of the Course

To acquaint the students about the basics of inorganic, physical and organic chemistry

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Inorganic Chemistry	1. Properties of Atoms, Molecules And Basic Elements 2. Chemical Bonding and Electronic Effects
2.	Basics of Physical Chemistry	1. Chemical Kinetics 2. Chemical Thermodynamics 3. Surface Chemistry 4. Solution and Electrochemistry
3.	Basics of Organic Chemistry	1. Reactive Intermediates in Chemical Reactions 2. Introduction to Stereochemistry 3. Chemistry of Aliphatic and Aromatic Compounds 4. Chemistry of Heterocyclic Compounds

VI. Theory

Block 1: Basics of Inorganic Chemistry

Unit 1: Properties of Atoms, Molecules and Basic Elements

Modern periodic law and periodic table, Properties of atoms, molecules and basic elements like C, H, O, S, and N, Atmospheric pollutants (oxides of C, N, and S), Atomic and ionic radii, Oxidation states and chemical reactivity, Acid-base chemistry, Introduction to organometallic and coordinated compounds

Unit 2: Chemical Bonding and Electronic effects

Nature of chemical bonding, hydrogen bonding, Van der Waals forces, Inductive effect, electromeric effect, Resonance effect, Hyperconjugation, Electronegativity and Dipole moment

Block 2: Basics of Physical Chemistry

Unit 1: Chemical Kinetics

Kinetic theory of gases, Collision theory, Maxwell - Boltzmann distribution law, Order and molecularity of reactions, First order and second order reactions, Effect of concentration, temperature, pressure and catalyst on rate of reaction, Arrhenius equation, Enzyme kinetics, Catalysis.

Unit 2: Chemical Thermodynamics

First law of thermodynamics, concept of work, internal energy and enthalpy, Second law of thermodynamics, entropy and free energy, Third law of thermodynamics

Unit 3: Surface Chemistry

Introduction to surface chemistry, Adsorption, physi-sorption, and chemisorption, Factors affecting adsorption of gases on solids- Freundlich and Langmuir adsorption isotherm

Unit 4: Solution and Electrochemistry

Colligative properties of solutions, law of mass action, Ionic equilibria in solutions, Phase rule and its application to one- and two- component systems, Hydrolysis, Solubility product, pH and buffer solutions, True solutions, colloid and suspensions, Electrochemistry, Redox reactions, Potentiometric analyses, Conductance in electrolytic solutions, Laws of electrolysis, Nernst equation, Metal corrosion

Block 3: Basics of Organic Chemistry

Unit 1: Reactive Intermediates in Chemical Reactions

Carbenes, carbanions, carbonium ion, free radicals and their role in organic reactions

Unit 2: Introduction to Stereochemistry

Chirality and optical isomerism, Geometric isomerism, Designation of configuration (D-L and R-S system), Conformations of acyclic and cyclic systems

Unit 3: Chemistry of Aliphatic and Aromatic Compounds

Preparation, properties and uses of some important aliphatic, alicyclic and aromatic compounds (halogenated, nitro, amino-compounds, diazonium salts, aromatic sulphonic acids, phenols, quinones and aromatic acids, naphthalene and naphthaquinone).

Unit 4: Chemistry of Heterocyclic Compounds

Preparation, properties and uses of some important heterocyclic compounds (furan, thiophene, pyrrole, pyrazole, imidazole, oxazole, thiazole, pyridine, piperidine, quinnoline, isoquinnoline etc.)

VII. Practicals

- Micro-weighing of compounds and preparation of different concentration of solutions Preparation of different pH solutions and buffer solutions
- Detection of elements (C, H, O, N, S Halogens) in organic compounds
- Detection of functional groups
- Experiments to demonstrate adsorption of a chemical on solid substrate
- Separation and identification of organic compounds in binary mixtures.
- Rate kinetics and Colligative properties.

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the fundamental aspects and concepts of basic chemistry

X. Suggested Reading

- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds*. Wiley-Interscience.
- Finar IL. 1989. *Organic Chemistry*. Vols. I, II. Longmans.
- Hendrickson JB, Cram DJ and Hammond GS. 1970. *Organic Chemistry*. McGraw-Hill.
- Morrison RT and Boyd RN. 1992. *Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI, Tatchell AR, Furnis BS and Hannaford AJ. 1996. *Vogel Textbook of Practical Organic Chemistry*. Forestmillbooks,UK.
- Negi AS and Anand SC. 2003. *A Text Book of Physical Chemistry*. Wiley Eastern.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- Alberty RA and Silbey RJ. 1996. *Physical Chemistry*. 2nd Ed. John Wiley & Sons.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- ICAR Institute/SAU *Practical Manual on Basic Chemistry*

I. Course Title : Natural Product Chemistry

II. Course code : AC 504*

III. Credit Hours : 2+1

IV. Why this Course?

Natural Product Chemistry course is useful to multidisciplinary students of chemistry, agricultural chemicals, entomology, pathology, and biochemistry. The course is designed to improve the student's understanding of bioactive natural products and their role in human welfare.

V. Aim of the Course

To apprise the students about the extraction, purification, and characterization of bioactive natural products and their use in human health, medicines and agriculture The course is organized as follows:

No.	Blocks	Units
1.	Natural Products: Chemistry and Uses	1. Chemistry and Uses of Fats, Lipids, Terpenoids, and Carotenoids 2. Chemistry and Uses f Alkaloids, Flavonoids, Steroids, and Triterpenoids 3. Chemistry and Uses of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids 4. Introduction to Metabolomics
2.	Natural Antioxidants and Food Colorants from Food and Non-Food Sources	1. Natural Antioxidants and Food Colorants from Food Crops 2. Nutraceuticals and Phytoceuticals from Non-Food Sources
3.	Natural Polymers And Enzymes	1. Natural Polymers and their Application 2. Enzymes and Their Industrial Applications

VI. Theory

Block 1: Natural Products: Chemistry and Uses

Unit 1: Chemistry of Fats, Lipids, Terpenoids, and Carotenoid

Introduction to natural products, Structure, chemistry, properties and function of fats, lipids, terpenoids, and carotenoid group of natural products

Unit 2: Chemistry of Alkaloids, Flavonoids, Steroids, and Triterpenoids

Structure, chemistry, properties and function alkaloids (berberine, morphine, caffeine, atropine), flavonoids (Luteolin, quercetin, catechin, naringin, anthocyanins, theaflavins) and phenolic acids (benzoic acid and cinnamic acid derivatives), steroids (cholesterol, cortisone, testosterone, progesterone), and saponin (steroidal, triterpenic and steroid-alkaloidal) group of natural products.

Unit 3: Chemistry of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids

Structure, chemistry, properties and function of carbohydrates, amino acids, proteins, and nucleic acids

Unit 4: Introduction to Metabolomics

Definition, Plant and microbial metabolomics, Metabolome analysis (profiling of secondary metabolites) by GC-MS, LC-MS and NMR spectrometery, Application of metabolomics in different fields

Block 2: Natural Antioxidants and Food Colorants From Food and Non-food Sources

Unit 1: Natural Antioxidants and Food Colorants from Food Crops

Natural oxidants and their mode of action, Different types of natural oxidants from vegetable, fruit and cereal crops (Examples: carotene, lycopene, betanaine, capsanthins, capsicinoids, anthocyanins, curcuminoids etc.)

Unit 2: Nutraceuticals and Phytoceuticals from Non-Food Sources

Nutraceuticals and phytoceuticals from microalgae (e.g. phycocyanins), seabuckthorn (phenolics and flavonoids), medicinal plants (boswellic acid, artemisinin, andrographinolides, withanolides, taxol, forskolinetc.) and marine products

Block 3: Natural Polymers and Enzymes

Unit 1: Natural Polymers and their Application

Different types of natural polymers, Chemistry of natural polymers (Starch, cellulose, Agar, inulin, chitosan, alginate, dextran, guar gum, gum Arabic, gum tragacanthin, xanthan gum, pectin, psyllium etc.). Application of polymers in agrochemical, food and other industries

Unit 2: Enzymes and their Industrial Application

Major classes of enzymes, Enzymes in food industry, industrial enzymes and their application in pharma, leather, textile, detergent and other industries

VII. Practicals

- Extraction of essential oil from mint leaves, lemon and orange peel etc.
- Extraction and purification of bioactive natural products like lycopene, from tomato or watermelon
- Extraction and purification of curcuminoids from turmeric rhizome
- Extraction and purification of anthocyanins from black carrot, purple cabbage, grapes or jamun etc
- Extraction and purification of bioactive natural products namely capsanthin and capsaicinoids from chili/paprika.

• Identification and characterization of the phytochemicals by GC-MS/LC-MS

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the bioactive natural products and their use in medicines, crop protection and other industrial applications

X. Suggested Reading

- Thomson RH (Ed). 1993. *The Chemistry of Natural Products*, DOI 10.1007/978-94-011-2144-6, Springer Netherlands, 453 pages
- Sujata V. Bhat, B.A. Nagasampagi, Meenakshi Sivakumar. 2005. *Chemistry of Natural Products* Springer Science & Business Media, 840 pages
- Rensheng Xu, Yang Ye, Weimin Zhao. 2011. *Introduction to Natural Products Chemistry*, CRC Press, 381 Pages
- Bernd Schaefer. 2014. *Natural Products in the Chemical Industry*, Springer-Verlag Berlin Heidelberg, 831 pages.
- Talapatra SK and Talapatra B. 2015. Chemistry of Plant Natural Products, Springer-Verlag Berlin Heidelberg, 1180 pages
- ICAR Institute/SAU. *Practical Manual on Natural Product Chemistry*

I. Course Title : Agrochemical Regulation, Quality Control and Management

II. Course Code : AC 505*

III. Credit Hours : 2+0

IV. Why this course?

Agricultural chemicals being inherently toxic need to be handled with caution during their production, transport, storage, usage and disposal. The national and international regulations and guidelines ensure their safe distribution and use. Students need to be aware of such regulations and guidelines

V. Aim of the course

To acquaint students about the provisions of Insecticide Act 1968, Food Safety and Standard Act 2006, pesticide registration process, and guidelines for their safe use. The course is organized as follows:

No.	Blocks	Units
1.	Pesticide Regulation and Food Safety	1. The Insecticides Act (1968) and Rules (1971) 2. Food Safety and Standard Act (2006) & Rules (2011) 3. Pesticide Registration in India
2.	National/ International Guidelines for Safe Use of Pesticides	1. Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

No.	Blocks	Units
		2. International Guidelines for Safe Use of Pesticides
3.	Quality Control, Quality Assurance and Accreditation	1. Quality *Assurance* and *Quality Control* in Pesticide Analysis 2. Accreditation of *Laboratories*

VI. Theory

Block 1: Pesticide Registration in India

Unit 1: The Insecticides Act (1968) and Rules (1971)

Provisions of the Insecticides Act 1968 and Insecticides Rules 1971, Schedule of the Insecticide Act. Directorate of Plant Protection, Quarantine & Storage (DPPQ&S), Central Insecticide Board and Registration Committee (CIB&RC),Guidelines for production and use of pesticides

Unit 2: Food Safety and Standard Act (2006) & Rules (2011)

Provisions of the Food Safety and Standard Act (2006) & rules (2011), Acts relating to protection of air, water and the general environment

Unit 3: Pesticide Registration in India

Requirement of data (Chemistry, Bioefficacy, Residue, Toxicology, Packaging etc) for pesticide registration in the country, Guidelines for pesticide export and import**,** Current status of registered, restricted, and banned pesticides in India

Block 2: National/ International Guidelines for Safe Use of Pesticides

Unit 1: Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

Definition of GAP and GLP, National and international guidelines for GAP, and GLP.

Unit-2: International Guidelines for Safe Use of Pesticides

WHO/FAO Joint Meeting on Pesticide Residues (JMPR), Codex Alimentarius Commission (CAC) EU and EPA guidelines for food safety, Sanitary and phytosanitary (SPS) measures and food safety

Block 3: Quality Control, Quality Assurance and Accreditation

Unit 1: Quality Assurance and Quality Control in Pesticide Analysis

Spurious/ fake pesticides and pesticide formulations, Quality Assurance (QA) and Quality Control (QC) Quality control procedures for pesticide residue analysis, Problems related to pesticide residue analysis in a regulatory laboratory.

Unit 2: Accreditation of Laboratories

Accreditation and its importance, General criteria for accreditation of chemical and food laboratories, Introduction to ISO/IEC 17025. NABL and GLP compliance of laboratories, Role of International Laboratory Accreditation Cooperation (ILAC) and Asia Pacific Laboratory Accreditation Cooperation (APLAC) in promoting accreditation recognition arrangements (MRAs) and practices

VII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire knowledge about the agrochemical regulation, quality control, management, and need for accreditation of chemical laboratory as per ISO/IEC 17025

IX. Suggested Reading

- EU.http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69.
- Pest Management Regulatory Agency Canada. 21 May 2014. ISSN: 1925-0843 (PDF version), Catalogue number: H113-24/2014-25E-PDF. Cucurbit vegetables (Crop group 9). http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/_pmrl2014-25/pmrl2014-25-eng.php.
- OECD (Organization for Economic Co-operation and Development), 2011. *OECD MRL calculator: spreadsheet for single data set and spreadsheet for multiple data set*, 2 March 2011. In: Pesticide Publications/Publications on Pesticide Residues. http://www.oecd.org.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed.* European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- USEPA (2016). https://www.epa.gov/sites/production/files/2016-03/documents/flubendiamide_ noic_published_03-04-16.pdf. (accessed 18 May 2016).
- USEPA 2016 United States Environmental Protection Agency https://www.epa.gov/sites / production/files/2016-03/documents/flubendiamide_noic_published_03-04-16.pdf.
- Gnther Voss, Gerardo Ramos &GüNther Voss. 2003. *Chemistry of Crop Protection: Progress and Prospects in Science and Regulation*. Wiley-vch Verlag Gmbh.

I. Course Title : Agrochemicals for Insect, Mite and Termite Management

II. Course Code : AC 506*

III. Credit Hours : 2+1

IV. Why this course?

Insect pests, mites and termites are the major destroyer of the agricultural crops, food commodities as well as buildings and wooden structures. Since synthetic insecticides are used to control such pests, students must learn about the chemistry, mode of action and safe use of such pest control chemicals

V. Aim of the course

To understandchemistry, synthesis, mode of action, and use of insecticides, acaricides and termiticides in agriculture and protection of buildings and wooden structures. The course is organized as follows:

No.	Blocks	Units
1.	Organochlorine, Carbamate and Organophosphorus Group Insecticides	1. Chemistry and Use of Organochlorine Insecticides 2. Chemistry and Use of Carbamate Insecticides

No.	Blocks	Units
		3. Chemistry and Use of Organophosphorus Insecticides
2.	Synthetic Pyrethroid and Neonicotinoid Group Insecticides	1. Chemistry and Use of Synthetic Pyrethroid Insecticides 2. Chemistry and Use of Neonicotinoid Insecticides
3.	Acaricides, Termiticides, Insect Growth Regulators and Newly Discovered Insecticidal Molecules	1. Chemistry and Use of Acaricides 2. Chemistry and Use of Termiticides 3. Chemistry and Use of IGRs and Newly Discovered Insecticidal Molecules
4.	Insecticide resistance	1. Insecticide Resistance and its Management

VI. Theory

Block 1: Organochlorine, Carbamate and Organophosphorus Insecticides

Unit 1: Chemistry and Use Of Organochlorine Insecticides

Introduction and classification of synthetic insecticides, Chemistry, use and mode of action of some important conventional organochlorine and cyclodiene insecticides, Present status of organochlorine pesticides

Unit 2: Chemistry and Use of Carbamate Insecticides

Chemistry, use, and mode of action of carbamate insecticides, Present status of carbamate pesticides

Unit 3: Chemistry and Use of Organophosphorus Insecticides

Chemistry, use and mode of action of some important organophosphorus insecticides. Important reactions namely Michaelis- Arbuzov reaction, Perkow reaction, Thiono-thiolo rearrangement. Present status of OP pesticides

Block 2: Synthetic Pyrethroid and Neonicotenoid Insecticides

Unit 1: Chemistry and Use of Synthetic Pyrethroid Insecticides

History and evolution of synthetic pyrethroid insecticides, Synthesis, properties, structure activity relationships, and mode of action of some important ester and non-ester synthetic pyrethroids. Current status of synthetic pyrethroids insecticides

Unit 2: Chemistry and Use of Neonicotinoid Insecticides

Neonicotinoids: Chemistry, classification, mode of action and uses, Preparation, properties anduses of some important neonicotinoids, Current status of neonicotinid insecticides

Block 3: Acaricides, Termiticides, Insect Growth Regulatorsand Newly Discovered Insecticidal Molecules

Unit 1: Chemistry and Use of Acaricides

Chemistry, classification, mode of action of some important acaricidal molecules.

Unit 2: Chemistry and Use of Termiticides

Termites of different types infesting crops and building materials, Chemistry, mode of action and uses of some important termiticides

Unit 3: Chemistry and Use of Igrs and Newly Discovered Insecticidal Molecules

Chemistry of insect growth regulators: Juvenile hormone mimics, anti-JH, Chitin synthesis inhibitors. Chemosterilants, Mode of action of IGRs, Endocrine disruptor compounds, Chemistry of newly discovered insecticidal molecules

Block 4: Insecticde Resistance

Unit 1: Insecticide Resistance and its Management

Definition, types and mechanism of insecticide resistance, Insecticide Resistance Action Committee (IRAC) guidelines for resistance management, Status of resistance to neo-nicotinoid, synthetic pyrethroids, and other group insecticides

VII. Practicals

- Preparation and characterization of organochlorine insecticides and their intermediates, metabolites and degradation products
- Preparation of representative organochlorine insecticide like dicofol
- Preparation of representative organophosphorus insecticide
- Preparation and characterization of a pesticide intermediate (oxime/oxime ether/ ester etc.)
- Phytotoxicity evaluation of insecticides through germination and growth inhibition study
- Bioefficacy of insecticides against stored grain insect pests

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will stand exposed to recent developments in agrochemicals and their use in insect, mite and termite management in crops, food commodities as well as buildings and wooden structures

X. Suggested Reading

- Melnikov NN. 1971. *Chemistry of Pesticides* (Ed: Gunther, F. A., Gunther, J. D. (Eds.), Springer Nature, Springer-Verlag New York, 480 pp
- Eto M. 1979. *Organophosphorus Pesticides: Organic and Biological Chemistry*. CRC Press.
- Kuhr RJ &Dorough HW. (1979). *Carbamate Insecticide Chemistry and Biochemistry*. CRC Press
- Fest C, Schmidt KJ. 1982. *The Chemistry of Organophosphorus Pesticides*, pp 362, DOI10.1007/978-3-642-68441-8, Springer-Verlag Berlin Heidelber
- Leahey JP. 1985. *The Pyrethroid Insecticides*. Taylor & Francis.
- Matolcsy G, Nadasy M and Andriska V. 1988. *Pesticide Chemistry*. Elsevier.
- Matolcsy M, Nádasy V Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Stenersen J. 2004. *Chemical Pesticides Mode of Action and Toxicology*. (ISBN-13: 978-0748409105), CRC Press; 1 edition., 296 pages.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection,*

Public Health, Environmental Safety. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142*. DOI: 10.2174/9781608051373 1120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry Of Pesticides Their Metabolism, Mode Of Action And Uses In Crop Protection* (ISBN: 9789386237118, 9386237113), Scientific Publishers India, pp 372.
- ICAR Institute/SAU *Practical Manual on Agrochemicals for Insect, Mite and Termite Management*

I. Course Title : Agrochemicals for Disease Management

II. Course Code : AC 507

III. Credit Hours : 2+1

IV. Why this course?

Plant diseases are caused by a diverse group of microorganisms which include fungi, bacteria, viruses, plant parasitic nematodes, etc. Besides reducing crop yield, they also reduce quality of the crop produce. Students must learn about diverse range of fungicidal and nematicidal products and their use in plant disease control

V. Aim of the course

To teach students about the chemistry and use of synthetic fungicides and nematicides and their role in plant diseases and nematode management.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Fungicides and Plant Disease Management	1. Important Plant Pathogenic Fungi, Diseases and Fungicides 2. Classification of Fungicides
2.	Chemical Control of Plant Diseases	1. Inorganic and Dithiocarbamate Fungicides 2. Heterocyclic and Organophosphorus Fungicides 3. Strobilurin (β-Methoxy-Acrylate) Group Fungicides 4. Miscellaneousand New Emerging Fungicides
3.	Chemical Control of Plant Parasitic Nematodes	1. Chemistry, Use and Mode of Action of Chemical Nematicides
4.	Fungicide Resistance	1. Fungicide Resistance and its Management

VI. Theory

Block 1: Introduction to Fungicides and Plant Disease Management

Unit 1: Important Fungicides, Plant Pathogenic Fungi and Diseases

Historical development of fungicides, Some important plant pathogenic fungi and crop diseases, Fungicide movement (translocation) in plant

Unit 2: Classification of Fungicides

Fungicide classification based on chemical nature, Fungicide classification based on mode of action.

Block 2: Chemical Control of Plant Diseases

Unit 1: Inorganic and Dithiocarbamate Fungicides

Chemistry, use and mode of action of inorganic fungicides (S, Cu, Hg, Sn, As), Dithiocarbamate fungicides.

Unit 2: Heterocyclic and Organophosphorus Fungicides

Chemistry, use and mode of action of heterocyclic fungicides (Imidazole, benzimidazole, triazole, oxazole, thiazole, pyridine, pyrimidine, quinoline, quinoxaline, morpholine etc.), Organophosphorus fungicides.

Unit 3: Strobilurin (â-methoxy-acrylate) Group Fungicides

Chemistry, use and mode of action of strobilurin (-methoxyacrylaye) group synthetic fungicides e.g. azoxystrobin, kresoximmethyl, picoxystrobin, fluoxastrobin, pyraclostrobin and trifloxystrobin.

Unit 4: Miscellaneous and New Emerging Fungicidal Molecules

Chemistry, use and mode of action of phenol, quinone, polyhalogen, alkane sulfenyl group, formamide, alkane, alkane carboxylic acid carboxamide and dicarboximide group of fungicides, Chemistry of newly discovered fungicide molecules

Block 3: Chemical Control of Plant Parasuitic Nematodes

Unit 1: Chemical Nematicides

Plant parasitic nematodes, Historical development of nematicides. Preparation, properties and uses of aliphatic halogen compounds, methyl isocyanate liberators, organophosphates and carbamates for nematode control.

Block 4: Fungicide Resistance

Unit 1: Fungicide Resistance and its Management

Definition and development of fungicide resistance in crop pathogens, Fungicide Resistance Action Committee (FRAC) guidelines for resistance management, Fungicide resistance status in India

VII. Practicals

- Preparation of chemical fungicide intermediate(s) like triazoles/ benzimidazoles
- Preparation and characterization of some important fungicides (e.g. Zineb, Bordeaux mixture, Burgundy mixture, dichlorophen, Glyodin, DBCP (nematicide), and an organophosphorus fungicide
- Determination of antifungal activity of the representative test agrochemical (bioassay)
- Characterization of the select fungicides by spectral (IR, UV, NMR or MS) analysis

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the recent developments in agrochemicals and their use in plant disease and nematode management in agricultural crops

X. Suggested Reading

- Matolcsy M, Nádasy V, Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Dehne HW, Deising HB, Gisi U, Kuck KH, Russell PE, Lyr H. (Eds.). 2008. *Modern Fungicides and Antifungal Compounds V*. Proceedings of the 15th International Reinhardsbrunn Symposium on Modern Fungicides and Antifungal Compounds. Friedrichroda, Germany (May 06 – 10, 2007), Deutsche Phytomedizinische Gesellschaft, Braunschweig, Germany, 2008 - ISBN 978-3-941261-02-0
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Carisse O. 2010. (Ed) Fungicides, (ISBN 978-953-307-266-1) Publisher: InTechJanezaTrdine 9, 51000 Rijeka, Croatia. pp 538. (A free online edition of this book is available at www.intechopen.com)
- Lukens RJ. *Chemistry of Fungicidal Action* (ISBN: 9783662113134, 3662113139). Springer-Verlag, Berlin, Heidelberg, Germany.
- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142.* DOI: 10.2174/97816080513731120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- Oliver and Hewitt H. (Eds). 2014. *Fungicides in Crop Protection*, CABI, Oxfordshire, OX10 8DE, UK pp 200 Pages
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Fungi and Nematode Management*

I. Course Title : Agrochemicals for Weed and Crop Management

II. Course Code : AC 508

III. Credit Hours : 2+1

IV. Why this Course?

Weeds compete with the crop plant for light, space, water and nutrients and hamper the overall growth of the desired crop. Chemical herbicides are employed to kill or control such weeds. This course provides detailed information about the chemistryand mode of action of diverse group of herbicides for weed management and PGRs for crop growth

V. Aim of the Course

To apprise the students about the chemistry, mode of action and use of different classes of herbicides for weed management, and plant growth regulators for crop growth.

The course is organized as follows:

No.	Blocks	Units
1.	Herbicides and Weed Management	1. Introduction to Herbicides and Weed Management
2.	Aliphatic, Aromatic, and other Group Herbicides	1. Aliphatic and Aromatic Acid Group Herbicides

No.	Blocks	Units
		2. Carbamate, Substituted phenyl urea, and s-Triazine 3. group Herbicides 4. Diphenyl Ethers, Dinitroanilines, Amide, and 5. Anilide Group Herbicides
3.	Heterocyclic and Sulfonyl Urea Herbicides	1. Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides
4.	Plant growth regulators, herbicide safeners, and newly discovered herbicidal molecules	1. Chemistry and Use of Plant Growth Regulators and Herbicide Safeners 2. Newly Discovered Herbicidal Molecules
5.	Herbicide resistance	1. Herbicide resistance and its management

VI. Theory

Block 1: Herbicides and Weed Management

Unit 1: Introduction to Herbicides and Weed Management

Important crop weeds, Introduction to synthetic herbicides, Classification of herbicides based on time of application, mode of action and selectivity, Herbicide resistance and its management

Block 2: Aliphatic and Aromatic Group Herbicides

Unit 1: Aliphatic Acid and Aromatic Acid Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of aliphatic and benzoic acid herbicides, phenoxy acid herbicides, phenoxy-phenoxy acid and phenoxy-phenoxy alkanoic acid herbicides

Unit 2: Carbamate, Substituted phenyl urea, and s-Triazine group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of carbamate, thiocarbamate, biscarbamate, oxime carbamate, sulfonyl carbamate, Substitutred phenyl urea herbicides, s-Triazine group herbicides

Unit 3: Diphenyl Ethers, Dinitroanilines, Amide, and Anilide Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship ofdiphenyl ethers, dinitroanilines, amide, and anilide group herbicides

Block 3: Heterocyclic and Sulfonyl Urea Herbicides

Unit 1: Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides

Chemistry, use, mode of action and factors governing structure activity relationship of triazine, pyridine, bipyridylium, pyridazine, pyrimidine, oxadiazole, imidazolinoneand sulfonylurea and sulfonylamides herbicides

Block 4: Plant Growth Regulators, Herbicide Safeners, and Newly Discovered Herbicidal Molecules

Unit 2: Chemistry and Use of Plant Growth Regulators and Herbicide Safeners

Chemistry and use of plant growth regulators (auxins, gibberallin, cytokinins, brassionosteroids, triacontanol, protein hydrolysates), Synthesis, structure activity relationships of auxins and gibberellins, Herbicide safeners and pro-safeners

Unit 3: Newly discovered Herbicidal Molecules

Structure and herbicidal activity of newly discovered herbicidal molecules

Block 5: Herbicide Resistance

Unit 1: Herbicide resistance and its management

History and types of herbicide resistance, Factors and mechanism of herbicide resistance, Management of herbicide resistance

VII. Practicals

- Synthesis and characterization of 2,4-D by m.p, TLC, and NMR,
- Identification and collection of weed samples from Institute research farm.
- Preparation of propionyl chloride and its use in the synthesis of the propanil herbicide
- Synthesis of maleic hydrazide and its characterization by TLC, NMR,
- Estimation of 2,4-D, alachlor, propanil, simazine and/or other available herbicides by HPLC and spectrophotometry.

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will be well versed with safe use of herbicides for weed management and PGR for crop growth

X. Suggested Reading

- Kearnay PC and Kaufman DD. 1975. *Herbicides: Chemistry, Degradation and Mode of Action*. Vols. I, II. Marcel Dekker.
- Matolcsy G, Nadasy M and Andriska V. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, pp 805
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley
- Kramer WK and Ulrich Schirmer. 2007. *Modern Crop Protection Compounds*. Wiley-vch Verlag Gmbh.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Sondhia S and Varshney JG. 2010. Herbicides. Satish Serial Publication House, New Delhi. P 567.
- Rao VS. CRC Press, 2000. *Principles of Weed Science*, 2nd Edition, 566 pp, ISBN 9781578080694 - CAT# N00115
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Weed and Crop Management*

I. Course Code : Chromatographic and Spectroscopic Techniques
II. Course Title : AC 509
III. Credit Hours : 2+1

IV. Why this course?

The chromatographic (GC, HPLC) and spectroscopic (IR, UV, NMR) methods are necessary tools for the detection, identification, and quantitation of organic molecules. The knowledge of such analytical techniques is necessary for the students pursuing research in R & D of pesticides and allied agrochemicals

V. Aim of the course

To acquaint the students with the chromatographic and spectroscopic techniques and their use in analysis and characterization of organic compounds.

The course is organized as follows:

No.	Blocks	Units
1.	Chromatographic Techniques	1. Introduction to Separation Science Techniques 2. Gas Chromatography (GC) and its Application 3. High Performance Liquid Chromatography (HPLC) and Its Application
2.	Spectroscopic Techniques	1. UV, Visible and IR Spectrophotometry, and its Application 2. NMR (^{1}H, ^{13}C) Spectroscopy and its Application 3. Mass Spectroscopy (MS) and its Application 4. Tandem Chromatographic and Spectroscopic Techniques

VI. Theory

Block 1: Chromatographic Techniques

Unit 1: Introduction to Separation Science Techniques

Principles of separation science, GC, GPC, and LC chromatography, Super critical fluid chromatograph (SCFC), and Ion exchange chromatography (IEC)

Unit 2: Gas Chromatography and its Application

Theory, principle and instrumentation of GC, GC detectors and columns of different types, Application of GC in analysis of organic compounds, Advantages and limitations of GC

Unit 3: High Performance Liquid Chromatography (HPLC) and its Application

Theory, principle and instrumentation of HPLC, LC detectors and columns of different types, Mobile phase, Application of HPLC in separation and analysis of organic compounds. Advantages and limitations of HPLC

Block 2: Spectroscopic Techniques

Unit 1: UV, Visible and IR Spectrophotometry and its Application

Theory, principle, and instrumentationof absorption (UV, Visible and IR) spectroscopy, Application of UV and IR in structure elucidation of organic compounds

Unit 2: NMR (^{1}H, ^{13}C) Spectroscopy and its Application

Theory, principal and instrumentation of NMR (^{1}H, ^{13}C) spectroscopy, Application of NMR spectroscopy in characterization of organic compounds

Unit 3: Mass Spectroscopy (MS) and its Application

Theory, principal, instrumentation of mass spectroscopy, Mass fragmentation pattern, Application of MS in structure elucidation and confirmation

Unit 4: Tandem GC-MS and LC-MS Techniques

Tandem chromatographic and spectroscopic techniques (GCMS-MS/LCMS-MS), Application of tandem techniques for confirmation of the chemical structure of the analyte constituents.

VII. Practicals

- Separation of organic compound mixture by GC and HPLC
- Application of UV and IR spectrophotometry for detection of organic compounds
- Identification and structure elucidation of organic compounds by NMR (^{1}H, ^{13}C) and MS
- Identification and structure elucidation of organic compounds by GC-MS, LC-MS and MS fragmentation pattern

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire working knowledge of chromatographic and spectroscopic methods for detection, identification, and quantitation of organic molecules.

X. Suggested Reading

- Sharma JM and Follweiler J. 1984. CRC. *Handbook of Chromatography: Pesticides and Related Organic Chemicals*. CRC Press
- Friebolin H and Becconsall JK. 1993. Basic One- and Two-Dimensional NMR Spectroscopy. John Wiley & Sons.
- Dyer JR. 1994. *Application of Absorption Spectroscopy of Organic Compounds*. Prentice Hall of India.
- Silverstein RM, Bassler GC and Morrill TC. 2005. *Spectrometric Identification of Organic Compounds*. 4th Ed. John Wiley & Sons. pages 512.
- Braithwaite A, Smith JF. 1999. *Chromatographic Methods* DOI 10.1007/978-94-011-0599-6, Springer Netherlands, pp 580
- Cazes J and Scott RPW. 2002. *Chromatography Theory* (Chromatographic Science, 88), CRC Press; 1 edition, 496 pages
- Williams DH and Fleming I. 2004. *Spectroscopic Methods in Organic*. Chemistry, Tata McGraw-Hill Education, New Delhi, India, pages 322.
- Nikalje. 2017. *A Handbook of Chromatography* (Editor: Marco Braga), Publisher: Scholar's Press Verlag Omniscriptam, Deutschland, Germany. (ISBN: 978-3-330-65032-9).
- *Practical Manual on Chromatographic and Spectroscopic Techniques* developed by the ICAR Institute/SAU.

I. Course Title : Pesticide Residue Chemistry

II. Course Code : AC 510*

III. Credit Hours : 2+1

IV. Why this course?

Pesticides are inherently toxic and their non-judicious use leaves behind toxic residues. Therefore it needs to be ensured that food commodities we consume are devoid of residues. This course provides exposure to analysis of pesticide residues in food commodities as well as in the soil and aquatic environment. It also provide information about consumer risk assessment and MRL fixation

V. Aim of the course

To teach the students extraction, cleanup, recovery and analysis techniques, develop and validate analytical methodology for risk assessment and MRL fixation.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Pesticide Residue Chemistry	1. Pesticide Residue – Concept and Significance 2. Laboratory Data and Proficiency Testing
2.	Analysis of Pesticide Residues	1. Extraction, Clean Up and Recovery 2. Method Development and Validation 3. Monitoring of Pesticide Residue in Food Commodities
3.	Consumer Risk Assessment and MRL Fixation	1. Consumer Risk Assessment 2. MRL Fixation of Pesticides in Food Commodities

VI. Theory

Block 1: Introduction to Pesticide Residue Chemistry

Unit 1: Pesticide Residue – Concept and Significance

Pesticide residue definition, source, Significance of Certified Reference Materials (CRMs) in pesticide residue analysis, Planning and layout of experiments, Good agricultural practices (GAP) and experimental design, Post-harvest interval (PHI)

Unit 2: Laboratory Data Documentation and Proficiency Testing

Documentation and audit of laboratory data, Inter laboratory comparison and laboratory proficiency testing, legal implications of pesticide residue data

Block 2: Analysis of Pesticide Residues

Unit 1: Extraction, Clean Up and Recovery

Sampling, sample processing and testing, Different extraction and clean up techniques for optimum recovery

Unit 2: Method Development and Validation

Method development, Validation and performance verification through linearity, sensitivity, matrix effect, limit of quantification (LOQ), limit of detection (LOD), accuracy and precision of recovery, Measurement uncertainty (MU)

Unit 3: Monitoring of Pesticide Residue

Monitoring of pesticide residue in agricultural produce and environment, Multiresidue analysis by quick, easy, cheap, effective, rapid and safe (QuEChERS) method, GC/LC, GC-MS, LC-MS method. ELISA and Radiotracer techniques in residue analysis.

Block 3: Consumer Risk Assessmentand MRL Fixation

Unit 1: Consumer Risk Assessment

Hazard and risk, Ecological and human health risk assessment, Acceptable daily intake (ADI), theoretical maximum daily intake (TMDI),estimated daily intake, Maximum Residue Limit, No Observed Adverse Effect level (NOAEL), Food factor.

Unit 2: MRL fixation of Pesticides in Food Commodities

Safe waiting period, Lowest, highest and median residue data, OECD MRL Calculator, Significance of Codex, EU and FSSAI MRLs.

VII. Practicals

- Collection, storage and preparation of samples for pesticide residue analysis
- Extraction and clean-up of food, soil and water sample prior to analysis of pesticide residues
- Study the percent recovery of pesticide residues from vegetable, soil, and/or water samples fortified with the standard pesticide analyte
- Validation of analytical method by studying linearity, matrix effect, LOD, LOQ, accuracy (recovery) and precision as per SANTE guidelines
- Identification of organochlorine insecticides in soil and water by TLC/GC/HPLC
- Identification of Carbamate insecticides in water by TLC/GC/HPLC,
- Estimation of carbamate insecticide residues in vegetable by visible spectroscopic method and HPLC
- Estimation of OP insecticide residues in soil by spectroscopic method and HPLC.

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutthe pesticide residue analysis, consumer risk assessment and MRL fixation

X. Suggested Reading

- Handa SK, Agnihotri NP and Kulshrestha G. 2000. *Pesticide Residue Analysis, Significance, Management and Analysis*.
- Gupta A. 2006. *Pesticide Residue in Food Commodities*. Agrobios (India).
- FAO. 2009b. *Submission and evaluation of pesticide residues data for the estimation of maximum residues levels in food and feed* (FAO Plant production and protection paper 197) <http://www.fao.org/ag/AGP/AGPP/Pesticide/p.htm>.
- FAO/WHO. 2013. *Codex Pesticides Residues in Food Online Database*. Pesticide Residues in Food and Feed, doi: http://www.codexalimentarius.net/pestres/data
- Sharma KK. 2013. *Pesticide Residue Analysis Manual* (Second edition), Directorate of

Knowledge Management in Agriculture, ICAR, KAB-I, Pusa, New Delhi-110012, India. pp 248

- Sondhia S. 2014. *Herbicides residues in soil, water, plants and non-targeted organisms and human health implications: an Indian perspective*. Indian Journal of Weed Science 46(1): 66–85.
- FSSAI. 2015. *Food Safety Standard Authority of India*, Fixation of MRL.
- Mohidus SK and Mohammad SR. (Eds.). 2017. *Pesticide Residue in Foods: Sources, Management and Control*. DOI 10.1007/978-3-319-52683-6, Springer Interntnl. Publishing, pp 200.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed*. European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- ICAR Institute/SAU. *Practical Manual on Pesticide Residue Chemistry*

Course Title with Credit Load
Ph.D. in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 601*	Agrochemical Formulation Technology	2+2
AC 602*	Chemistry of Biopesticides	2+1
AC 603	Advanced Organic Chemistry	2+1
AC 604	Pesticide Metabolism, Persistence, and Decontamination	2+1
AC 605	Term Paper (Special Topics In Agrochemicals)	1+0
AC 691	Doctoral Seminar-I	1+0
AC 692	Doctoral Seminar-II	1+0
AC 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Agricultural chemicals

I. Course Title : Agrochemical Formulation Technology

II. Course Code : AC 601*

III. Credit Hours : 2+2

IV. Why this course?

Several advancements have been reported in pesticide formulation technology. The course intends to cover recent developments on the subject and will be useful to students interested in pursuing research in R & D of pesticide formulation technology

V. Aim of the course

To apprise the students about the recent developments in formulation technology and delivery systems.

The course is organized as follows:

No.	Blocks	Units
1.	Conventional Pesticide Formulations	1. Overview of Conventional Pesticide Formulations 2. Selection of Adjuvants and Synergists in Formulation Chemistry 3. Physico-Chemical Properties of Pesticide Formulations
2.	New Generation Pesticide Formulations	1. Water and Oil Based Novel Formulation 2. Dry, Controlled Release, and Other Novel Formulations 3. Pesticide Application and Delivery 4. Systems
3.	Nanotechnology and its Application in Pesticide Formulation	1. Production and Characterization of Nano-Materials 2. Application of Nanotechnology in Pesticide Formulation and Delivery

VI. Theory

Block 1: Conventional Pesticide Formulations

Unit 1: Overview of Conventional Pesticide Formulations

Solid and liquid formulation, Conventional pesticide formulations such as Dust (D), Granule, pallet (P), Wettable Powder (WP), Emulsifiable Concentrate (EC), and Solution (S). Biopesticide formulations-specifications and types, Limitations of conventional formulations

Unit 2: Selection of Adjuvants and Synergists in Formulation Chemistry

Role of adjuvants (carriers, diluents, surfactants, emulsifiers, dispersing agent, wetting agents, stickers and spreaders, penetrants,safeners, encapsulants etc.), synergists,antioxidants, stabilizers etc. in formulation chemistry.

Unit 3: Physico-chemical Properties of Pesticide Formulations

Physico-chemical properties (solubility, octanol-water partition coefficient, vapor pressure, soil adsorption coefficient, emulsion stability, half-life, shelf-life etc.) and their testing, Formulant-toxicant interactions.

Block 2: New Generation Pesticide Formulations

Unit 1: Water and Oil Based Novel Formulation

Water soluble concentrates (WSC), Suspension concentrates (SC), Oil-in-water emulsion (EW), suspo-emulsion (SE), Micro-emulsion (ME), Water soluble bags and packets(WSB/WSP), Oil dispersion (OD), Aqueous flowable (AF).

Unit 2: Dry, Controlled Release, and Other Novel Formulations

Water soluble powder, liquid and dispersible granules, Dispersion concentrates, Effervescent tablets, Control/time release formulations. Aerosols, baits, fumigants, and formulations of pesticide mixtures, Seed treatment formulations, Seed dressing.

Unit 3: Pesticide Application and Delivery Systems

Packaging and labelling of pesticide formulations, Machinery and equipment for pesticide formulation, Pesticide application and delivery systems - principles, distribution and coverage.

Block 3: Nanotechnology and its Application in Pesticide Formulation

Unit 1: Production and Characterization of Nanomaterials

Development of nanomaterials – bottom up and top-down approach, nano-sizing of inorganic materials, Techniques for characterization of nanomaterials [Zeta sizer, Dynamic light scattering (DLS), X-ray diffraction (XRD), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), and Scanning tunneling microscopy (STM)].

Unit 2: Application of Nanotechnology in Pesticide Formulation and Delivery

Production and use of nano-enabled pesticide formulation (nanoemulsions, nanodispersions, nanoencapsulation, and other polymer based formulations), Nanocarriers for targeted and controlled release, Benefits and environmental risks of nanopesticides.

VII. Practicals

- Study of liquid carriers for the determination of (i) flash point, (ii) specific gravity, (iii) viscosity, and (iv) micelle formation with the surfactants
- Study of solid carriers: Determination of (i) Surface acidity by volumetric method, (ii), surface area, (iii) Sorptivity, and (iv)particle size, of the solid carriers
- Preparation of solid formulations: wettable powder (WP)/granules (G)/WDG/WSG
- Physico-chemical analysis of solid formulations based on BIS/CIPAC/FAO guidelines.
- Physico-chemical analysis of liquid/gel formulations based on BIS/CIPAC/FAO guidelines
- Preparation of toxicant based insect repellent formulations.
- Preparation of liquid and gel formulations: EC/SC/SL/OD/EW/gel, etc.
- Preparation and characterization of a nanopesticide formulation

- Preparation of controlled release (CR) formulation and the release of active ingredient in soil and water

VI. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

VII. Learning outcome

After successful completion of the course, student will acquire knowledge about new generation pesticide formulation and their use in pest control

VIII. Suggested Reading

- Chester L. Foy, David W. 1996. Pritchard Pesticide Formulation and Adjuvant Technology. ISBN-13: 978-0849376788. CRC Press, 384 pages
- Knowles DA. 1998. *Chemistry and technology of Agrochemical Formulations* DOI https://doi.org/10.1007/978-94-011-4956-3 Kluwer Academic Publishers, Springer Nature Switzerland AG.
- Alan K. Viets, Jane C. Mueninghoff (Editors). 2001. *Pesticide Formulations and Application Systems*, 20 ASTM International, 2001, 196 pages.
- Jane C. Mueninghoff, Alan K. Viets (Editors) Pesticide Formulations and Application Systems: A New Century for Agricultural Formulations. 21, (1414), ASTM publication. *Journal of ASTM International: Selected technical papers*, ISSN 1040-1695, 260 pages.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Valkenburg WV. 2008. *Pesticide Formulation: Recent Developments and Their Applications in Developing Countries* (ISBN-13: 978-8122410693) New Age International (P) Limited, Publishers; First edition (2008) pp 488.
- Goss GR (Editor). 2014. *Pesticide Formulation and Delivery Systems*: 35th Volume, Pesticide Formulations, Adjuvants, and Spray Characterization. ISBN-13: 978-0803176195 (Publisher: ASTM International 2016), 93 pages .
- Teicher HB. 2017. *Pesticides and Biopesticides: Formulation and Mode of Action* (Publisher: BioComm Press) pp 166.
- Practical Manual on Pesticide Formulation Technology developed by the ICAR Institute/ SAU.

I. Course Title : Chemistry of Biopesticides

II. Course Code : AC 602*

III. Credit Hours : 2+1

IV. Why this course?

Biopesticides derived from natural sources (plant, animal, nematodes, bacteria, fungi, virus, natural minerals) are considered as safer alternative to chemical pesticides. In view of their safety, such ecologically sound products are increasingly sought after for use in agriculture, veterinary and public health.

V. Aim of the course

To apprise the students about the usefulness of phytochemical biopesticides, microbial pesticides insect behaviour modifying chemicals, and role of biotechnology in pest management.

The course is organized as follows:

No.	Blocks	Units
1.	Phytochemical Biopesticides	1. Conventional Botanical Pesticides 2. New Generation Botanical Pesticides
2.	Insect Behaviour Modifying Chemicals	1. Insect Hormones and Related Products 2. Pheromones and Allelochemicals 3. Insect Feeding Deterrents and Repellents
3.	Microbial Pesticides and Bioagents	1. Microbial Insecticides 2. Microbial Fungicides and Herbicides 3. Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes 4. Application of Biotechnology in Pest Management

VI. Theory

Block 1: Phytochemical Biopesticides

Unit 1: Conventional botanical pesticides

Isolation, characterization, use and mode of action of natural pyrethrins, rotenones,nicotine and neem based azadirachtiniods

Unit 2: New generation botanical pesticides

Isolation, characterization, use and mode of action of toosendanin, ryanodine, rocaglamides, annonins, isobutylamides, quassinoids, and sugar esters from plant sources, Plant essential oils and their constituents as botanical pesticides, Photo-activated pesticides like á-terthieyl, acetylenes and acetylenic thiophenes

Block 2: Insect Behaviour Modifying Chemicals

Unit 1: Insect hormones and related products

Insect hormones (Juvenile hormones, Moulting hormones, Brain hormones), their chemistry, mode of action and use in insect pest control)

Unit 2: Pheromones and allelochemicals

Pheromones (sex, alarm, trail, territorial, aggregation, etc.), Semiochemicals, Allelochemicals – allomones, kairomones, synomones, apneumones, Phytoalexins

Unit 3: Insect feeding deterrents and repellents

Sources, chemistry and mode of action of feeding deterrent and insect repellents

Block 3: Microbial Pesticides And Bioagents

Unit 1: Microbial Insecticides

Pesticides of microbial origin, Bacillus (*Bt, Bs*) and NPV based Insecticides. Chemistry and mode of action of macrolides such as avermectins, milbimycins and spinosyns

Unit 2: Microbial Fungicides and Herbicides

Natural fungicides like strobilurins and other methoxyacrylates, Bioherbicides like biolaphos and phosphonothricin

Unit 3: Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes

Entomopathogenic nematodes and entomopathogenic fungi in insect control, Pesticidal secondary metabolites (biotoxins) from EPN (*Photorhabdus* and *Xenorhabdus)* and EPF (Metarrahiza etc.), Plant inhabiting fungal endophytes and their role in plant protection

Unit 4: Application of Biotechnology in Pest Management

Plant incorporated protectants, Recombinant DNA technology, **Genetically-modified** (GM) herbicide resistant crops, **Genetically-modified**insect resistant crops, Potential benefits and risks of GM crops

VII. Practicals

- Isolation of curcuminoids from turmeric rhizome and their characterization,
- Extraction of tobacco leaves, isolation of nicotine and its identification,
- Extraction of neem seed kernels to isolate neem oil
- Saponification of neem oil
- Isolation of azadirachtin concentrate from neem seed kernel powder
- Quantification of azadirachtin content in isolated azadirachtin powder
- Characterization of biopesticides by chromatographic and spectral analysis

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will get acquainted with production of biopesticides from natural sources and their use in crop protection as safer alternative to chemical pesticides.

X. Suggested Reading

- Jacobson M. 1970. *Naturally Occurring Insecticides*. Wiley Khan SU. 1980. Pesticides in the Soil Environment. Elsevier.
- Parmar BS and Devakumar C. 1990. *Botanical and Biopesticides*. Westvill Publ. House
- Copping LG. 1996. *Crop Protection Agents from Nature: Natural Products and Analogues*. Royal Soc. Chem., London.
- Dev S and Koul O. 1997. *Insecticides of Natural Origin*. Harwood Acad. Publ. Godfrey CRA. 1995. Agrochemicals from Natural Products. Marcel Dekker.
- Schmutterer H. 2002. *The Neem Tree: Source of unique natural products for integrated pest management, medicine, industry and other purposes.* (2nd edition) Neem Foundation, Mumbai-400 049, India
- Parmar BS, Walia S, Anupama and Kumar J. 2008. *Neem Pesticides in India, An update of the recent developments*. SPS Publication No. 15, Society of Pesticide Science, India 50pp
- Parmar BS and Walia S. 2001. *Prospects and problems of phytochemical pesticides*. In: O. Koul and G.S. Dhaliwal (eds) Phytochemical Biopesticides, Harwood Academic Publishers Gmbh. Netherlands pp 133-210.
- Koul. 2004. *Insect antifeedants*. CRC Press LLC Boca Raton, Florida 33431, USA, pp 1005
- Franklin R. Hall and Julius J. Menn (Ed) *Biopesticides: Use and Delivery*. DOI 10.1385/0896035158, 2010 edition, 626 pages. Humana Press, Springer Nature. Switzerland. AG
- Singh D. 2014. *Advances in Plant Biopesticides*, Springer Nature India Private Limited, DOI 10.1007/978-81-322-2006-0. Pages 421.

- Leo ML. Nollet and Rathore HS. 2017. *Green Pesticides Handbook: Essential Oils for Pest Control* (ISBN-13: 978-1498759380), CRC Press pp 570.
- ICAR Institute/SAU. *Practical Manual on Chemistry of Biopesticides.*

I. Course Title : Advanced Organic Chemistry

II. Course code : AC 603

III. Credit Hours : 2+1

IV. Why this course?

This course provides a deeper understanding of organic chemistry and covers advanced topics of stereochemistry, photochemistry, pericyclic reactions, name reactions, chemical reagents etc. The knowledge of advanced organic chemistry is essential to students interested in synthesis and technology development of organic compounds including pesticides

V. Aim of the course

The course aims to equip the students with the advanced knowledge about stereochemistry, chemical reactions, chemical reagents in organic synthesis, and photochemistry.

The course is organized as follows:

No.	Blocks	Units
1.	Stereochemistry	1. Understanding Spatial Arrangement of Organic Molecules 2. Application Of Stereochemistry
2.	Important Chemical Reactions and their Mechanisms	1. Electrophilic and Nucleophilic Substitution Reactions 2. Elimination and Addition Reactions 3. Pericyclic Reactions 4. Organic Name Reactions
3.	Reagents in Organic Synthesis	1. Different Reagents and their Application in Organic Synthesis 2. Protection and Deprotection of Functional Groups
4.	Photochemistry	1. Basic Principles and Application of of Photochemistry

VI. Theory

Block 1: Stereochemistry

Unit 1: Understanding Spatial Arrangement of Organic Molecules

Enantimerism and diastereoisomerism, mesomers, Racemic mixture (racemate), Different methods of resolution of enantiomers (optical resolution), Walden inversion, Asymmetric synthesis of stereoisomers

Unit 2: Application of Stereochemistry

Nomenclature of stereo-chemicals with particular reference to agrochemical molecules, Stereospecific and stereoselective reactions, Chiral synthesis

Block 2: Important Chemical Reactions and their Mechanisms

Unit 1: Electrophilic and Nucleophilic Substitution Reactions

Electrophilic aromatic and Electrophilic aliphatic substitution reactions, Nucleophilic substitution reactions, (SN1, SN2 and SNi), Reactions involving carbonium ion, carbanion, carbene and free radicals.

Unit 2: Elimination and Addition Reactions

Elimination reactions (*syn* vs. *anti*-elimination, orientation in elimination reaction, molecular rearrangement, decarboxylation reactions, etc.). Addition reactions. Electrophilic addition of bromine. hydrogenation, hydroboration

Unit 3: Pericyclic Reactions

Cyclic transition states, Types of pericyclic reactions - cycloadditions, sigmatropic rearrangements, and electrocyclic reactions.

Unit 4: Organic Name Reactions

(i) Diels Alder reaction, (ii) Grignard reaction, (iii) Aldol, condensation, (iv) Perkin reaction, (v) Benzoin condensation, (vi) Friedel Craft alkylation and acylation reaction, (vii) Fries rearrangement (viii) Reformatsky reaction, (ix) Wittig Reaction and Sandmeyer reaction (x) Oppenaeur oxidation, (xi) Ziegler Natta reaction

Block 3: Reagents in Organic Synthesis

Unit 1: Different Reagents and their Application in Organic Synthesis

Reagents in organic synthesis: complex metal hydrides, Gilman's reagent, lithium dimethyl curparate, lithium di-isopropyl amide (LDA), dicyclohexylcarbodimide, 1,3-di-thiane, trimethyl selyl iodide, triselenium dioxide, tri-butyl tin hydride, osmium tetroxide, dichlorodicyano quinone etc. Organometallic reagents in organic synthesis, phase transfer catalysis, crown ethers and Merrifield resins

Unit 2: Protection and Deprotection of Functional Groups

Different methods of protection of functional groups in organic synthesis with examples, Deprotection to release the functionality

Block 4: Photochemistry

Unit 1: Basic Principles and Application of Photochemistry

Definition and laws of photochemistry, Light-induced excitation of organic molecules, Singlet and triplet state of oxygen, Application of photochemistry in biological systems, agriculture and industry. Role of light in degradation of pesticides and related xenobiotics

VII. Practicals

- One experiment each of methylation, acetylation, elimination, oxidation, reduction, and hydrolysis
- Preparation of acid chlorides, amides, esters,
- Friedal craft reaction (Alkylation/Acylation),
- Aldol/Claisen/Schmidt reaction,
- Pechmann condensation/Perkin reaction,
- Characterisation of prepared organic compounds by NMR and IR spectroscopy

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will get familiar with advanced organic chemistry and its application for planning, understanding and conducting organic reactions

X. Suggested Reading

- Finar IL. *Organic Chemistry*, Longman Publishing Group
- Corey FA and Sundberg RJ. 1983. *Advanced Organic Chemistry*. *Subseries:* Part A. *Structure & Mechanism*. Part B. *Reaction and Synthesis*. 2nd Ed. Plenum Press,
- Morrison RT, and Boyd RN. 1992. *Organic Chemistry*, 6th edition, ISBN 0136400612 (ISBN13: 9780136436690) Prentice Hall, 1278 pages.
- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds*. John Wiley & Sons. Finar IL. 1959. *Text book of Organic Chemistry*. Vols. I, II. 25th Ed. Pearson Edu.
- Kalsi PS. 1996. *Stereochemistry and Mechanism through Solved Problems*. 2nd Ed. New Age International Publ.
- Peter Sykes. 1996. *Organic Chemistry*. *Guidebook to Mechanism in Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Printice Hall.
- Ahluwalia VK and Aggarwal R. *Comprehensive Practical Organic Chemistry - Preparation and Quantitative Analysis*. Universities Press.
- Bahl A and Bahl BS. 2005. *A Textbook of Organic Chemistry*, S Chand and Company, New Delhi, India, 1074 pages.
- Smith MB and March J. 2007. *March's Advanced Organic Chemistry Reactions, Mechanisms, And Structure*, John Wiley & Sons, Inc., Hoboken, New Jersey, 2190 pages
- Clayden J, Geeves N, Warren S. 2012. *Organic Chemistry* 2nd Edition (ISBN: 978-0199270293), Oxford University Press, Pages 1234.
- ICAR Institute/SAU *Practical Manual on Advanced Organic Chemistry*

I. Course Title : Pesticide Metabolism, Persistence and Decontamination

II. Course Code : AC 604

III. Credit Hours : 2+1

IV. Why this ourse?

The study of pesticide metabolism and dynamics is necessary to understand behaviour of pesticides in the biological systems and the environment. The course is designed to provide deep understanding of the biotic and abiotic transformations affecting fate of the pesticides in the environment

V. Aim of the ourse

To acquaint the students about the persistence, dissipation, and fate of pesticides in the crops and the environment. and about bio-remedial measures to decontaminate pesticide residues.

The course is organized as follows:

No.	Blocks	Units
1	Pesticide Movement in the Environment	1. Translocation of Pesticides in the Plant, Soil and Aquatic Environment 2. Different Phases of Pesticide Metabolism
2	Abiotic and Biotic Transformations of Pesticides	1. Abiotic Transformation of Pesticides 2. Microbial Degradation of Pesticides 3. Metabolism of Pesticides in the Living Systems
3	Pesticide Persistence and Dissipation Kinetics	1. Persistence of Pesticides in the Environment (Soil, Water and Crops) 2. Pesticide Dissipation and Fate in the Environment
4.	Decontamination and Bioremediation Measures	1. Decontamination of Pesticide Residues 2. Bioremediation of Pesticides and Pesticide Contaminated Sites

VI. Theory

Block 1: Pesticide Movement in the Environment

Unit 1: Translocation of Pesticides in the Plant, Soil and Aquatic Environment

Introduction to pesticide metabolism, penetration, uptake, translocation, excretion, and mineralization etc. (Highlight the role of physico-chemical parameters). Uptake, bio-accumulation, bio-concentration, and biomagnifications of pesticides in the plant and the environment.

Unit 2: Different Phases of Pesticide Metabolism

Fate of pesticides in the plant, animal and other living systems, Phase I metabolism (oxidation, reduction, hydrolysis, enzymatic degradation, etc.), Phase II metabolism (conjugation with sugar, amino acid, glutathione, etc.), Phase III metabolism (further conjugation of phase II metabolites), Non-extractable (Bound) residues.

Block 2: Abioticand Biotic Transformations of Pesticides

Unit 1: Abiotic Transformations of Pesticides

Physical and chemical factors affecting fate of pesticides in the environment, Photochemical transformation of pesticides, Role of photosensitizers, quenchers, and light filters in pesticide degradation.

Unit 2: Metabolism of Pesticides in the Living Systems

Biotic transformations and metabolic pathways of different group pesticides in thecrops, insects, animal models.

Unit 3: Microbial Degradation of Pesticides

Types of pesticides-degrading microorganisms in the environment, Factors affecting microbial degradation, Microbial degradation of different group pesticides.

Block 3. Pesticide Persistence and Dissipation in the Environment

Unit 1: Persistence of Pesticides in the Environment

Low, moderate and high persistent pesticides, Persistent organic pollutants, Physical, chemical, biochemical and environmental factors affecting pesticide persistence in the environment.

Unit 2: Pesticide Dissipation and Fate in The Environment

Various dissipation processes, Role of drift, volatilization, adsorption, desorption, runoff etc.in pesticide dissipation, Leaching and risk of groundwater pollution, Dissipation time (Half-life-DT_{50}, DT_{90}), Rate kinetics (1st order, 2^{nd} order), Behaviour and fate of pesticides in soil and crops.

Block 4: Decontamination and Bioremediation Measures

Unit 1: Decontamination of Pesticide Residues

Decontamination of pesticide residues in water and food (vegetables and fruits) commodities, Effect of different processing/culinary methods on reduction pesticide residues, safer methods of pesticide decontamination.

Unit 2: Bioremediation of Pesticides and Pesticide Contaminated Sites

Bioremediation-advantages and applications, Biodegradation and bioremediation of pesticides and related xenobiotic compounds, Microbe-mediated bioremediation, Use of enzymes in bioremediation, bioremediation of pesticide polluted sites.

VII. Practicals

- Synthesis of a pesticide metabolite
- Photodegradation of pesticides on glass and leaf surface,
- Microbial degradation of pesticides in soil.
- Leaching of pesticides in soil columns,
- Recovery of residues from pesticide-spiked farm soil

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about pesticide metabolism and dynamics in the biological systems and the environment and get acquainted with bio-remedial measures for to decontaminating food commodities and pesticide contaminated sites

X. Suggested Reading

- Schnoor JL. (Ed). 1992. *Fate of pesticides and chemicals in the environment*. Wiley New York. 436 pages:
- Alexander M. 1999. *Biodegradation and bioremediation*. 2nd Ed. Academic Press.
- Racke KD, Skidmore MW, Hamilton DJ, Unsworth JB, Miyamoto J and Cohen SZ. 1997. *Pesticide Fate in Tropical Soils*. Pure and Appl. Chem. 69 (6): 1349-1371.
- Hall JC, Hoagland RE and Zablotowicz RM. 2001. *Pesticide Biotransformation in Plants and Microorganisms: Similarities and Divergences*. ACS Symposium Series 777. Washington, DC.
- Shahamat U Khan. 1980. *Pesticides in the Soil Environment* (Editor: R. J. Wakeman) Elsevier. 248 pages.
- Perry AS, Yamamoto I, Ishaaya I, Perry RY. 1998. Insecticides in Agriculture and Environment- Retrospects and Prospects, DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-

Verlag Berlin Heidelber.
- Wheeler WB. (Ed) 2002. *Pesticides in Agriculture and the Environment* (1st Edition), CRC Press.
- Matsumura F (Ed) 2013. *Biodegradation of Pesticides* (ISBN-13: 978-1468440904) Publisher: Springer, pp 312 pages.
- ICAR Institutes/SAU. *Practical Manual on Pesticide Residues and Dynamics in the Environment*

I. Course Title : Term Paper (Special Topics in Agro Chemicals)

II. Course code : AC 605

III. Credit Hours : 1+0

IV. Aim of the course

To develop proficiency of the student in his/her area of specialization. The teacher will give a topic relevant to the area of specialization of the student as a term paper to develop proficiency in his field of research. The term paper can be based on one of the selected current topics in agrochemicals

V. Suggested Reading

Literature on the relevant subject of the term paper in his area of research

Journals

- *Archives of Environmental Contamination and Toxicology*
- *Biopesticide International*
- *Bulletin of Environmental Contamination and Toxicology*
- *Chemosphere*
- *Crop Protection*
- *Current Science*
- *Environment Monitoring and Assessment*
- *Environmental Toxicology and Chemistry*
- *Food Additives and Contaminants*
- *Food Chemistry*
- *Indian Journal of Agricultural Chemistry*
- *Industrial Crops and Products*
- *Integrated Pest Management Reviews*
- *International Journal of Pest Management*
- *International Journal of Pesticide Reform*
- *Journal of Agriculture and Food Chemistry*
- *Journal of AOAC*
- *Journal Environ. Science and Health Part A & B*
- *Journal of Essential Oil Bearing Plants*
- *Outlooks on Pest Management*
- *Pest Management Science*
- *Pesticide Biochemistry and Physiology*
- *Pesticide Research Journal*
- *Pesticide Science Japan*
- *Weed Research*
- *Weed Science*
- *Weed Technology*

e-Resources

- Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Plant Protection, Quarantine & Storage. http://ppqs.gov.in/about-us/about-department

- Central Insecticide Board and Registration Committee (CIB&RC) www.cibrc.nic.in; http://ppqs.gov.in/contactus/central-insecticide-board-and-registration-committee-cibrc
- The Food Safety and Standards Authority of India (FSSAI) https://www.fssai.gov.in/home
- *Insecticides in Agriculture and Environment- Retrospects and Prospects*, Authors: Perry, A.S., Yamamoto, I., Ishaaya, I., Perry, R.Y. (1998) DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-Verlag Berlin Heidelber
- *CRC Handbook of pest management in agriculture, Volume 1. Author:* Pimentel, D., CRC Series in Agriculture; Editor: Hanson, A.A.]. 1981. 597 pp.
- Food and Agricultural Organization Statistics (FAOSTAT) *Pesticides Use*. http://www.fao.org/faostat/en/#data/RP
- Food and Agricultural Organization (FAO/WHO) *Codex Pesticides Residues in Food Online Database. Pesticide Residues in Food and Feed*, doi: http://www.codexalimentarius.net/pestres/data
- European Food Safety Authority: http://www.efsa.europa.eu/en/pesticides/mrls.htm
- Pest Management Regulatory Agency Canada. https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html
- OECD (Organization for Economic Co-operation and Development), (2011). OECD MRL calculator: spreadsheet for single data set and spreadsheet for multiple data set, 2 March 2011. In: Pesticide Publications/Publications on Pesticide Residues. http://www.oecd.org.
- Bureau of Indian Standards (BIS), New Delhi, India. http://www.bis.org.in/cert/bis_proc_obt_lic.htm
- EU. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69. (accessed 21 October 2016).
- US Environment Protection Agency (USEPA) https://www.epa.gov, https://www.epa.gov/pesticide-registration/about-pesticide-registration

Suggested broad topics for master's/ doctoral research

- New generation pesticides (insecticides, fungicides, herbicides, nematicides), plant growth stimulants, and other allied agrochemicals from synthetic and botanical sources
- Biopesticides from natural sources (plants, fungi, bacteria, algae, nematodes, etc),
- Novel insect antifeedants and other insect behaviour modifying chemicals (pheromones and other semio-chemicals)
- Novel pesticide formulations, time-release formulations, and delivery systems for enhanced activity and stability of single and combination pesticides
- Analysis of pesticide residues (multi-class pesticides, metabolites, degradation products, impurities) in soil, water, food commodities as well as in technical materials and formulations
- Investigations on safety evaluation, fixation of MRLs and safe waiting periods, and risk assessment
- Biotechnological and nanotechnological intervention for developing ecologically sound agrochemicals
- Pesticide-environment (plant, air, water, microbes) interaction, Pesticide persistence, degradation (biotic, abiotic)
- Impact of pesticides on the non-target organisms.
- Pesticide detoxification, decontamination and disposal, Bioremediation of pesticide contaminated sites for safe environment
- Increasing agricultural input (pesticides, water, fertilizers, micronutrient etc.) use-efficiency through technological interventions.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Biochemistry

Preamble
(Biochemistry)

The global advancement of agriculture in the fields of crop production and improvement, crop protection, development of newer and high yielding varieties of different crops are all going hand-in-hand with the advancement and application of biochemistry. Education and research in agriculture, specifically in the fields of photosynthetic efficiency, nitrogen fixation, applications of recombinant DNA technology, genomics and proteomics in varietal development and plant protection, animal and human nutrition and health and the environmental impact of agricultural chemicals are some examples of the wide array of topics in which biochemistry plays significant contributions.

Restructuring the courses of biochemistry associated with agricultural education in our country has become demand of the day to keep pace with the rapid development of the subject as well as to fulfil the objective of doubling farmer's income through use of these cuttingedge developments under the global context. Keeping this in view the ICAR has initiated modification of the existing courses both of M.Sc. and Ph.D. curricula in biochemistry. These alterations will not only help the students to understand the subject better but will also create ample scope to gather advanced knowledge in different areas of the subject which will enable them to proceed a step further towards excelling in advanced studies and research and also serving the industrial field causing benefit to the mankind.

M.Sc. courses

A total of eleven courses belonging to five different categories have been proposed for M.Sc. programme:

1. Basic and fundamental course: BIOCHEM 501 (Basic Biochemistry) deals with the basic andfundamental aspects of biochemistry. It is one of the core courses of M.Sc. study programme which has the objective to enrich the students of biochemistry as well as other disciplines with the knowledge of the basics of the subject. The students will gather basic idea and will have a strong footing prior to entering into the vast realm of the subject. The topic of photosynthesis in this course is replaced by plant secondary metabolites, PR proteins and immunoglobulins. Several relevant and new practicals have also been introduced.

2. Courses covering the major areas of the subject including one of analytical aspects: This category includes four courses, BIOCHEM 502 (Intermediary Metabolism), BIOCHEM 503 (Enzymology), BIOCHEM 504 (Molecular Biology) and BIOCHEM 505 (Techniques in Biochemistry). Students will be able to have a comprehensive idea of the metabolic processes occurring in the living cells, the catalytic activity of the enzymes in the biological systems and the molecular basis of transmission of hereditary information through generations. These courses will appraise the students about the basic biochemical activities occurring in the living systems and will also help them to choose the avenues of their future research programmes with the knowledge of essential tools of analytical techniques being extremely helpful for the students of other disciplines besides thosebelonging to biochemistry itself. The qualitative and quantitative estimation of the plant metabolites is also an important aspect of crop improvement programmes.

In BIOCHEM 502, topics such as, biochemical reaction types, bioavailability of nutrients, defined metabolic processes, and nucleotide metabolism are newly introduced. Course outlines in BIOCHEM 503 are redefined in broader aspects with introduction of enzyme kinetic models and large scale production technology of enzymes in theory and effect of inhibitors on enzyme activity and electrophoretic analysis of isozymes in practical. New topics for theory have also been added to BIOCHEM 504, such as genome editing, DNA sequencing, *in vitro* mutagenesis and techniques in molecular biology. The course BIOCHEM 505 is redesigned with introduction of several modern and widely used techniques, viz. mass spectroscopy - MS/MS, LC-MS, GC-MS, MALDI-TOF, atomic absorption spectrophotometry, microscopic techniques, imaging techniques – MRI and CT scan and immunochemical techniques. Emphasis is also given to practicals with introduction of several important techniques – separation and analysis of fatty acids/lipids by GC, $(NH_4)_2\ SO_4$ precipitation and dialysis, PCR, ELISA and Western blotting/Dot blotting.So the course BIOCHEM 505 will enable the students to acquaint with the methods to estimate the phytochemicals and cellular constituents along with their theoretical backgrounds.

3. Courses related to plant metabolism: Two courses within this category are BIOCHEM 507 (Plant Biochemistry) and BIOCHEM 510 (Nitrogen and Sulphur Metabolism). Understanding the basic plant metabolic processes is of prime importance for improvement of crop plants. So these courses will give the basic idea in this field and will help the students to explore further for development of the crops.

Credit load in BIOCHEM507 is changed from 3 (3+0) to 3 (2+1) with one credit for practicals and with introduction of new topic - effect of biotic and abiotic factors on plant metabolism. For BIOCHEM 510 also, the course title is changed from Carbon and Nitrogen metabolism to Nitrogen and Sulfur metabolism as the topics under carbon metabolism have been well addressed in BIOCHEM 501 and BIOCHEM 507. An elaborative course outline on nitrogen as well as sulfurmetabolism covering all the aspects is prescribed. New practicalslikeestimation of cysteine, methionine, pyruvate and glutathione and assay of APS activity are introduced.

4. Courses dealing with diverse specialized areas: Three courses, viz. BIOCHEM 506 (Immunochemistry), BIOCHEM 509 (Nutritional Biochemistry) and BIOCHEM 511 (Biochemistry on Xenobiotics) under this categoryaddress the biochemical aspects of immunity, nutrition and environmental applications of biochemistryrespectively. These courses will widen the area of understanding as well as application of the subject on environmental components and human health as a whole.

In BIOCHEM 506 course outline, aspects on plant immunity, proteasome mediated process, plantibodies, additional immunological techniques: immunoblotting, FACS; basics of PCR and hybridization based methods of detection, microarray based detection, multiplexing are newly introduced. Similarly ELISA, Western blotting, Fluorescent Ab test and Hybridoma technique are newly introduced in the practical part.

Course title for BIOCHEM 509 is changed from Food and Nutritional Biochemistry to Nutritional Biochemistry and the course outline is modified to suit the present aspects in nutrition science with inclusion of phytonutrients, prebiotics and probiotics, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, factors affecting bioavailability of nutrients and food sensitivity. New practicals are also introduced.

A new course, Biochemistry on xenobiotics(BIOCHEM511) is proposed considering the pollution from industrial chemicals and waste water leading to heavy metals contamination of the agricultural crops and thebiological and non-biological remediation techniques.

5. Animal Biochemistry (BIOCHEM 508): Agriculture is a multidisciplinary stream and includes animal husbandry. So study of the topics related to animal system will be of immense help for the students.

The Unit–II in the earlier syllabus under BIOCHEM 508 (Animal Biochemistry) is restructured with inclusion of vitamins, energy nutrients, bioactive peptides and functional oligosaccharides with deletion of biochemistry of reproduction from the Unit-III.

Ph. D. courses

There are seven (7) coursesat the Ph. D. level, most of which are of advanced nature. No new course is proposed in the syllabus. Modification of the courses was done as per suggestions from different experts from state agricultural universities and ICAR institutions.

- Units under BIOCHEM 601 (Advanced Enzymology) are redefined with incorporation new topics such as pseudoenzyme and enzyme promiscuity, extremozymes, catalytic nucleic acids (ribozymes, catalytic DNA), immobilization of enzymes, semisynthetic enzymes and their use as industrial biocatalysts and their practical significance, modern information technologies in enzyme engineering.
- In BIOCHEM 602 (Advanced Molecular Biology), the units are redefined with inclusion of several new topics like concept of epigenome, role of histones, riboswitches, genome sequencing technologies, gene silencing technologies, genome editing – TALENs, CRISPR/cas, ZFN and their application and a new unit Aspects of molecular breeding.
- The different units are newly addressed for BIOCHEM 603 (Biochemistry of Biotic and Abiotic Stresses), a course having enormous importance for understanding the interfaring effects of stresses specially with crop growth and development .
- The course title and the credit load for BIOCHEM 604 are changed with new title Frontier topics in biochemistry and with credit load of (2+0). The broad topics for oral presentations to be delivered by the students registering this course are divided into eight major heads.
- The course title for BIOCHEM 605 is changed to Concepts and Application of Omics in Biological Science with fresh inclusion of ionomics part.
- The course title for BIOCHEM 607 is changed to Application of Techniques in Biochemistry. The entire course is divided into five units with Molecular biology and immunochemical techniques in the fifth unit.

Biochemistry courses are offered to a large number of students hence need for a few common types of equipment in multiple numbers cannot be avoided. Moreover, with the advancement of techniques and to cater quality teaching and research, sophisticated equipment like ultra-low freezers, high speed refrigerated- and ultra-centrifuges, automated bioseparation systems like GLC or HPLC, GC-MS, LC-MS; UV-Vis spectrophotometers suitable for enzyme studies, AAS for minerals, PCRs, electrophoresis systems for proteins and DNA are required as essentials in a Biochemistry laboratory. Additional funds may also be required forpurchasing spare parts and for AMC for the instruments. Provisions for training to the teachers to the new areas in the field of Biochemistry and exposure to modern laboratories within and outside the country become a primary need with the changing academic scenario. Moreover, funds may also be required for the proposed exposure visits of the students to other institutes. Financial assistance for these non-recurring and recurring expenses to the tune of a one-time grant of ₹ 5 crores and ₹ 20 lacs per annum respectively, is the need of the time to effectively run Master's and Doctoral programmes in the Discipline of Biochemistry at ICAR-IARI and State Agricultural Universities.

Course Title with Credit Load
M.Sc. (Ag) in Biochemistry

Code Code	Course Title	Credit Hours
BIOCHEM 501*	Basic Biochemistry	3+1
BIOCHEM 502*	Intermediary Metabolism	3+0
BIOCHEM 503*	Enzymology	2+1
BIOCHEM 504	Molecular Biology	2+1
BIOCHEM 505*	Techniques In Biochemistry	2+2
BIOCHEM 506	Immuno Chemistry	2+1
BIOCHEM 507	Plant Biochemistry	2+1
BIOCHEM 508	Animal Biochemistry	3+0
BIOCHEM 509	Nutritional Biochemistry	2+1
BIOCHEM 510	Nitrogen And Sulphur Metabolism	2+1
BIOCHEM 511	Biochemistry On Xenobiotics	2+0
BIOCHEM 591	Master's Seminar	1+0
BIOCHEM 599	Master's Research	30

*Core course

Course Contents
M.Sc. (Ag) in Biochemistry

I. Course Title : Basic Biochemistry

II. Course Code : BIOCHEM 501*

III. Credit Hours : 3+1

IV. Why this course?

To impart the fundamental knowledge on structure and function of cellular components involved in biological processes and an elementary introduction to the study of molecular biology.

V. Aim of the course

The course is designed to provide elementary knowledge/overview of structure and function of proteins, carbohydrates, lipids, nucleic acids and other biomolecules and their metabolism.

No.	Blocks	Units
1.	Introduction to Biochemistry	1. Scope and importance of biochemistry 2. Foundation of life 3. Water 4. Physical techniques for structure determination
2.	Structure and function of biomolecules	1. Biomolecules 2. Immunoglobulins and PR proteins 3. Plant secondary metabolites
3.	Metabolism – the basics	1. Molecules aiding metabolism 2. Thermodynamics –principles and energetic of life
4.	Catabolism and its regulation	1. Catabolism of energy molecules 2. ATP formation
5.	Fundamentals of Molecular biology and genetic engineering	1. Molecular biology processes 2. Recombinant DNA technology

VI. Theory

Block 1: Introduction to Biochemistry

Unit 1: Scope and importance of biochemistry (1 Lecture)

Biochemistry as modern science and its various divisions, Scope and importance of biochemistry in agriculture and allied sciences.

Unit 2: Foundation of life (2 Lectures)

Fundamental principles governing life, supramolecular structures, significance of weak non covalent interactions in biology

Unit 3: Water (3 Lectures)

Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship.

Unit 4: Physical techniques for structure determination (2 Lectures)

General introduction to physical techniques for determination of structure of biopolymers.

Block 2: Structure And Function of Biomolecules

Unit 1: Biomolecules (10 Lectures)

Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids.

Unit 2: Immunoglobulins and PR proteins (2 Lectures)

Structure, formation and different forms of immunoglobulins, PR proteins and their classification.

Unit 3: Plant secondary metabolites (3 Lectures)

Structure, classification and function of plant secondary metabolites.

Block 3: Metabolism – The Basics

Unit 1: Molecules aiding metabolism (2 Lectures)

Structure and biological functions of vitamins and coenzymes, enzymes: classification and mechanism of action; regulation, factors affecting enzyme action. Hormones: animal and plants.

Unit 2: Thermodynamics –principles and energetic of life (2 Lectures)

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

Block 4: Catabolism and its Regulation

Unit 1: Catabolism of energy molecules (5 Lectures)

Important and basic degradative metabolic pathways of carbohydrates, lipids and proteins and their regulation.

Unit 2: ATP formation (3 Lectures)

Formation of ATP, substrate level phosphorylation, electron transport chain and oxidative phosphorylation, chemiosmotic theory and proton motive force.

Block 5: Fundamentals of Molecular Biology and Genetic Engineering

Unit 1: Molecular biology processes (4 Lectures)

Overview of replication, transcription and translation.

Unit 2: Recombinant DNA technology (3 Lectures)

Restriction enzymes, DNA cloning, applications of cloning, transgenics.

VII. Practicals

- Preparation of standard and buffer solutions
- Detection of carbohydrates, amino acids and proteins
- Extraction and estimation of sugars
- Extraction and estimation of amino acids
- Extraction and estimation of proteins

- Estimation of acid value of fat/oil
- Estimation of peroxide value of fat/oil
- Estimation of saponification value in fats and oils
- Fatty acid composition in fat/oil by GC
- Estimation of DNA and RNA by spectroscopic methods
- Estimation of Ascorbic acid
- Separation of biomolecules by TLC and Paper chromatography
- Estimation of alpha amylase activity
- Qualitative tests for secondary plant metabolites.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz

IX. Learning outcome

With this course, the students are expected to be able to understand the actual chemical concepts and fundamental processes of biology at molecular level.

X. Suggested Reading

- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana U and Chakrapani U. 2017. *Biochemistry*. 5th edition, Elsevier
- Moran LA, Horton HR, Scrimgeour KG and Perry MD. 2012. *Principles of Biochemistry*. 5th edition Pearson.
- Voet D and Voet JG. 2011. *Biochemistry*. 4th edition John Wiley.
- Pratt CW and Cornely K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press
- Conn EE, Stumpf PK, Bruening G and Doi RH. 2006. *Outlines of Biochemistry*. 5th edition. Wiley.

I. Course Title : Intermediary Metabolism

II. Course Code : BIOCHEM 502*

III. Credit Hours : 3+0

IV. Why this course?

To understand the interconversion of chemical compounds in the living system, the pathways taken by individual molecules, their interrelationships and the mechanisms that regulate the flow of metabolites through the pathways.

V. Aim of the course

The course is designed to give an insight into the different metabolic pathways, their interrelationship, regulation, metabolic disorders in human and pathway engineering in plants.

No.	Blocks	Units
1.	Introduction to metabolism	1. Overview of metabolism 2. Metabolic pathways
2.	Metabolism of energy nutrients	1. Carbohydrate metabolism

No.	Blocks	Units
		2. Lipid metabolism 3. Protein metabolism 4. Energy transduction and oxidative phosphorylation
3.	Sulphur and nucleotide metabolism	1. Sulphur metabolism 2. Nucleotide metabolism
4.	Metabolic regulation and defects in metabolism	1. Regulation of metabolic pathways 2. Defects in metabolism

VI. Theory

Block 1: Introduction To Metabolism

Unit 1: Overview of metabolism (4 Lectures)

The living cell - a unique chemical system, biochemical reaction types, bioenergetics, bioavailability of nutrients, transport mechanism, signal transduction.

Unit 2: Metabolic pathways (5 Lectures)

Catabolism and anabolism, compartments of metabolic pathways, experimental approaches to study metabolism, metabolic profiles of major organs.

Block 2: Metabolism of Energy Nutrients

Unit 1: Carbohydrate metabolism (5 Lectures)

Major catabolic and anabolic pathways of carbohydrate metabolism, the glyoxylate pathway.

Unit 2: Lipid metabolism (5 Lectures)

Fatty acid oxidation, ketone bodies, fatty acid biosynthesis, synthesis of triacylglycerols, cholesterol, eicosanoids.

Unit 3: Protein metabolism (3 Lectures)

General reactions of amino acid metabolism, degradative and biosynthetic pathways of amino acids, urea cycle, amino acids as metabolic precursors.

Unit 4: Energy transduction and oxidative phosphorylation (4 Lectures)

Mechanisms of energy transduction, electron transport system, oxidative phosphorylation, control of ATP production.

Block 3.sulphur and Nucleotide Metabolism

Unit 1: Sulphur metabolism (5 Lectures)

Sulphate reduction and incorporation of sulphur in to amino acids.

Unit 2: Nucleotide metabolism (3 Lectures)

Synthesis and degradation of purine and pyrimidine nucleotides.

Block 4: Metabolic Regulation and Defects in Metabolism

Unit 1: Regulation of metabolic pathways (4 Lectures)

Regulation of carbohydrate, lipid, protein, nucleotide metabolism and oxidative phosphorylation.

Unit 2: Defects in metabolism (4 Lectures)

Disorders of carbohydrates, lipids, amino acids and nucleic acid metabolism, and inborn errors of metabolism. Metabolic pathway engineering.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

With this course, the students are expected to learn the set of life-sustaining chemical processes that enables organisms transform the chemical energy stored in molecules into useful form and the process by which organisms respond to stimuli and metabolic disorders.

IX. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana, U. and Chakrapani, U. 2017. *Biochemistry*. 5th edition, Elsevier
- Campbell M. K. and Farrell S.O. 2009. *Biochemistry*. 6thedition Thomson Higher Education.
- Moran L. A., Horton H. R., Scrimgeour K. G. and Perry, M. D. 2012. *Principles of Biochemistry*. 5th edition Pearson,
- Voet, D. and Voet J. G. 2011. *Biochemistry*. 4thedition . John Wiley.
- Pratt, C. W. and Cornely, K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy, K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press

I. Course Title : Enzymology

II. Course Code : BIOCHEM 503*

III. Credit Hours : 2+1

IV. Why this course?

Being highly specific and incredibly efficient biological catalysts, enzymes are responsible for bringing about almost all of the chemical reactions in living organisms. Otherwise these reactions will take place at a rate far too slow for the pace of metabolism. The course will help students in understanding the physical, chemical and kinetic properties of enzymes.

V. Aim of the course

To impart knowledge about the catalytic role of enzymes, their structure, physico-chemical, kinetic and regulatory properties and mechanism of action.

No.	Blocks	Units
1.	Introduction to enzymes	1. Structure and function of enzyme 2. Extraction and purification of enzymes
2.	Enzyme structure and function	1. Chemical nature of enzyme 2. Cofactors and coenzymes 3. Nature of active site
3.	Enzyme kinetics	1. Single substrate kinetics 2. Enzyme inhibition 3. Kinetics of allosteric enzymes

No.	Blocks	Units
		4. Regulation of enzyme activity
4.	Application of enzymology	1. Industrial application of enzymes 2. Biotechnological application of enzymes

VI. Theory

Block 1: Introduction To Enzymes

Unit 1: Structure and function of enzyme (2 Lectures)

Historic perspective, general properties of enzymes, enzyme compartmentalization in cell organelles, nomenclature and classification of enzymes, ribozymes, isozymes, abzymes.

Unit 2: Extraction and purification of enzymes (2 Lectures)

Extraction of soluble and membrane-bound enzymes, purification of enzymes, measurement of enzyme activity.

Block 2: Enzyme Structure and Function

Unit 1: Chemical nature of enzyme (3 Lectures)

Enzyme specificity, monomeric and oligomeric enzymes, catalytic mechanism, mechanism of enzyme action, pseudoenzymes, enzyme promiscuity.

Unit 2: Cofactors and coenzymes (2 Lectures)

Chemical nature and involvement of cofactors and coenzymes in enzyme catalyzed reactions, metal activated enzymes and metalloenzymes, mechanism of enzyme catalyzed reactions without cofactors.

Unit 3: Nature of active site (2 Lectures)

Active site, identification of binding sites and catalytic sites.

Block 3. Enzyme Kinetics

Unit 1: Single substrate kinetics (4 Lectures)

Relationship between initial velocity and substrate concentration, Michaelis-Menten equation, Lineweaver-Burk and Eadie-Hofstee plots, analysis of kinetic data, numerical exercises.

Unit 2: Enzyme inhibition (2 Lectures)

Reversible and irreversible enzyme inhibition, uses of enzyme inhibition.

Unit 3: Kinetics of allosteric enzymes (3 Lectures)

Nature of allosteric enzymes, sigmoidal kinetics, MWC model and allosteric regulation, KNF model and allosteric regulation.

Unit 4: Regulation of enzyme activity (3 Lectures)

Feedback regulation, regulatory enzymes, control of enzymatic activity, symmetry and sequential model, reversible covalent modification of enzymes.

Block 4: Application of Enzymology

Unit 1: Industrial application of enzymes (3 Lectures)

Industrial application of enzyme catalysis in sectors like food processing, detergents, biofuels, paper and pulp, biosensors and clinical applications of enzymes.

Unit 2: Biotechnological application of enzymes (2 Lectures)

Large scale production and purification of enzymes, immobilization of enzymes.

VII. Practicals

- Soluble protein estimation
- Enzyme assay by taking any model enzyme
- Isolation and purification of any model enzyme
- Study of the effect of enzyme and substrate concentrations on enzyme activity
- Determination of K_m and V_{max}
- Determination of pH and temperature optima
- Effect of inhibitors on enzyme activity
- Determination of pH and temperature stability of enzyme
- Electrophoretic analysis of isozymes.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the chemical principles of enzyme catalysis, action of enzymes as biocatalysts and factors that influence enzyme activity and understand the kinetics of enzymatic reactions. Students will have experience with purification, handling and characterization of proteins and also get exposure of wide applications of enzymes and their future potential.

X. Suggested Reading

- Palmer T and Bonner PL. 2007. *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*. 2nd edition. Woodhead Publishing
- Okotore RO. 2015. *Essentials of Enzymology*. XLIBRIS
- Herald J. 2016. *Essentials of Enzymology*. Syrawood Publishing House
- Suzuki, H. 2015. *How Enzymes Work: From Structure to Function*. Jenny Stanford Publishing.
- Bugg TDH. 2012. *Introduction to Enzyme and Coenzyme Chemistry*, 3rd Edition. WILEY
- Guo Y. 2014. *Enzyme Engineering*. Science Press
- Bisswanger H. 2011. *Practical Enzymology*. Wiley-Blackwell

I. Course Title : Molecular Biology

II. Course Code : BIOCHEM 504

III. Credit Hours : 2+1

IV. Why this course?

Molecular biology is the study of biology at a molecular level. The concepts and techniques of molecular biology are the foundation for the studies of all aspects of biology in modern time. This course is designed to provide an intensive exposure to the theoretical concepts and experimental techniques of molecular biology and the interrelationship of DNA, RNA and protein synthesis and their regulation.

V. Aim of the course

To provide knowledge of life processes at the molecular and cellular levels, including the storage, transfer and regulation of genetic information and specialist theoretical knowledge and practical experience of gene manipulation and the analysis of nucleic acids and proteins.

No.	Blocks	Units
1.	Introduction to nucleic acids	1. History 2. Properties of nucleic acid 3. Genes and genome
2.	Synthesis of nucleic acids	1. DNA replication 2. Transcription
3.	Protein synthesis	1. Translation machinery 2. Mechanism of protein synthesis 3. Post-translational events
4.	Gene manipulation	1. DNA sequencing 2. Recombinant DNA technology 3. Techniques in molecular biology

VI. Theory

Block 1: Introduction to Nucleic Acids

Unit 1: History (1 Lecture)

Historical development of molecular biology, nucleic acids as genetic material.

Unit 2: Properties of nucleic acid (2 Lectures)

Nucleic acid structure, chemical and physical properties of nucleic acids, spectroscopic and thermal properties of nucleic acids, DNA supercoiling.

Unit 3: Genes and genome (3 Lectures)

Concept of genes and genome,genome complexity, genome organization in prokaryotes and eukaryotes, chromatin structure and function, repetitive and non-repetitive DNA, satellite DNA central dogma, genome editing.

Block 2: Synthesis of Nucleic Acid

Unit 1: DNA replication (3 Lectures)

Modes of replication, DNA polymerases, topoisomerases, DNA ligase, model of replisome, semi conservative replication in prokaryotes and eukaryotes, inhibitors of replication, DNA damage and repair.

Unit 2: Transcription (3 Lectures)

Basic principles of transcription, transcription initiation, elongation and termination, RNA processing, RNA interference, siRNAs, miRNAs and other ncRNAs, DNA/ RNA editing. regulation of transcription, reverse transcription.

Block 3. Protein Synthesis

Unit 1: Translation machinery (2 Lectures)

Ribosomes structure and function, organization of ribosomal proteins and RNA genes, genetic code, aminoacyl tRNA synthases.

Unit 2: Mechanism of protein synthesis (2 Lectures)

Initiation, chain elongation and termination of translation, energetics, inhibitors of translation.

Unit 3: Post-translational events (2 Lectures)

Post translational modifications of nascent polypeptide, protein targeting and turnover, regulation of gene expression in prokaryotes and eukaryotes, nucleases and restriction enzymes.

Block 4: Gene Manipulation

Unit 1: DNA sequencing (3 Lectures)

Importance, Sanger method,High-Throughput Sequencing (HTS) techniques, applications of DNA sequencing.

Unit 2: Recombinant DNA technology (4 Lectures)

Vectors, isolation of genes, recombinants vector, selection of recombinants, characterization and expression of cloned DNA, transformation, transgenesis, mutation, molecular mechanism of mutation, site directed mutagenesis, *in vitro* mutagenesis.

Unit 3: Techniques in molecular biology (3 Lectures)

Polymerase chain reaction (PCR), expression cloning, gel electrophoresis, molecular markers, macromolecule blotting and probing, arrays (DNA array and protein array) – principles and application.

VII. Practicals

- Isolation and purification of DNA and RNA
- To check the purity of isolated DNA and RNA
- Restriction fragmentation of genomic DNA
- Separation of oligos by agarose gel electrophoresis
- Southern blotting experiments
- Northern blotting experiments
- Cloning of DNA fragment in vector
- Selection of recombinant
- SSR analysis of DNA
- cDNA synthesis using RT- PCR
- Basic tools in bioinformatics analysis

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

After completion, the student should be able to explain central cell biological processes and how they are regulated and quality assured and understands how molecular cell biology forms the foundation of biotechnology.

X. Suggested Reading

- Snape A, Papachristodoulou D, Elliott, W. H. and Elliott, C. 2014. *Biochemistry and Molecular*

Biology. Oxford University Press.
- Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. 2018. *Lewin's GENES XII*. Jones & Bartlett Learning.
- Lodish, H.,Berk, A., Kaiser, C. A., Krieger, M. And Bretscher, A. 2016. *Molecular Cell Biology*.W H Freeman & Co.
- Hoffmann, A. And Clokie, S. 2018. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge University Press.
- Primrose SB, Twyman RM and Old RW.2002. *Principles of Gene Manipulation*: 6th Ed. Wiley
- Karp, G. 2013. *Cell and Molecular Biology*. Wiley.
- Neidle, S. 2008. *Principles of Nucleic Acid Structure*. Elsevier Inc.
- Watson J, Baker TA, Bell SP, Gann A, Levine M and Losick, R. 2014. *Molecular biology of the gene* 7th edition, Pearson.

I. Course Title : Techniques in Biochemistry

II. Course Code : BIOCHEM 505*

III. Credit Hours : 2+2

IV. Why this course?

Biochemical studies rely on the availability of appropriate analytical techniques and their applications. This course will examine modern methods and technologies that are used in biochemical analysis with emphasis on instrumentation, underlying principles, aims, strategies and current applications.

V. Aim of the course

To provide hands-on experience to different biochemical techniques commonly used in research along with the knowledge on principles and the instrumentation.

No.	Blocks	Units
1.	Separation techniques	1. Chromatography techniques 2. Electrophoretic technique 3. Hydrodynamic methods 4. Centrifugation
2.	Spectroscopic techniques	1. Spectrophotometry 2. Mass spectroscopy 3. Atomic absorption spectrophotometry
3.	Microscopy	1. Microscopic techniques
4.	Tracer, imaging, immunochemical and other techniques	1. Tracer techniques 2. Imaging techniques 3. Immunochemical techniques 4. Other techniques

VI. Theory

Block 1: Separation Techniques

Principles and applications of separation techniques.

Unit 1: Chromatography techniques (4 Lectures)

Principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, column & HPTLC, GC, HPLC and FPLC.

Unit 2: Electrophoretic technique (2 Lectures)

General principles,paper and gel electrophoresis, native and SDS-PAGE, 2D-PAGE, capillary electrophoresis.

Unit 3: Hydrodynamic methods (2 Lectures)

Hydrodyanmic methods of separation of biomolecules such as viscosity and sedimentation velocity, - their principles.

Unit 4: Centrifugation (2 Lectures)

Basic principles of sedimentation, type, care and safety aspects of centrifuge preparative and analytical centrifugation.

Block 2: Spectroscopic Techniques

Unit 1: Spectrophotometry (3 Lectures)

Principles and applications of UV-visible, Fluorescence, IR and FTIR, Raman, NMR and FTNMR, ESR and X-Ray spectroscopy.

Unit 2: Mass spectroscopy (3 Lectures)

MS/MS, LC-MS, GC-MS, MALDI-TOF, applications of mass spectrometry in biochemistry.

Unit 3: Atomic absorption spectrophotometry (2 Lectures)

Principle, function and instrumentation ofatomic absorption spectrophotometry.

Block 3. Microscopy

Unit 1: Microscopic techniques (2 Lectures)

Principles and applications, light, UV, phase contrast, fluorescence and electron microscopy, flow cytometry.

Block 4: Tracer, Imaging, Immunochemical and Other Techniques

Unit 1: Tracer technique (2 Lectures)

Tracer techniques in biology: concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of á, â and ã emitters, scintillation counters, γ-ray spectrometers, autoradiography, applications of radioactive tracers in biology.

Unit 2: Imaging techniques (2 Lectures)

Principles and applications of phosphor imager, MRI and CT scan.

Unit 3: Immunochemical technique (2 Lectures)

Production of antibodies, immunoprecipitation, immunoblotting, immunoassays, RIA and ELISA.

Unit 4: Other techniques (2 Lectures)

Cryopreservation, polymerase chain reaction (PCR), FACS.

VII. Practicals

- Expression of concentration in terms of dilution, molarity, normality, percent expression
- pH measurement and buffer preparation
- Determination of absorption maxima of biomolecules

- Estimation of biomolecules through spectrophotometry and other methods
- Separation of carbohydrates and amino acids by paper chromatography
- Separation and analysis of fatty acids/lipids by GC
- Separation/estimation of biomolecules through HPLC and FPLC
- Separation of proteins using ion exchange, gel filtration and affinity chromatography
- Electrophoretic separation of proteins and nucleic acids
- Centrifugation- differential and density gradient
- $(NH_4)_2SO_4$ precipitation and dialysis
- Use of radioisotopes in metabolic studies
- PCR
- ELISA
- Western blotting/ Dot blotting

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

At the end of the course, the student will acquire the basic knowledge of the main biochemical methods used in the separation, identification, characterization and analysis of biomolecules.

X. Suggested Reading

- Boyer R. 2011. *Biochemistry Laboratory: Modern Theory and Techniques* 2nd Edition. Pearson
- Hofmann A and Clokie S. 2010. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. 7th edition. Cambridge University Press.
- Sawhney SK and Singh R. 2000. *Introductory Practical Biochemistry*. 2nd Ed. Narosa
- Katoch R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer
- Boyer R. 2009. *Modern Experimental Biochemistry*. Fifth impression. Pearson
- Lottspeich F and Engels JW. (Eds). 2018. *Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology*. Wiley-VCH
- Wilson K and Walker J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition. Cambridge University Press

I. Course Title : Immunochemistry

II. Course Code : BIOCHEM 506

III. Credit Hours : 2+1

IV. Why this course?

This is an introduction to the field of immunology with emphasis on the biochemical aspects of the systems. This course is intended to equip the student with the knowledge and understanding of the vertebrate immune system, its component and mechanism of immune responses with specific reference to the human immune defence system and plant immunity

V. Aim of the course

To give an insight into the biochemical basis of immunity

No.	Blocks	Units
1.	Basics of Immunology	1. Introduction to immunology 2. Antibodies 3. The immune responses 4. Immunoregulation and immunological techniques

VI. Theory

Block 1: Basics of immunology

Unit 1: Introduction to immunology (7 Lectures)

History and scope of immunology, antigens, adjuvants, immune system, organs, tissues and cells, immunoglobulins, molecular organization of immunoglobulin. Haptens, ag-ab interaction, plant immunity, proteasome mediated process, plantibodies

Unit 2: Antibodies (5 Lectures)

Classes of antibodies, antibody diversity, theories of generation of antibody diversity, vaccine, monoclonal and polyclonal antibodies, hybridoma, recombinant antibodies, complement system - classical and alternate.

Unit 3: The immune responses (8 Lectures)

Cellular interactions in immune response, major histocompatibility complex, cell mediated immune response, cytokines.

Unit 4: Immunoregulation and immunological techniques (8 Lectures)

Immunoregulation, immunological tolerance, hypersensitivity, mechanisms of immunity, innate resistance and specific immunity, current immunological techniques – elisa, ria, immunoblotting, facs; basics of pcr and hybridization based methods of detection, microarray based detection, multiplexing.

VII. Practicals

- Handling, inoculation and bleeding of laboratory animals
- Preparation of antigens and antisera, natural antibodies
- Carbon clearance test
- Lymphoid organs of the mouse
- Morphology of the blood leucocytes
- Separation of lymphocytes from blood, viable lymphocyte count
- Antigen-antibody interaction,
- Precipitation and agglutination
- Direct and indirect haemagglutination
- Immunoelectrophoresis
- Complement fixation
- Quantitation of immunoglobulins by zinc sulphate turbidity and single radial immunodiffusion
- ELISA
- Western blotting
- Fluorescent Ab test
- Hybridoma technique

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

It is expected that the student should understand and explain the structure, functioning and importance of human immune system in term of health and disease.

Suggested Reading

- Punt J, Stranford S, Jones P and Owen J. 2018 . Kuby Immunology. 8th edition. W. H. Freeman
- Renshaw S. 2016. *Immunohistochemistry and Immunocytochemistry: Essential Methods*, 2nd Edition. John Wiley & Sons, Ltd.
- Abbas AK, Lichtma AH and Pillai S. 2018. *Cellular and Molecular Immunology*. 9th edition. Elsevier
- Delves PJ, Martin SJ, Burton DR and Roitt IM. 2017. *Roitt's Essential Immunology*, 13th Edition. Wiley-Blackwell

I. Course Title : Plant Biochemistry
II. Course Code : BIOCHEM 507
III. Credit Hours : 2+1

IV. Why this course?

Harnessing sunlight, plants produce a diverse array of chemical compounds to survive in challenging ecological niches. Plant-derived metabolites are major sources of human food, fibre, fuel, and medicine. This course covers topics related to plant metabolism and discusses how plants generate carbon and energy sources by photosynthesis and synthesize various compounds through complex networks of metabolic pathways.

V. Aim of the course

To provide an understanding of metabolic processes in plants and the role of different biosynthetic pathways in plant growth and development.

No.	Blocks	Units
1.	Photosynthesis	1. Photosynthetic machinery 2. Carbon reduction
2.	Conversion of photosynthates	1. Synthesis of major biomolecules 2. Nitrogen and sulphur metabolism
3.	Growth and development	1. Germination and fruit ripening 2. Phytohormones
4.	Secondary metabolites	1. Biochemistry of plant secondary metabolites

VI. Theory

Block 1: Photosynthesis

Unit 1: Photosynthetic machinery (3 Lectures)

Structure and function of plant cell and its organelles, phytochromes, chloroplast morphology structure, structure and chemistry of photosynthetic pigments, light reaction of photosynthesis.

Unit 2: Photosynthesis – the process (4 Lectures)

Carbon reduction in C_3, C_4 and CAM plants, photorespiration, sucrose-starch interconversion.

Block 2: Conversion of Photosynthates

Unit 1: Synthesis of major biomolecules (3 Lectures)

Biosynthesis of structural carbohydrates, storage proteins and lipids.

Unit 2: Nitrogen and sulphur metabolism (5 Lectures)

Basic concepts of nitrogen and sulphur metabolism: biological nitrogen fixation, nitrate assimilation in plants, sulphur chemistry and function, reductive sulphate assimilation pathway, sulphated compounds.

Block 3: Growth and Develpoment

Unit 1: Germination and fruit ripening (4 Lectures)

Biochemistry of seed germination – stages, requirements, metabolism and mobilization of storage material; Biochemistry of fruit ripening – ripening process, cell wall degrading enzymes, role of ethylene and regulation of ethylene production.

Unit 2: Phytohormones (3 Lectures)

Different classes of phytohormones, their biosynthesis and mode of action.

Block 4: Secondary Metabolites

Unit 1: Biochemistry of plant secondary metabolites (6 Lectures)

Biochemistry and significance of plant secondary metabolites – phenolics, terpenoids, alkaloids, cyanogenic glycosides and glucosinolates, effect of biotic and abiotic factors on plant metabolism and plant defense system.

VII. Practicals

- Fractionation of cell organelles,
- Estimation of starch,
- Assay of ADPG pyrophosphorylase/starch synthase,
- Assay of PAL/SOD
- Assay of PPO/LOX,
- Estimation of individual amino acids,
- Qualitative tests of secondary metabolites (alkaloids, sterols etc.)
- Content and composition of carotenoids, anthocyanin and chlorophylls
- Determination of polyphenols/phenolics
- Fractionation of storage proteins
- Estimation of glucosinolates
- Estimation of cyanogenic compounds.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

Successful completion of this course will provide students with fundamental knowledge of biochemistry and specific knowledge of compounds and biochemical pathways that occur in plants.

X. Suggested Reading

- Buchannan BB, Gruissem W and Jones R.L. (eds.). 2000. *Biochemistry and Molecular Biology of Plants*. 2nd edition. WILEY Blackwell
- Heldt, H-W. 2010. *Plant Biochemistry and Molecular Biology*. 4th ed. Oxford University Press
- Goodwin TW and Mercer EI. 2005. *Introduction to Plant Biochemistry*. 2nd edition. CBS
- Heldt, H-W. and Piechulla, B. 2010.*Plant Biochemistry*. 4th Edition. Elsevier
- Harinda, Makkeaand Klaus. 2007. *Plant Secondary Metabolites*. Springer
- Cseke LJ, Kirakosyan A, Kaufman PB, Warber S, Duke JA, Brielmann HL. 2006. *Natural Products from Plants*. 2ndEdition. CRC Press

I. Course Title : Animal Biochemistry

II. Course Code : BIOCHEM 508

III. Credit Hours : 3+0

IV. Why this Course?

Biochemistry is one of the few basic sciences where animal and plant kingdoms meet. It provides the knowledge base for all human and animal health studies. Knowledge of biochemistry will enable one to study, or to pursue a line of research in applied sciences.

V. Aim of the Course

To impart knowledge regarding biochemistry of various physiological processes, specialized tissues and hormone action in animal system

No.	Blocks	Units
1.	Animal biochemistry	1. Biochemistry of assimilation 2. Nutrients and their biochemistry 3. Hormones and their role 4. Immune system

VI. Theory

Block 1: Animal Biochemistry

Unit 1: Biochemistry of assimilation (7 Lectures)

Digestion and absorption of food, Detoxification, biochemistry of specialized tissues – connective tissue, skin, muscle, nervous tissue and blood and other body fluids.

Unit 2: Nutrients and their biochemistry (7 Lectures)

Water, electrolyte and acid-base balance, structure, function and mechanism of major trace elements, vitamins, energy nutrients and biochemistry of respiration, bioactive peptides and functional oligosaccharides.

Unit 3: Hormones and their role (7 Lectures)

Hormones of thyroid, hypothalamus, pituitary, pancreas, adrenals and sex hormones, Membrane receptors of hormones, signal transduction.

Unit 4: Immune system (7 Lectures)

Immune systems, immunoglobulins, monoclonal antibodies, formation of antibody, antibody diversity, complement system – classical and alternate, major histocompatibility complexes, cell mediated immune response, mechanisms of immunity.

VII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

VIII. Learning outcome

Students can acquire essential foundation knowledge for further study in life sciences, agriculture, environmental science, health science, etc.

IX. Suggested Reading

- Bradley, A. 2018. Animal Physiology and Biochemistry. 1st edition. Edtech Press
- Agarwal RA, Srivastava, A.K. and Kumar, K. 2010. *Animal Physiology and Biochemistry*. Fifth revised edition S. Chand.
- Rodwell VA, Bender DA, Botham KM, Kennelly PJ and Weil PA. 2018. *Harper's Illustrated Biochemistry*, 31st edition. McGraw-Hill Education.

I. Course Title : Nutritional Biochemistry

II. Course Code : BIOCHEM 509

III. Credit Hours : 2+1

IV. Why this course?

Nutritional biochemistry deals with the structural and functional characteristics of macro and micronutrients in food consumed by humans. The course will expand understanding of the biological roles of nutrients and their metabolism using basic knowledge in physiology, biochemistry, cell biology and molecular biology. It will integrate information on the roles of nutrients in nutrition and health.

V. Aim of the course

To impart knowledge regarding the biochemical aspects of various nutrients and their interactions in foods during processing, storage and deterioration.

No.	Blocks	Units
1.	Nutritional biochemistry	1. Fundamentals of human nutrition 2. Biochemical functions of nutrients 3. Bioavailability of nutrients 4. Food sensitivity

VI. Theory

Block 1: Nutritional Biochemistry

Unit 1: Fundamentals of human nutrition (7 Lectures)

Fundamentals of human nutrition, concept of balanced diet, biochemical composition, energy and food value of various food grains (including cereals, pulses, oilseeds), fruits and vegetables. Physico-chemical, functional and nutritional characteristics of carbohydrates, proteins and fats and their interactions (emulsions, gelation, browning etc.). Digestion and absorption, digestive secretions, their characteristic features and control, protection of microflora of the GI tract

Unit 2: Biochemical functions of nutrients (7 Lectures)

Biochemical functions of nutrients, macro- and micronutrients- carbohydrates, fats and proteins, vitamins, water soluble and fat soluble vitamins, mineral and phytonutrients, prebiotics and probiotics, enzymes and metabolic protein factors, cofactor role, electrolytic function, constituents of skeletal tissues, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, antinutritional factors, biochemistry of postharvest storage.

Unit 3: Bioavailability of nutrients (7 Lectures)

Factors affecting bioavailability of nutrients, biological value of proteins; effect of cooking, processing and preservation of different food products on nutrients, energy- and micronutrient malnutrition, deficiency diseases of macro and micronutrients.

Unit 4: Food sensitivity (7 Lectures)

Food sensitivity: immunologically mediated food sensitivity, nature and properties of antigens in foods, mechanism of induction of all allergic reactions, diagnostic tests for food, hypersensitivity, non-immunologically mediated food sensitivity, food sensitivity due to metabolic diseases, gastrointestinal diseases, food additives, pharmacologic agents, food toxins and poisonous and psychological factors.

VII. Practicals

- Estimation of amylose and amylopectin
- Estimation of resistant starch
- Estimation of ù3, ù6 and trans fatty acid
- Estimation of phenols in plant tissue/sample
- Estimation of carotenoids
- Estimation of amylase, trypsin and chymotrypsin inhibitor activities
- Estimation of Vitamin C in fruits
- Estimation of reducing & non reducing sugar in fruits
- Estimation of protein contents
- Estimation of dietary fibre
- Determination of limiting amino acids
- Estimation of phytate/ oxalate
- Estimation of total antioxidant activity by different methods
- Estimation of curcumin.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

On successful completion of this course students should be able to critically analyse and evaluate concepts in nutritional biochemistry that are important for an understanding of human nutrition, provide nutritional advice based on sound scientific findings, discuss the efficacy and appropriate use of functional foods and critically evaluate nutrition information appearing in popular magazines and other forms of media.

X. Suggested Reading

- Damodaran S. and Parkin KL (ed.) 2017. *Fennema's Food Chemistry*. CRC Press
- Gibney MJ, Lanham-New SA, Cassidy, A and Voster HH (ed.) 2009. *Introduction to Human Nutrition*. Wiley-Blackwell
- Trueman, P. 2007. *Nutritional Biochemistry*. MJP Publishers
- Cox, C. 2015.*Nutritional Biochemistry: Current Topics in Nutrition Research*. Apple Academic Press Inc.
- Haugen, S. and Meijer, S. 2010. *Handbook of Nutritional Biochemistry: Genomics, Metabolomics & Food Supply*. Nova Science Publishers Inc.

I. Course Title : Nitrogen and Sulfur Metabolism

II. Course Code : BIOCHEM 510

III. Credit Hours : 2+1

IV. Why this course?

Nitrogen and sulfur compounds are continuously synthetized, degraded and converted into other forms in nature. They coexist in the biosphere as free elements or in the form of oxyanions which are to be reduced before undergoing anabolic processes to form N and S containing compounds. This course will provide the students a fundamental understanding of their reduction, assimilation and metabolism in plants.

V. Aim of the course

To impart knowledge of general nitrogen and sulfur metabolism in plants and the assimilatory pathways.

No.	Blocks	Units
1.	Nitrogen and sulfur metabolism	1. Nitrogen metabolism 2. Sulfur metabolism

VI. Theory

Block 1: Nitrogen and Sulfur Metabolism

Unit 1: Nitrogen metabolism (18 Lectures)

Nitrogen cycle, assimilation of inorganic nitrogen, nitrate uptake and transporters, enzymology of nitrate reduction - Nitrate reductase (NR) and Nitrite reductase (NiR), NR regulation, nitrate signaling.

Assimilation of inorganic nitrogen and N-transport amino acids - glutamine synthetase (GS), glutamate synthase (GOGAT), glutamate dehydrogenase (GDH), aspartate amino transferase (AspT) and asparagine synthetase (AS), interaction between carbon metabolism and amino acid synthesis, biosynthesis of amino acids. Nitrogen fixation - an overview, enzymology of nitrogen fixation - nitrogenase, *nif* genes and their regulation, symbiotic nitrogen fixation - biochemical basis of rhizobial infection, nodule development. Mechanism of creation of microaerobic environment for nitrogen fixation. metabolic exchange between host plant and bacteroids.

Unit 2: Sulphur metabolism (10 Lectures)

Overview of sulfate assimilation, sulfur chemistry and function, sulfate uptake and transport, reductive sulfate assimilation pathway, synthesis and function of sulfur containing amino acids, glutathione and its derivatives, role of sulfated compounds in metabolism.

VII. Practicals

- Estimation of nitrite content,
- Estimation of nitrate content,
- *In vivo* assay of nitrate reductase activity,
- *In vitro* assay of nitrate reductase activity,
- *In vitro* assay of nitrite reductase activity,
- *In vitro* assay of glutamine synthetase activity,
- *In vitro* assay of glutamate synthase and glutamate dehydrogenase activity,
- Estimation of ureides and amides,
- Assay of nitrogenase activity by acetylene reduction method,
- Estimation of hydrogen evolution by legume nodules,
- Estimation of cysteine, methionine, pyruvate and glutathione,
- Assay of APS activity.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

Students will get an insight into the nitrogen and sulfur metabolism in plants and the coordination between nitrogen (N) and sulfur (S) assimilation

X. Suggested Reading

- Bothe, H. and Trebst, A. (eds.). 1981. *Biology of Inorganic Nitrogen and Sulfur*. Conference proceedings. Springer-Verlag
- De Kok *et al*. 2012. *Sulfur Metabolism in Plants*. Part of the Proceedings of the International Plant Sulfur Workshop book series. Springer
- Bray CM. 1983. *Nitrogen Metabolism in Plants*. Longman.
- Bidwell, R.G.S. 1983. *Plant Physiology: A Treatise*, Vol. 8: Nitrogen Metabolism. Academic Press
- Foyer. C. H. and Zhang, H. 2010. *Nitrogen Metabolism in Plants in the Post-Genomic Era.* Annual Plant Reviews, Vol.42. Wiley-Blackwell
- Buchanan B.B., Gruissem W. and James R. L. (Eds.). 2000. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists.

I. Course Title : Biochemistry on Xenobiotics

II. Course Code : BIOCHEM 511

III. Credit Hours : 2+0

IV. Why this course?

Xenobiotics are compounds that are foreign to an organism that include compounds like drugs, food additives, and environmental pollutants. Knowledge on metabolic conversion of xenobiotics, especially drugs and environmental contaminants in living system becomes pertinent in present day scenario with increased levels of pollution.

V. Aim of the course

To impart knowledge on xenobiotics and the mechanism of their metabolism and detoxification in living system.

No.	Blocks	Units
1.	Biochemistry on xenobiotics	1. Xenobiotics 2. Mode of degradation 3. Plant metabolism of xenobiotics 4. Phytoremediation

VI. Theory

Block 1: Biochemistry on Xenobiotics

Unit 1: Xenobiotics (7 Lectures)

Xenobiotics: classification and their effects on biological systems, Problems related to xenobiotics degradation, potential effects of toxic agents on immune system function, biotic metabolism of xenobiotics - biodegradation/biotransformation

Unit 2: Mode of degradation (7 Lectures)

Mode of degradation - Enzymatic and Non-enzymatic, Metabolism of toxic compounds with reference to role of detoxifying enzymes, Mechanism of xenobiotics detoxification - in animal using the enzymes of Phase I and Phase II, Role of microbes in xenobiotics degradation and co-metabolism, Biodegradation and its genetics, manipulation of xenobiotic degradative genes

Unit 3: Plant metabolism of xenobiotics (7 Lectures)

Plant metabolism of xenobiotics - transformation, conjugation and compartmentation, Metabolic responses of pesticides in plants, Impact, metabolism, and toxicity of heavy metals in plants, Regulation of xenobiotics in higher plants: signalling and detoxification.

Unit 4: Phytoremediation (7 Lectures)

Phytoremediation, Advances in development of transgenic plants for remediation of xenobiotic pollutants, safety assessment of xenobiotics

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Students will gain the basic knowledge and perspectives of bioelimination of xenobiotic compounds.

IX. Suggested Reading

- Richardson, M. 1996. *Environmental Xenobiotics*. CRC Press
- Singh, A., Prasad, S.M. and Singh, R.P.(eds). 2016. *Plant Responses to Xenobiotics*. Springer.
- Chang, Y-C. (ed). 2019. *Microbial Biodegradation of Xenobiotic Compounds*. CRC Press
- Costas Ioannides (ed). 2002. Enzyme Systems that Metabolise Drugs and Other Xenobiotics. Wiley
- Lee, P., Aizawa, H., Gan, L., Prakash, C. And Zhong, D. 2014. *Handbook of Metabolic Pathways of Xenobiotics*. –
- Emerson, M.L. 2012. Xenobiotics*: New Research*. Nova Science
- Shamaan, N.A. 2008. *Biochemistry of xenobiotics: towards a healty lifestyle and safe environment*. PenerbitUniversiti Putra Malaysia.

Course Title with Credit Load
Ph.D. in Biochemistry

Course Code	Course Title	Credit Hours
BIOCHEM 601*	Advanced Enzymology	2+1
BIOCHEM 602	Advanced Molecular Biology	3+0
BIOCHEM 603	Biochemistry Of Biotic And Abiotic Stresses	3+0
BIOCHEM 604	Frontier Topics In Biochemistry	2+0
BIOCHEM 605	Concepts And Aplication Of Omics In Biological Science	3+0
BIOCHEM 606	Biomembranes	2+0
BIOCHEM 607*	Application Of Techniques In Biochemistry	1+2
BIOCHEM 691	Doctoral Seminar I	1+0
BIOCHEM 692	Doctoral Seminar II	1+0
BIOCHEM 699	Doctoral Research	75

*Core course

Course Contents
Ph.D. in Biochemistry

I. Course Title : Advanced Enzymology
II. Course Code : BIOCHEM 601*
III. Credit Hours : 2+1

IV. Why this course?

The course will make the students able to make a conceptual analysis of the enzymatic reaction mechanism and know the principles of the application of enzymes in analytical biochemistry, and some industrial applications.

V. Aim of the course

To provide advanced knowledge about the structure of enzymes, mechanism, kinetics and regulation of enzymatic reactions and use of enzymes as biosensors.

No.	Blocks	Units
1.	Enzymology and enzyme engineering	1. Enzyme catalysis and specificity 2. Enzyme kinetics 3. Enzyme mechanism and regulation 4. Industrial enzymology

VI. Theory

Block 1: Enzymology And Enzyme Engineering

Unit 1: Enzyme catalysis and specificity (Seven Lectures)

Theory of enzymatic catalysis, Specificity and editing mechanisms, concept of active site and enzyme substrate complex, active site mapping, factors associated with catalytic efficiency, mechanism of enzyme reactions,detection of intermediates in enzymatic reactions.

Unit 2: Enzyme kinetics (7 Lectures)

Transition state theory, Arrhenius equation, Determination of energy of activation, effect of pH and temperature on enzyme kinetics, pre-steady state and steady state kinetics, single substrate kinetics, allosteric enzymes and mixed inhibition, substrate and product inhibition, numerical exercises.

Unit 3: Enzyme mechanism and regulation (7 Lectures)

Mechanism determination by radioisotope exchange, role of enzymes in regulation of metabolism, bifunctional enzymes, pseudoenzyme and enzyme promiscuity, extremozymes, catalytic nucleic acids (ribozymes, catalytic DNA).

Unit 4: Industrial enzymology (7 Lectures)

Advantages and disadvantages of biocatalysis in technology driven processes, stabilization and regeneration of enzyme systems used in biotechnology, protein engineering of enzymes, creation of chimeric, bifunctional, immobilization of enzymes, semisynthetic enzymes and their use as industrial biocatalysts, and their practical significance, modern information technologies in enzyme engineering.

VII. Practicals

- Purification and characterization of some model enzymes (peroxidise, á-amylase, lipase)
- Study kinetics of inhibited and un inhibited enzyme catalysed reactions
- Determination of Km values of single substrate reactions
- Determination of enzyme activity by coupled assay
- Electrophoretic separation of isozymes
- Enzyme immobilization.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completing the course students will understand the mode of action of enzymes, mechanisms of enzymatic catalysis and also possible applications of enzymes in various technological processes.

X. Suggested Reading

- Aehle, W. 2007. *Enzymes in Industry. Production and Application.* (Third, Completely Revised Edition*).* Wiley-VCH Verlag GmbH & Co. KGaA
- Buchholz, K., Bornscheuer, U., Kasche, V. 2012. *Biocatalysts and Enzyme Technology.* UK: Wiley-VCH Verlag GmbH
- Fessner, W. and Anthonsen, T. 2009. *Modern Biocatalysis.* Germany: Wiley-VCH Verlag GmbH
- Frey, P.A. and Hegeman, A.D. 2007. *Enzymatic Reaction Mechanisms.* Oxford University Press
- Young Je Yoo, Yan Feng, Yong-Hwan Kim, Camila Flor J. Yagonia. 2017. *Fundamentals of Enzyme Engineering.* Springer

I. Course Title : Advanced Molecular Biology

II. Course Code : BIOCHEM 602

III. Credit Hours : 3+0

IV. Why this course?

To impart knowledge on genome organization and analysis, gene expression and its regulation and modern techniques for genome.

V. Aim of the course

To provide latest information on structure and organisation of genetic materials; genes, their expression in plants and biochemical approaches employed in genetic engineering.

No.	Blocks	Units
1.	Genome organisation and manipulation	1. Concepts of gene and genome 2. Regulation of gene expression 3. Techniques in genome analysis 4. Techniques for gene transfer and genome manipulation 5. Aspects of molecular breeding

VI. Theory

Block 1: Genome Organisation and Manipulation

Unit 1: Concepts of gene and genome (5 Lectures)

Genes, their relationship with chromosomes, gene number hypothesis; Genome – definition, variation and organization in plants and animals, structure of organelle genomes; concept of epigenome, genome size and genome evolution.

Unit 2: Regulation of gene expression (6 Lectures)

Prokaryotic and eukaryotic gene regulation, transcriptional and posttranscriptional regulation; regulation at genome level, role of histones, riboswitches.

Unit 3: Techniques in genome analysis (6 Lectures)

Genome sequencing technologies, Sanger sequencing, next generation sequencing, nanopore sequencing; genome mapping – genetic map construction, physical mapping.

Unit 4: Techniques for gene transfer and genome manipulation (6 Lectures)

Methods of gene isolation and transfer in plants and animals, agrobacterium mediated and direct transfer of genes in plants and animals; gene silencing technologies: virus induced gene silencing, RNA interface; genome editing -TALENs, CRISPR/cas, ZFN and their application, site directed mutagenesis,Application of genetic engineering in different fields, gene therapy.

Unit 5: Aspects of molecular breeding (5 Lectures)

Genome browsing, primer design, marker application for breeding, application of MAS in case studies. Bioethics and bio safety guidelines, IPR in recombinant DNA research

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

On completion of this course, studentswill get an insight into the genome structure, its organization and means for its manipulation for applications in areas such as human and animal health, agriculture, and the environment.

IX. Suggested Reading

- Brown, T. A. 2018. *Genomes 4*. Garland Science

- Rippe, K. 2011. *Genome Organization and Function in the Cell Nucleus*. Wiley VCH Verlag
- Primrose, S. B. and Twyman, R.2006. *Principle of Gene Manipulation and Genomics.* 7th edition. Blackwell Publishing
- Christopher Howe. 2007. *Gene Cloning and Mani*pulation. 2nd edition. Cambridge University Press
- S. Mohan Jain, D S Brar.(eds.). 2009. *Molecular Techniques in Crop Improvement*. 2nd edition. Springer
- Boopathi, N. M. 2013. Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits. Springer
- Brown, T. A. 2010. *Gene Cloning and DNA Analysis. An Introduction*. Wiley-Blackwell
- Singh, K. K. 2015. *Biotechnology and Intellectual Property Rights. Legal and Social Implications.* Springer

I. Course Title : Biochemistry of Biotic and Abiotic Stresses

II. Course Code : BIOCHEM 603

III. Credit Hours : 3+0

IV. Why this course?

Plants are constantly confronted to both abiotic and biotic stresses that seriously reduce their productivity. Plant responses to these stresses involve numerous physiological, biochemical, molecular, and cellular adaptations. This course will help to have an insight into the mechanism underlying the stress tolerance and to elucidate the molecular basis of stress adaptation.

V. Aim of the course

To impart knowledge on biochemistry of biotic and abiotic stresses in plants.

No.	Blocks	Units
1.	Biochemistry of biotic and abiotic stresses	1. Plant-pathogen interaction and disease development 2. Biochemistry of plant defence mechanisms 3. Plant host-virus interaction 4. Biochemical basis of abiotic stresses 5. Tolerance against biotic and abiotic stress

VI. Theory

Block 1: Biochemistry of Biotic and Abiotic Stresses

Unit 1: Plant-pathogen interaction and disease development (4 Lectures)

Molecular mechanisms of fungal and bacterial infection in plants; changes in metabolism, cell wall composition and vascular transport in diseased plants.

Unit 2: Biochemistry of plant defence mechanisms (7 Lectures)

Role of secondary metabolites, Plant defence response, antimicrobial molecules; genes for resistance, hypersensitive response and cell death; systemic and acquired resistance, pathogen derived resistance.

Unit 3: Plant host-virus interaction (4 Lectures)

Plant viruses, host-virus interactions, disease induction, virus movement, and host range determination; viroids.

Unit 4: Biochemical basis of abiotic stresses (7 Lectures)

Biochemical basis of abiotic stresses namely osmotic (drought, salinity), temperature, heavy metals, air and water pollutants, synthesis and functions of proline and glycine betaine in stress tolerance interaction between biotic and abiotic stresses; stress adaptation.

Unit 5: Tolerance against stress (6 Lectures)

Reactive oxygen species and biotic and abiotic stress, antioxidants, enzymes of defense system. Role of calcium, nitric oxide and salicylic acid in plant development. Molecular strategies for imparting tolerance against biotic and abiotic stress.

VII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

VIII. Learning outcome

Upon completion of the course, students will get the suite of molecular and cellular processes that are triggered by plant stress responses.

IX. Suggested Reading

- Buchanan, Bob B., Gruisem, W. and Jones, R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley Blackwell.
- Dresselhaus, T. and Hückelhoven, R. (Eds.) 2019. *Biotic and Abiotic Stress Responses in Crop Plants*. MDPI. https://doi.org/10.3390/agronomy8110267
- Rout, G.R. and Das, A.B. 2013. *Molecular Stress Physiology of Plants*. Springer. DOI 10.1007/978-81-322-0807-5
- Shanker, A.K. and Shanker, C. (Eds.) 2016. *Abiotic and Biotic Stress in Plants - Recent Advances and Future Perspectives*.InTech. http://dx.doi.org/10.5772/60477
- Ramakrishna, A. and Gill, S.S. 2018. *Metabolic Adaptations in Plants During Abiotic Stress*. CRC Press
- Khan, M.I.R. and Khan, N.A. (Eds.). 2017. *Reactive Oxygen Species and Antioxidant Systems in Plants: Role and Regulation under Abiotic Stress*. Springer
- Smirnoff, N. (ed.) 2005. *Antioxidants and reactive oxygen species in plants*, Blackwell

I. Course Title : Frontier Topics in Biochemistry

II. Course Code : BIOCHEM 604

III. Credit Hours : 2+0

IV. Why this course?

To update the students to the recent developments in various fields of biochemistry.
Aim of the Course
To acquaint the students with the advanced developments in the field of biochemistry and to inculcate the habit of searching and reading the topics of current importance.

No.	Blocks	Units
1.	Frontier topics in Biochemistry	1. There will be 8 Units related to different areas in Biochemistry

V. Theory

Block 1: Frontier Topics in Biochemistry

Unit 1: Latest development in metabolic nutrition.

Unit 2: Latest development in environmental and industrial biochemistry.

Unit 3: Latest development in molecular biology techniques.

Unit 4: Latest development in metabolic engineering.

Unit 5: Latest development in regulation of gene expression.

Unit 6: Latest development in biotic and abiotic stress response in plants.

Unit 7: Latest development in protein chemistry.

Unit 8: Topics related to recent approaches concerning application of biochemical tools and techniques

VI. Teaching methods/activities

– Oral presentation by students on specified topics based on recent published research paper
– Group discussion

VII. Learning outcome

Students will build up the habit of searching and studying the topics of current importance and the recent developments in the field of biochemistry.

VIII. Suggested Reading

- Selected articles from recent issues of *Thomson Reuters and NAAS rated journals*

I. Course Title : Concepts and Application of Omics in Biological Science

II. Course Code : BIOCHEM 605

III. Credit Hours : 3+0

IV. Why this course?

Omics is a rapidly evolving, multi-disciplinary, and emerging field that encompasses genomics, epigenomics, transcriptomics, proteomics, and metabolomics. This course will be helpful for the students to understand the scope of omics research and methods therein.

V. Aim of the course

To impart knowledge in the upcoming areas of biochemistry and to understand the recent developments in omic technologies.

No.	Blocks	Units
1.	Concepts and aplication of omics in biological science	1. Protein and nucleic acid sequencing 2. Genomics–methods of analysis and application 3. Proteome technology 4. Metabolomics and ionomics

VI. Theory

Block 1: Concepts and Aplication of Omics in Biological Science

Unit 1: Protein and nucleic acid sequencing (7 Lectures)

Various methods of sequencing including automated sequencing and microarrays, whole genome sequence analysis.

Unit 2: Genomics – methods of analysis and application (7 Lectures)

Comparative genomics, functional genomics, nutrigenomics, transcriptomics, gene identification, gene annotation, pairwise and multiple alignments, application of genomics, quantitative PCR, SAGE, MPSS, microarray, role of bioinformatics in functional genomics.

Unit 3: Proteome technology (7 Lectures)

2D-PAGE, MSMS, MALDI-TOF, comparative proteomics and structural proteomics

Unit 4: Metabolomics and ionomics (7 Lectures)

Elucidation of metabolic pathways, Sample preparation for metabolomics. Techniques involved in metabolite identification- LCMS, NMR, FTIR, MS. Metabolomics in biotic and biotic stress in crop plants, SPE, SPME, metabolic pathway engineering and its application, Concept and application of ionome and ionomics.

VII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

VIII. Learning outcome

The applications of omics allow the complete profiling of genes, proteins and metabolites to understand the intricacy, complexity and dynamics of biological system. This course serves as an applied course for understanding the applications, research methodologies and data analysis of omics approaches enabling students to apply such skills in their respective projects

IX. Suggested Reading

- Lieber D.C. 2002. *Introduction to Proteomics - Tools for the New Biology*. Humana Press.
- Leung, H.E. 2012. *Integrative Proteomics*. InTech
- Lesk, A.M. 2012. Introduction to Genomics, 2nd Edition. Oxford University Press
- Aizat, W.M., Goh, H-H. and Baharum, S.N. (Eds.) 2018. Omics Applications for Systems Biology. Springer International Publishing
- Arivaradarajan, P., Misra, G. (Eds.) 2018. *Omics Approaches, Technologies and Applications*. Springer Singapore
- Fan TWM, Lane AN and Higashi RM. (Eds.) 2012. *The Handbook of Metabolomics*. Humana Press, Totowa, NJ

I. Course Title : Biomembranes

II. Course Code : BIOCHEM 606

III. Credit Hours : 2+0

IV. Why this course?

Biomembranes define the boundaries of cells and their internal organelles and, consequently, are fundamental to the compartmentalisation of vital enzymatic reactions. This course will help the students to acquire an integrated overview of the structure, function and biogenesis of biological membranes and their components and their impacts on different cell activities.

V. Aim of the course

To impart knowledge on the molecular basis of the structure, function and biogenesis of eukaryotic cell membranes.

No.	Blocks	Units
1.	Biomembranes	There will be 4 Units relating to biomembrane structure, organization, movement and signal transduction.

VI. Theory

Block 1: Biomembranes

Unit 1: Concept of biomembranes and their classification based on cellular organelles; physico-chemical properties of different biological and artificial membranes, cell surface receptors and antigen.

Unit 2: Membrane biogenesis and differentiation; membrane components-lipids, their distribution and organization; proteins, intrinsic and extrinsic, their arrangement; carbohydrates in membranes and their function.

Unit 3: Various membrane movements; Membrane transport: Organization of transport at plant membranes, pumps, carriers, ion channels, water transport through aquaporins, transport of macro molecules: exocytosis and endocytosis, energy transduction.

Unit 4: Role of membrane in cellular metabolism, cell recognition and cell-to-cell interaction; signal transduction, recent trends and tools in membrane research.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

This course summarizes the structure and functions of membranes and the proteins within them, and describes their role in trafficking and transport, control the passage of selected compounds, thus maintaining the biochemical integrity of cytosol; communication, allowing the exchange of information between the extra- and intracellular environments, and the physical interaction with the extracellular phase.

IX. Suggested Reading

- Watson, H. 2015. *Biological membranes*. Essays Biochem. **59**, 43–70: doi: 10.1042/BSE0590043
- Shinitzky, M. 2008. *Biomembranes: Structural and Functional Aspects*. VCH. DOI: 10.1002/

9783527616114
- Berk, A., Kaiser, C. A., Lodish, H., Amon, A., Ploegh, H., Bretscher, A., Krieger, M. And Martin, K. C. 2016. *Molecular Cell Biology*. Macmillan Learning
- Stillwell, W. 2013. *An Introduction to Biological Membrane: From Bilayers to Rafts*. Elsevier
- Yeagle, P. 2016. *The Membranes of Cell*. 3rd edition. Academic Press

I. Course Title : Application of Techniques in Biochemistry

II. Course Code : BIOCHEM 607*

III. Credit Hours : 1+2

IV. Why this course?

This course will provide the students the theoretical basis of various separation techniques and their application with practical experience in the use of different biochemical and molecular biology techniques.

V. Aim of the course

To train students the application ofcuttingedge laboratory techniques in research in biochemistry and molecular biology.

No.	Blocks	Units
1.	Application of techniques in Biochemistry	1. Isolation, purification and analysis of metabolites 2. Electrophoretic separation 3. Application of centrifugation 4. Enzyme techniques 5. Molecular biology and immunochemical techniques

VI. Theory

Block 1: Application of Techniques in Biochemistry

Unit 1: Isolation, purification and analysis of metabolites (3 Lectures)

Isolation and purification of important metabolites from microbial/plant/animal source, Applications of paper, thin layer and gas liquid chromatography, PAGE, FPLC and HPLC in the separation of biomolecules. Determination of molecular weight of protein using PAGE/ gel filtration method.

Unit 2: Electrophoretic separation (3 Lectures)

Electrophoretic separation of protein, Experiments on DNA: Isolation, agarose gel electrophoresis and restriction analysis of DNA. Techniques in DNA-protein and protein-protein interaction.

Unit 3: Application of centrifugation (2 Lectures)

Isolation of chloroplast and mitochondria by differential centrifugation and their purification by density gradient centrifugation.

Unit 4: Enzyme techniques (3 Lectures)

Isolation, purification and characterization of enzymes, isozymic analysis and enzyme immobilization.

Unit 5: Molecular biology and immunochemical techniques (3 Lectures)

Application of PCR, yeast 2 hybrid system, Antigen-Antibody interaction, ELISA, Chromatin immunoprecipitation, gel based and gel free proteasome tools.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Demonstration and hands on training
- Exposure visit to institutions equipped with modern facilities

VIII. Learning outcome

This course will help the students in acquiring the laboratory skills required for success in experimental biochemistry and molecular biology.

IX. Suggested Reading

- Katoch, R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer
- Wilson, K. and Walker, J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition. Cambridge University Press
- Hegyi, G., Kardos, J., Kovács, M., Málnási-Csizmadia, A., Nyitray, L. Pál, G., Radnai, L., Reményi, A. and Venekei, I. 2013. *Introduction to Practical Biochemistry*. EötvösLoránd University

Journals

- *Annual Review of Biochemistry*
- *Annual Review of Genetics*
- *Annual Review of Plant Physiology and Plant Molecular Biology*
- *Biochemical and Biophysical Research Communication*
- *Biochemical Journal*
- *Biochimica Biophysica. Acta*
- *Cell*
- *Current Science*
- *Federation of European Biochemical Society*
- *Food Chemistry*
- *Indian Journal of Experimental Biology*
- *Journal of Agriculture and Food Chemistry*
- *Journal of Biological Chemistry*
- *Journal of Immunology*
- *Journal of Molecular Modelling*
- *Journal of Plant Biochemistry and Biotechnology*
- *Nature*
- *Physiologia Plantarum*
- *Plant Physiology*
- *Plant Science*
- *Planta*
- *Proceedings of National Academy of Sciences, USA*
- *Protein Science*
- *RNA*
- *Science*
- *Scientific American*
- *Trends in Biochemical Sciences*
- *Trends in Biotechnology*
- *Trends in Plant Sciences*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Microbiology

Preamble
(Microbiology)

World is experiencing a rapid shift of national priorities in research and development. Biological science is emerging as one of the top priorities in the field of science, and among the biological sciences microbiology has gained new stature. Microoganisms and their activities are increasingly central to many of the concerns of the society both nationally and internationally. The problem of global environment, the recognition of the need to recycle natural resources, the discovery of genetic engineering – these and other development have placed microbiology in limelight. It is required to restructure and modify the curriculum and the syllabus to enable graduate students to be reacquainted with the developments through providing comprehensive exposure to the M.Sc and Ph.D. students, on new developments in different areas of microbial science.With this background the structure of curriculum for M.Sc. and Ph.D. programmes and syllabi for the courses needs to be developed keeping in view the mandate of agriculture universities and ICAR institutes.

Microbes are indispensable to our life. Interactions of microbes involved in soil, environment, food, fermentation, medical, or agriculture has been studied using modern techniques. New antibiotics, vaccines are also being produced. Moreover, genome sequence of important genes of interest or complete sequence of microbes, plants, human beings or animals has further paved the ways for detailed study of interactions and their manipulations in the desired direction. Molecular analysis of relevant factors in the plant and microbes and components that modulate plant-microbe interactions for soil and plant health for sustaining crop productivity is now being revealed using different molecular techniques. Microbial diagnostic micro arrays have been developed for the parallel, high-throughput identification of many microorganisms.

There is growing recognition in the potential of microorganisms in many applied areas. The ability of microorganisms to decompose materials such as herbicides, pesticides and oil in oils pills; the potential of microorganisms as food supplements; the exploitation of microbial activity to produce energy such as methane gas for natural consumption; and the potential of new therapeutic substances produced by microorganisms – these and other uses of microorganisms are becoming increasingly attractive. Increased attention has been directed towards use of microorganisms (bioremediation) for wastewater treatment involving decolorization of different industrial effluents, which include distillery waste, textile industries and paper and pulp industries. Microbial degradation and decolorization holds promise and can be exploited. But genetic improvement of strains can be explored in future for improving their decolorization efficiency. Some of the agro wastes are being used for the production of biofuels. Use of recombinant microorganisms for industrial production of useful compounds has reached at commercial levels. All these aspects are covered in the coursecurricula.

For MSc programme, 14 courses including master's seminar and master's research are finalized, out of which minor changes have been done in existing 9 courses and one course MICRO 506, Microbial biotechnology, is completely reframed and modified. The aim is to teach students about industrially useful microorganisms and use of fermenter for the production of various primary and secondary metabolites, this course is job oriented. The students can be absorbed by various agro-industries. One new course MICRO501 entitled

Techniques in microbiology has been newly introduced in the syllabus. This course aims to introduce various techniques and instrumentation methods required for the study of microorganisms. This course provides understating on techniques and methods of microscopy, spectroscopy, chromatography and electrophoresis. Courses MICRO 503 and MICRO 504 entitled Microbial physiology and Microbial genetics, respectively, include recombinant DNA technology, commonly related to as genetic engineering, as one of the principal thrust of the emerging technologies in the biological and agricultural sciences. Recombinant DNA technology makes it feasible to consider genetically manipulated (engineered) microorganisms for commercial production of new and valuable products for variety of purposes, e.g., medicinal, fuel and food.

Course No MICRO 505, Soil Microbiology and MICRO 604 Recent approaches in environmental microbiology are introduced with certain important changes with great emphasis on integrated use of chemical fertilizers, pesticides, herbicides along with biofertilizers, biopesticides and biocontrol agents for sustaining modern agriculture and soil health. Biocontrol agents for control of plant diseases, insects, nematodes have been developed and some of these are commercially available and being used by the farmers. Microbe-plant symbiosis within plant rhizosphere have come up as an effective clean up technology.From the earlier syllabus one course entitled Plant microbe interactions has been upgraded from master's programme to Ph.D. level (MICRO 605).

In Ph.D. programme, 8 courses are finalized (including doctoral seminar and research) out of which 3 are the thorough modifications of existing courses.

MICRO 602 Microbial physiology and regulation has been formulated keeping in view following important concepts:

- Basic metabolic pathways can lead to different metabolic groups such as heterotrophs/phototrophs, etc.
- Measurement of growth as influenced by various factors such as media and environmental factor can help to design specific culture media.
- The role of environmental factors in key regulatory points in microorganisms is important in their adoption to the environment
- Enzyme regulation occurs for the cell to adopt in different conditions.
- Role of enzymes in the microorganisms for degradation of substrates for their growth through metabolic pathways may be inductive or conservative determines their expression.

Course No. MICRO 604 Recent Approaches in environmental microbiology has been introduced with the concept:

- How microbes contribute to successful colonization in environment and their interaction with the environment
- Microbiological prospective of public health.
- Certain process like adsorption, immobilization, mobilization and transformation of metal are main processes that can be mediated by action of several microorganisms.
- Microbial bioremediation, biodegradation through species or strains or consortia which are specific to the degradation of one or more types of contaminants for reclamation of environment or remediate polluted sites.

New course MICRO 605 Plant microbe Interaction has been introduced with the concept that–

- The dynamics of plant community is influenced by the microbial association and activity.

- In the plant ecosystems microbes play a defined role to ascertain that plants benefit through provision of nutrients and growth promoting factors.
- At times pathogenic microbes play havoc on the plants, sometimes threatening their very existence.
- The plant serves as habitat for microbial communities. It is the interplay of the interaction between the plant and the microbiome it hosts, that is critical for the establishment and the maintenance of host-microbial homeostasis and defines the overall health and productivity

With a degree in microbiology, students can get opportunities to work in both government as well as private sector, in various fields like healthcare organizations, forensic science laboratories, environmental organizations, higher education institutions, publicly funded research organizations, pharmaceuticals, food and beverages industries, chemical industries, agriculture department, agro-industries, etc.

Microbiology courses are offered by a large number of students hence need small equipment in multiple numbers. To do quality teaching and research, sophisticated equipment like ultra-low freezers, high speed refrigerated-automated bioseparation systems like GLC or HPLC and UV-Vis spectrophotometers suitable for enzyme studies, PCRs, electrophoresis systems for proteins and DNA are required for Microbiology lab. Consumables will also be needed accordingly. An approximate recurring budget of ₹ 20 lacs per annum apart from one time equipment and maintenance grant of ₹ 2 crore will be required.

Course Title with Credit load
M.Sc. (Ag) in Microbiology

Course Code	Course Tittle	Credit Hours
MICRO 501	Techniques in microbiology	0+2
MICRO 502*	Principles of microbiology	3+1
MICRO 503*	Microbial physiology and metabolism	3+1
MICRO 504	Microbial genetics.	2+1
MICRO 505*	Soil microbiology	2+1
MICRO 506	Microbial biotechnology	2+1
MICRO 507*	Food microbiology	2+1
MICRO 508	Bacteriophages	1+1
MICRO 509	Environmental microbiology	2+1
MICRO 510	Industrial microbiology	2+1
MICRO 511	Biofertilizer technology	2+1
MICRO 512	Cyanobacterial and algal biotechnology	2+0
MICRO 591	Master's seminar	1+0
MICRO 599	Master's research	30

*Core Courses

Course Contents
M.Sc. (Ag) in Microbiology

Course Title : Techniques in Microbiology
Course Code : MICRO 501
Credit Hours : 0+2

Why this course?

The science of microbiology is the study of microorganisms and their activities. It is concerned with their form, structure, reproduction, physiology, metabolism and identification. It includes the study of their distribution in nature, their relationship to each other and to their living things, their beneficial and detrimental effects on agriculture and the physical and chemical change they make in their environment. In microbiology laboratories, some special equipment and apparatus are commonly used. Students of microbiology should have a general idea of these equipment regarding their constructive features, operation, precaution for use and also the maintenance of the equipment.

Aim of the course

This course aims to introduce various techniques and instrumentation methods required for the study of microorganisms. This course provides understating on techniques and methods of microscopy, spectroscopy, chromatography and electrophoresis.

The course is organized as follows:

No.	Blocks	Units
1	Techniques in microbiology	1. Practical include estimation of microbiological contents of samples like water, soil, air, etc. 2. Operation and care of microscopes 3. Preparation of smears and their morphological observation using microscope 4. Performance of various staining techniques, study of biochemical activities, Identification of microorganisms, preparation of culture media etc.

Practicals

- Awareness about lab safety measures
- Study of general microbiological equipment, cleaning of glassware and apparatus for laboratory use
- Methods of sterilization used in microbiology laboratory
- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and chromatography)
- Types of culture media

- Isolation techniques and direct microscopic count
- Environmental factors affecting bacterial growth: physical chemical, temperature, pH, osmotic pressure, light (UV) and bacteriostatic agents. Bacteriology of air, water, and soil.
- Characteristics of important types of micro-organisms: major functional groups of bacteria, lactic acid, spore forming and coliforms bacteria, fungi, yeast and mold.
- Assessment of microbial quality of portable water.
- Working in microscope

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of general microbiology and relate the key learning to the job of an microbiologist professional
- Utilise methods and tools for microbial agricultural development for the nation.
- Increase the probability of use of different microbial cultures for the benefits of agriculture production

Suggested Reading

- Roy A.K. 2010. *Laboratory Manual of Microbiology* (Practical Manual Series).
- Goldman E and Green LH. 2015. *Practical Handbook of Microbiology*. 3rd Edition. http/ www. CRC press life science Microbiolgy
- Brock, T.D. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark D.P., 12th ed. Pearson, New Jersey.
- Pelczar, M.J. Jr., Chan, E.C.S. and Kreig, N.R. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S. 2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M.T., J.M. Martinko, P.V. Dunlap and D.P. Clark. 2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.
- Singh, U.S. and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G.J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

Course Title : **Principles of Microbiology**
Course Code : **MICRO 502***
Credit Hours : **3+1**

Why this course?

Microbes has become a part and parcel of our lives This course is required for the future battle against infectious diseases worldwide, understanding the environmental importance of microbes and to exploit them for food production, biotechnological and industrial applications. Hence, this customized course.

Aim of the course

The main focus of our course is the potential of the organisms that cause disease and benefits in the society. You will also cover aspects of the biochemistry, physiology and genetics of microorganisms.

The course is organized as follows:

No.	Blocks	Units
1.	Scope and History of Microbiology and microscopy	1. Scope of microbiology 1. History routes 2. Staining and microscopy
2.	Evolutionary link of prokaryotes	1. Phylogenetic classification 2. Methods of sequencing
3.	Microbial growth, characterization and regulation	1. Microbial growth and reproduction 2. Sterilization techniques 3. Nutritional requirements for microbial growth

Theory

Block 1: Scope and History of Microbiology and Microscopy

Unit 1: Scope of microbiology

Scope of microbiology, microbes and microbiologist. Emergence of Special Fields of Microbiology.

Unit 2: History Routes

The Germ Theory of Disease, Early Studies: Pasteur's Further Contributions, Koch's Contributions, Work Toward Controlling Infections, spontaneous generation theory.

Unit 3: Staining and microscopy

Microscopy; Bright field, Dark field, Phase contrast, Confocal, Fluorescence, TEM, SEM – Working Principles and applications; Properties of light; Simple staining, differential and special staining.

Block 2: Evolutionary Link of Prokaryotes

Unit1: Phylogenetic classification

Evolutionary relationship among prokaryotes. Prokaryotes and Eukaryotes, Phylogenetic and numerical taxonomy. Species concept.

Unit2: Methods of sequencing

Use of DNA and r-RNA sequencing in classifications.

Block 3: Microbial Growth, Characterization And Regulation

Unit1: Microbial growth and reproduction

Microbial growth and reproduction-communication, bacteria, yeast and virus growth, Replication, Cultivation methods, Normal micro flora of Human body; Immune response- specific and non-specific host resistance.

Unit 2: Sterilization techniques

Physical and chemical methods of sterilisation.

Unit 3: Nutritional requirements for microbial growth

Classification of microbes: electron, energy and carbon sources.

Practicals

- Working principles and handling of different types of microscopes – Bright and Dark field microscopy
- Working principles and handling of different types of microscope- SEM and TEM
- Methods of isolation from different environments – soil, water, milk and food
- Use of selective media for isolation
- Purification techniques of bacteria and fungi
- Enumeration and Quantification techniques
- Maintenance and preservation of cultures
- Assessment of microbial quality of portable water.
- Morphological characterization of Bacteria
- Morphological characterization of fungi
- Biochemical characterization of bacteria
- Biochemical characterization of fungus

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

After successful completion of this course, the students are expected to be able to:

- Knowledge on historical perspective of Microbiology
- Basic knowledge on different structure of microbes

Suggested Reading

- Brock TD. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark DP, 12th ed. Pearson, New Jersey.
- Pelczar MJ. Jr., Chan, ECS and Kreig NR. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S.2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M. T., J. M. Martinko, P.V. Dunlap and D.P. Clark.2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.

- Singh, U.S and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G. J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York
- Davis BD, Dulbecco R, Eisen HN and Ginsberg HS. 1990. *Microbiology* (4th edition). J.B.Lippincott company, Newyork.
- Alexopoulus CJ and C W. Mims. 1993. *Introductory Mycology* (3rd edition).Wiley Eastern Ltd, NewDelhi.
- Elizabeth Moore-Landecker. 1996. *Fundamentals of the fungi*. (4th edition).Prentice Hall International, Inc, London.
- Heritage,J. Evans E.G.V. and Killington, R.A. 1996. *Introductory Microbiology*. Cambridge University Press.
- Webster J. 1993. Introduction to Fungi.(2nd edition).Cambridge University press,Cambridge.
- Prescott LM, Harley JP and Klein DA. 2006. Microbiology (7th edition) McGraw Hill, Newyork.
- Schaechter M and Leaderberg J. 2004. The Desk encyclopedia of Microbiology. Elseiver Academic press, California.
- Nester, E.W., Roberts, C.V. and Nester, M.T. 1995. *Microbiology: A human perspective*. IWOA, U.S.A.
- Pelczar Jr, M.J. Chan, E.C.S. and Kreig, N.R. 1993. *Microbiology*, Mc. Graw Hill. Inc, New York.
- Holt JG and Bergey DH. 1994. *Bergey's Manual of Determinative Bacteriology* (9th Edition), Williams and Wilkins, Baltimore.
- Mara D. and Horan N. 2003. *The Handbook of Water and waste water Microbiology*. Academic Press-An imprint of Elsevier.
- Madigan M T, Bender K S, Buckley HD, Sattley WM, Stahl DA 2017. *Brock Biology of Microorganisms* - 15th edition. Pearson Education, USA.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

I. Course Title : Microbial Physiology and Metabolism

II. Course Code : MICRO 503*

III. Credit Hours : 3+1

IV. Why this course?

Microbial physiology is defined as the study of how microbial cell structures, growth and metabolism function in living organisms. Microbial physiology is important in the field of metabolic engineering and also functional genomic. The study of diversity of microbial metabolic processes & their regulation, how microbes respond to environment stress and manipulation and the genetic control of these processes are essential for their potential applications of microbial process for the production of commercial products.

V. Aim of the course

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favourable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and photosynthesis and how do they respond to the changes in environment. It will elaborate the anaerobic respiration by variety of groups of microbes and non-genetic regulation at metabolic pathways.

The course is organized as follows:

No.	Blocks	Units
1.	Scope of microbial growth and physiology	1. Structure, function and biosynthesis of cellular components
2.	Pathways and their significance; Growthkinetics and nutritional classifications	1. Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism. 2. Growth and factors affecting growth and culture systems. 3. Nutritional classification and spore formation and germination
3.	Enzymes and microbial metabolisms	1. Kinetics and Mechanism of Enzymes 2. Microbial metabolism
4	Synthesis of macromolecules	1. Biosynthesis of macromolecules

VI. Theory

Block 1: Scope of Microbial Growth and Physiology

Unit 1: Structure, function and biosynthesis of cellular components

Microbial nutrition – Chemical composition of microbial cell – Structure, function and assembly of cell membrane in prokaryotes, archaea and fungi – Macro and Micro- nutrients and their physiological functions – Transport of solutes across the membrane

Block 2: Pathways and their Significance; Growth Kinetics and Nutritional Classifications

Unit 1: Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism

Microbial growth. Cell cycle and cell division. Bioenergetics -carbohydrate utilization via EMP, HMP, ED, TCA pathways, Aerobic and anaerobic respiration. Fermentative metabolism. Assimilation of nitrogen and sulphur - Oxygenic and anoxygenic photosynthesis - Mechanisms of carbon-dioxide fixation in prokaryotes. Ethanol, lactic acid, butanol, acetone and mixed acid fermentation. Fermentation of nitrogenous organic compounds Regulation of microbial metabolism.

Unit 2: Growth and factors affecting growth and culture systems

Effects of physical, chemical and other environmental factors on growth Continuous culture, Diauxic growth and Synchronous culture. Method of growth measurement. Morphogenesis and cellular differentiation.

Unit 3: Nutritional classification and spore formation and germination

Metabolic diversity in photoautotrophs, photoheterotrophs, chemoautotrophs and chemoheterotrophs. Nutritional grouping/classification of microorganisms. Bacterial endospore-types, morphology, biochemistry and regulation of formation and germination

Block 3: Enzymes and Microbial Metabolisms

Unit 1: Kinetics and Mechanism of Enzymes

Enzyme kinetics: Michaelis Menten kinetics - mechanisms of inhibition of enzyme activity - coenzymes and prosthetic groups.

Unit 2: Microbial metabolism

Methods to determine free energy of biochemical reactions - high energy compounds. Microbial metabolism: generation of ATP, reducing power, development of proton gradient and biosynthesis of ATP.

Block 4: Synthesis of Macromolecules

Unit 1: Biosynthesis of macromolecules

Biosynthesis of macromolecules – Synthesis and assembly of cell wall components – Methods of studying biosynthesis - regulation of microbial metabolism.

VII. Practicals

- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and GLC, etc.).
- Determination of viable and total number of cells.
- Measurement of cell size.
- Gross cellular composition of microbial cell. Growth – Factors affecting growth.
- Study of bacterial spores and factors affecting germination.
- Enzyme activity and kinetics – calculating Km and V_{max} of enzyme.
- Demonstration of thermos-, meso-, and psychrophilic micro-organisms.
- Production and testing of inducible enzymes in bacteria.
- Sporulation and spore germination in bacteria.
- Protoplasts formation and regeneration.
- Estimation of generation time and specific growth rate for bacteria and yeast.
- Diauxic growth curve.
- Production of synchronous cells.
- Effect of chemicals and environmental factors on bacterial growth.
- Isolation and Identification of reserve food material (Glycogen/ polyphosphates, PHB) from bacteria (*Azotobacter*, *Bacillus megaterium*).
- Growth of microorganisms on various carbon and nitrogen sources.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Publication Review
– Student presentation
– Group discussion
– Case Analysis and case studies
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Knowledge about cell cycle and microbial pattern
– Growth and practical training on methods to determine microbialgrowth

X. Suggested Reading

- Moat, A. G. and J. W. Foster. 2002. *Microbial Physiology*. John Wiley & Sons, New York,

USA. 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- Madigan, M.T, J.M. Martinko and J. Parker. 2006. *Brock: Biology of Microorganisms*, 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- White, D. 2007. *The Physiology and Biochemistry of Prokaryotes*, 3rd Edition. Oxford University Press.
- Downs, D. M. 2006. *Understanding microbial metabolism*. Annual Review of Microbiology 60, 533–559.
- Hosler *et al.* 2006. *Energy Transduction: Proton Transfer Through the Respiratory Complexes.* Annual Review of Biochemistry 75, 165-187.
- Okuno *et al.* 2008. *Correlation between the conformational states of F1-ATPase as determined from its crystal structure and single-molecule rotation*. PNAS 105(52): 20722-20727.
- Itoh et al (2004) Mechanically driven ATP synthesis by F1-ATPase. Nature 427, 465-468.
- Doelle HW. 1969. *Bacterial Metabolism*. Academic Press.
- Gottschalk G. 1979. *Bacterial Metabolism*. Springer Verlag.
- Nelson DL and Cox MM. 2017. *Lehninger*, *Principles of Biochemistry,* 4th Edition, W.H.Freeman & Company, 2004. (T1)
- Voet D and Voet JG. 2002. *Fundamentals of Biochemistry*, Upgrade Edition, Wiley.

Journals
- *Journal of Bacteriology.*
- *Advances in Microbial Physiology.*
- *Soil Biology and Biochemistry.*
- *Journal of Applied Bacteriology.*
- *Applied and Environmental Microbiology.*
- *Microbiology.*

Websites
- http://www.asmscience.org
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- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.textbookofbacteriology.net
- https://www.e-education.psu.edu
- http://www.ncbi.nlm.nih.gov/pubmed/12050002
- http://www.journals.elsevier.com/bba-bioenergetics/
- http://www.bmb.leeds.ac.uk/illingworth/oxphos
- http://www.atpsynthase.info/
- https://ocw.um.edu.my/course/view.php?id=67
- https://mic.microbiologyresearch.org/content/journal/micro/10.1099/mic.0.037143-0

I. Course Title : Microbial Genetics

II. Course Code : MICRO 504

III. Credit Hours : 2+1

IV. Why this course?

Microbial Genetics has traditionally been a field of basic science research as microorganisms offer several features that facilitate the study of evolutionary process,understanding the genotype and its expression system. Students also hone their abilities to read, understand and critically evaluate research articles as well as improve presentation skills.

V. Aim of the course

This course is designed to provide an understanding of the fundamentals of genetic

processes in prokaryotes and eukaryotes. The study of microbial genetics has provided much of the understanding of fundamental genetic processes for all organisms, especially through the use of *in vivo* and *in vitro* genetic tools.
The course is organized as follows:

No.	Blocks	Units
1.	Introduction to microbial genetics	1. Historical perspectives of microbial genetics 2. Genome of prokaryote, eukaryote (fungi) and virus 3. Genetic elements - chemical structure and property, enzymes associated and replication 4. Extra-chromosomal DNA in bacteria and eukaryotic cells
2.	Gene expression and regulation	1. Introduction to Gene structure and expression 2. Regulation of gene expression
3.	Mutation, genetic recombination and sequencing	1. Principles of mutation and types 2. Mutagens and their mode of action 3. DNA damage – DNA repair mechanisms in bacteria 4. Genetic recombination in bacteria 5. Gene Sequencing

VI. Theory

Block 1: Introduction to Microbial Genetics

Unit 1: Historical perspectives of microbial genetics

Introduction to Microbial genetics; Historically important events and major contributions of scientists in the field of Microbial genetics; Terminologies employed in microbial genetics and definitions; Nucleic acid – overview DNA, RNA.

Unit 2: Genome of prokaryote, eukaryote (fungi) and virus

Bacterial genome Eukaryotic genome; Viral genome; Difference between prokaryotic and eukaryotic genome; Mechanisms and role of prokaryotic genome- an overview.

Unit 3: Geneticelements - chemical structure and property, enzymes associated and replication

Structure of DNA – A form, B form, Z form; RNA- tRNA, mRNA, rRNA; Role and Replication of DNA and RNA; Enzymes involved in Replication and its role.

Unit 4: Extra-chromosomal DNA in bacteria and eukaryotic cells

Plasmids, Mitochondrial DNA, Chloroplast DNA – structure and function.

Block 2: Gene Expression and Regulation

Unit 1: Introduction to gene structure and expression

Gene structure and expression, principles of operon, gene expression in prokaryote and eukaryotes, intron and exons, post transcriptional modifications.

Unit 2: Regulation of gene expression

Regulation of gene expression, negative expression (lac operon and trp operon), positive regulation (cAMP).

Block 3: Mutation, Genetic Recombination and Sequencing

Unit 1: Principles of mutation and types

Principles of mutation, spontaneous and induced mutation, different types of mutations, selection principles of mutants.

Unit 2: Mutagens and their mode of action

Mutagens and their mode of action, transposable elements and insertion sequences.

Unit 3: DNA damage - DNA repair mechanisms

DNA damage, DNA repair mechanisms in bacteria.

Unit 4: Genetic recombination in bacteria

Genetic recombination in bacteria, mechanisms of recombination, transformation, conjugation, transduction.

Unit 5: Gene sequencing

Gene cloning and gene sequencing. Impact of gene cloning, polymerase chain reaction, DNA sequencing, recombinant DNA technology.

VII. Practicals

- Isolation of genomic DNA from pure cultures of bacteria and fungi.
- Visualization of mega plasmids of bacteria.
- Isolation of bacterial plasmids and Plasmid curring.
- Qualitative and quantitative assay of DNA by spectrometry and gel-electrophoresis.
- Inducing mutation by chemicals, physical and biological agents.
- Transformation and selection of transformants.
- Amplification of gene of interest by PCR – cloning and expression.
- Isolation of metagenomic DNA from environmental samples.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group work in practical
– Field visit
– Case studies

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Identify and distinguish genetic regulatory mechanisms at different levels
– Plan basic experiments in Microbial genetics
– Describe and summarize experimental work in a correct way.

X. Suggested Reading

- Brown TA. 2001. *Gene Cloning and DNA Analysis: An Introduction*. Fourth Edition. Blackwell Science Inc., Oxford, UK.
- Levin B. 2002. *Gene VIII*. Oxford Univ. Press, New York. p.990.
- Maloy SR, Cronan JE, Freifelder D. 2008. *Microbial Genetics* - second edition. Narosa Publising house, New Delhi. p. 525.
- Omoto CK and Lurquin PF. 2004. *Genes and DNA: a beginner's guide to genetics and its applications*. Colambia University Press, USA.
- Sambrook J, Fritsch EF, Maniatis T. 2000. *Molecular Cloning: A laboratory Manuel*. Third Edition. Cold Spring Harbor Press, New York.

- Streips UN, Yasbin RE. 2006. *Modern Microbial Genetics*. Wiley – Liss. John Wiley & sons, Inc. Publication, NY.
- Birge EA. 1981. *Bacterial and Bacteriophage Genetics*. Springer Verlag.
- Gardner JE, Simmons MJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley& Sons.
- Lewin B.1999. *Gene*. Vols. VI-IX. John Wiley & Sons.
- Maloy SR, Cronan JE and Friedfelder D. 2008. *Microbial Genetics*. Narosa.
- Scaife J, Leach D and Galizzi A 1985. *Genetics of Bacteria*. Academic Press. William Hayes 1981. *Genetics of Bacteria*. Academic Press.
- Strips UN, Yasbin RE *2006. *Modern Microbial Genetics*. Wiley-Liss, NY.

Websites

- http://highered.mcgraw-hill.com/sites/0072552980/student_view0/chapter9/
- http://highered.mcgrawhill.com/sites/0072835125/student_view0/animations.html
- http://cwx.prenhall.com/brock/
- http://www.cliffsnotes.com/sciences/biology/microbiology
- http://plato.acadiau.ca/courses/biol/Microbiology/home.HYPERLINK "http://plato.acadiau.ca/courses/biol/Microbiology/home.html"html
- http://www.learner.org/courses/biology/index.html

I. Course Title : Soil Microbiology

II. Course Code : MICRO 505*

III. Credit Hours : 2+1

IV. Why this Course?

Understanding the function of the soil ecosystem in relation to ever changing soil conditions is key to understanding the basic mechanisms of soil productivity. This is important in light of the urgency to change agricultural practices and also the problems of xenobiotic compounds in soils. The possible perturbations caused by pollution, intense agricultural practices or changing land use–are of major concern.

The possibility of involvement of nonculturable or minute cell fractions requires innovative research using molecular biological techniques. Information on the effects of different root parts versus bulk soil is interesting. Role of microorganisms in biogeochemical cycles and their interactions decide the nutrients available to crops.

The rhizosphere–the micro environment around plant roots houses intense biological, physical and geochemical activity distinguishing it from surrounding soil. Diversity, distributions, activities and interactions of innumerable organisms affect and are affected by availability of energy and nutrients, soil-water content and rhizosphere redox states. Soil food webs and nutrient cycling in agro ecosystems is of prime concern.

V. Aim of the course

- To help unlock and harness the potential of microorganisms in soil.
- To know the potential benefit of consortia of microorganisms to protect plants from different stresses.
- To study the role of microorganisms in the ecosystem functioning, nutrient cycling and biogeochemical processes including soil enzymes, through their metabolic activity and interactions.

The course is organized as follows:

No.	Blocks	Units
1.	Developments in soil Microbiology and Soil parameters	1. Historical prospective of soil microbiology. Factors affecting soil microflora 2. Ecology of soil microbiology
2.	Microbiology and Biochemistry of Plant parts	1. Plant parts and soil interface interaction
3.	Role of microorganisms in nutrient biocycle	1. Microbial transformations of various nutrients 2. Microbial degradation of organic matter 3. Microbial diversity 4. Role of microorganisms in biodegradation of xenobiotics and pesticides.

VI. Theory

Block 1: Developments in Soil Microbiology and Soil Parameters

Unit 1: Historical prospective of soil microbiology. Factors affecting soil microflora.

Landmarks in the history of soil microbiology. Abiotic factors (physical and chemical) affecting soil microflora as pH, chemicals, moisture, air, temperature etc.

Unit 2: Ecology of soil microbiology

Soil biota, Soil microbial ecology, types of organisms in different soils; Soil microbial biomass; Microbial interactions: unculturable soil biota.

Block 2: Microbiology and Biochemistry of Plant Parts

Unit 1: Plant parts and soil interface interaction

Microbiology and biochemistry of root-soil interface; phyllosphere, plant growth promoting rhizobacteria, soil enzyme activities and their importance.

Block 3: Role of Microorganisms in Nutrient Biocycle

Unit 1: Microbial transformation of various nutrients

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil. Siderophores and antimicrobials.

Unit 2: Microbial degradation of organic matter

Biochemical composition and biodegradation of soil organic matter and crop residues.

Unit 3: Microbial diversity

Endophytic microorganisms Mycorrhizae, types and role in phosphate mobilization. Potassium releasing bacterium. Microbes in biotic and abiotic stress management.

Unit 4: Role of microorganisms in biodegradation of xenobiotics and pesticides

Biodegradation of pesticides, Organic wastes and their use for production of biogas and manures: Biotic factors in soil development.

VI. Practicals

- Determination of soil microbial population

- Determination of Soil microbial biomass
- Decomposition studies in soil, Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification
- N_2 fixation, S oxidation, P solubilization and mineralization of other micro nutrients
- Study of rhizosphere effect
- Microbial diversity Endophytic microorganisms
- Mycorrhizae, types and role in phosphate mobilization Potassium releasing bacterium
- Microbes in biotic and abiotic stress management

VII. Teaching methods/activities

- Lectures. To use ppt and video clippings whenever necessary based on the topics that are hard to understand.
- The students must be assigned either in individual or in groups to identify the soils and crops grown and must get respective soil samples and plants for analyzing the microorganisms. They must subject the culture for various analysis depending upon the culture such a nitrogen fixing ability, phosphate solubilising property etc.
- Testing their efficiency through growth studies

VIII. Learning outcome

- Students will become familiar to the types of microbes in soil and their association with plants.
- The exclusive role of microorganisms in plant growth can be thoroughly understood.

IX. Suggested Reading

- Paul EA. 2015. *Soil Microbiology, Ecology and Biochemistry*. Elsevier
- Jan Dirk Van Elsas, Trevors JT and Elizabeth M.H. Wellington, 1997. *Modern Soil Microbiology*. Marcel Dekker, Inc.
- Paul EA. 2007. *Soil Microbiology and Biochemistry* 3rd Edition. Academic Press.
- Cardon ZG and Whitbeck JL. 2007. *The Rhizosphere An Ecological Perspective*. Academic Press.
- Schulz BJE, Boyle CJC and Sieber TN (Edrs). 2006. *Microbial Root Endophytes*. Pub Springer.
- Magesin R and Schinner F. (Edrs). 2005. *Manual of soil analysis monitoring and assessing soil Bioremediation*. Pub: Springer.
- Pinton R, Varanini Z and Nannipiers P. The Rhizosphere Biochemistry & organic substances at the soil-plant interface. Pub: CRC Press.
- Prasad TV. 2011. *A Text Book of Soil Microbiology*. Dominant Publishers & Distributors, New Delhi.
- Mukerji KG, Manoharachary C and Singh J. 2006. *Microbial activity n the Rhizosphere*. Pub: Springer.

Journals

- *European Journal of Soil biology.*
- *Canadian Journal of Microbiology*
- *Annual Review of Microbiology*
- *Journal of the Indian Society of Soil Science.*
- *Soil Biology and Biochemistry*
- *Applied soil ecology*

Websites

- www.nature.com
- www.microbiologysociety.org
- www.sare.org

I. Course Title : Microbial Biotechnology

II. Course Code : MICRO 506

III. Credit Hours : 2+1

IV. Why this course?

To give practical knowledge on fermentation and to develop fermentation for industrial application. Hence, this customised course.

V. Aim of the course

The aim is to teach students about industrially useful microorganisms and use of fermentor for the production of various primary and secondary metabolites
The course is organized as follows:

No.	Blocks	Units
1.	Scope of Microbial Technology and Fermentation Metabolism	1. Microbial Biotechnology 2. Fermentation Metabolism 3. Fermenter/bioreactor design and 4. operation 5. Fermentation system
2.	Recombinant products	1. Production of recombinant
3.	Microbial conversion and their product formation	1. Industrial production of beverages, acids and solvent 2. New tools and recent advances in microbial biotechnology

VI. Theory

Block 1: Scope of Microbial Technology and Fermentation Metabolism

Unit1: Microbial Biotechnology:

Introduction, Scopes, historical development, application and challenges.

Unit 2: Fermentation Metabolism

Fermentative metabolism, isolation, preservation screening and genetic improvement of industrially important microbes; Microbial growth kinetics.

Unit 3: Fermenter/bioreactor design and operation

Fermenters – types of fermenter, stirred tank reactor, bubble column reactor, airlift reactor, packed bed reactor, fluidized bed reactor and trickle bed reactor, agitation and aeration in a reactor, mass transfer. Foam formation and control.

Unit 4: Fermentation system

Types, Batch, Fed batch and continuous fermentation- multistage system. Solid state fermentation, Overproduction of primary and secondary metabolites e.g. amino acids, organic acids, alcohols, enzymes, organic solvents, antibiotics, etc. Immobilization of enzymes; and cells; Scale-up principles; Down-stream processing, etc.

Block 2: Recombinant Products

Unit 1: Production of recombinant

Current advances in production of antibiotics, vaccines, and biocides; Steroid transformation; Bioprocess engineering; Production of recombinant DNA products, Immobilization techniques.

Block 3: Microbial Conversion and their Product Formation

Unit 1: Industrial production of beverages, acid and solvent

Production of alcohol (ethanol, wine and beer) and improvement by genetic engineering. Microbial production of acids (citric, acetic and gluconic acid) solvents (glycerol acetone and butanol) aminoacids (lysine and glutamic acid).

Unit 2: New tools and recent advances in microbial biotechnology

Concept of probiotics and applications of new tools of biotechnology for quality feed/food production; Microorganisms and proteins used in probiotics; Lactic acid bacteria as live vaccines; Bioconversion of substrates, anti-nutritional factors present in feeds; Microbial detoxification of aflatoxins; Microbial polysaccharides: fermentative production of xanthan gums. Bacterial bioplastics, genetic engineering of microorganisms for the production of poly-3 hydroxyalkanoates. Single cell protein, Bio-insecticides; Bio-fertilizers; Waste as source of energy/food Microbiologically-produced food, colours, and flavours. Retting offlax. Recent advances in microbial biotechnology.

VII. Practicals

- Isolation and maintenance of industrially important microbes
- Production of alcohol
- Production of beer
- Production of citric acid
- Production of lactic acid
- Standardization of physical factors for the higher production of citric acid
- Production and assay of antibiotics
- Production of pullulan
- SCP production
- Study of bioreactors and their operation

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Publication Review
– Student presentation
– Group discussion
– Case Analysis and case studies
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Better knowledge on industrially important microbes
– Important downstreaming processes followed for product development

X. Suggested Reading

- Cruger W and Cruger A. 2004. *Biotechnology - A Textbook of Industrial Microbiology*. 2nd Ed. Panima.
- Ward OP. 1989. *Fermentation Biotechnology*. Prentice Hall.
- Wiseman A. 1983. *Principles of Biotechnology*. Chapman & Hall

• Peppler HJ and Perlman D.1979. *Microbial Technology*. 2nd Ed. Academic Press.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

I. Course Title : Food Microbiology

II. Course Code : MICRO 507*

III. Credit Hours : 2+1

IV. Why this course?

Food Microbiology focuses on a wide variety of current research on microbes that have both beneficial and deleterious effects on the safety and quality of foods, and are thus a concern of public health.

This course, food microbiology focuses specifically on issues of food spoilage caused by the presence of food-borne pathogens. Students are instructed in methods of sanitation and preservation during food preparation and processing.

V. Aim of the course

To familiarize the students with recent advances in food microbiology including fermented foods, dairy, food preservation, detection of food- borne diseases, their control measures.

The course is organized as follows:

No.	Blocks	Units
1	Historical Perspective and Scope of Microbiology in relation to food	1. Importance and significance of microorganisms in food 2. Factors of special significance in Food Microbiology 3. Microbial spoilage of different types of foods
2	Fermentation and Food Preservation methods	1. Food fermentation 2. Preservatives and preservation methods
3	Food safety and Quality Management Systems	1. Advanced techniques in detecting food-borne pathogens and toxins.

VI. Theory

Block 1: Historical Perspective and Scope of Microbiology in Relation to Food

Unit 1: Importance and significance of microorganisms in food

Introduction and scope; Food Microbiology Important microorganisms in food and their sources. Importance and significance of microorganisms in food.

Unit 2: Factors of special significance in Food Microbiology

Intrinsic and extrinsic factors influencing microbial growth in foods; Spores and their significance; Indicator organisms and Microbiological criteria.

Unit 3: Microbial spoilage of different types of foods

Microbial spoilage of meat, milk, fruits, vegetables and their products. Food-borne pathogens (bacteria, fungi and viruses) and intoxication.

Block 2: Fermentation and Food Preservation Methods

Unit 1: Food fermentation

Fermented dairy, vegetable, meat products.

Unit 2: Preservatives and preservation methods

Physical methods, chemical preservatives and natural antimicrobial compounds. Biologically based preservation systems. Foods for Specified Health Probiotic bacteria; Bifidus factor. Bacteriocins and their applications; Pre-, probiotics and symbiotics. Microbes as food single cell protein.

Block 3: Food Safety and Quality Management Systems

Unit 1: Advanced techniques in detecting food-borne pathogens and toxins

Food safety and Quality Management Systems- General principles of food safety risk management, Recent concerns on food safety- Safe food alternatives (Organic foods), Good agricultural Practices (GAP), Food Indicators of water and food safety and quality Advanced techniques in detecting food-borne pathogens and toxins. HACCP (Hurdle technology and Hazard analysis. Critical control point) CODEX, FSSAI (Food Safety and Standard Authority of India) systems in controlling microbiological hazards infoods. Food safety regulations

VII. Practicals

- Statutory, recommended and supplementary tests for microbiological analysis of various foods
- Infant foods, canned foods, milk and dairy products, eggs, meat, vegetables, fruits, cereals, surfaces, containers, normal, spoiled, processed, fermented food and water
- Testing of antimicrobial agents
- Analysis of water
- HACCP Plan
- Visit to Food processing Industries

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in Practical
– Visit to Food processing Industries

IX. Learning outcome

With this course the students are expected to be able to learn
– Important microorganisms in food and their sources.
– Various Factors of special significance in Food Microbiology.
– Biologically based preservation systems of foods.
– Advanced techniques in detecting food-borne pathogens and toxins.

X. Suggested Reading

- Bibek Ray. 1996. *Fundamentals of Food Microbiology*. CRC Press.
- Frazier W.C. and Westhoff D.C. 1991. *Food Microbiology*. 3rd Ed. Tata McGraw Hill.
- George J Banwart. 1989. Basic Food Microbiology. AVI. James M Jay. 1987. Modern Food Microbiology. CBS.

- Peppler H.J. and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Adams, M.R., and M. O. Moss 1996. *Food Microbiology*, New Age International (Rt) Ltd., New Delhi.
- Frazier, W.C. and D.C. Westhoff, 1988. *Food Microbiology* (Reprint 1995), Tata McGraw Hill Publishing Ltd., New Delhi.
- James M. Jay., Loessner, M.J. and Golden D.A. 2005. *Modern Food Microbiology*, Seventh edition.
- Verma, L.K. and Joshi, V.K. 2000. *Post Harvest Technology of Fruits and Vegetables*, Tata McGraw Hill Publication.
- Bhunia AK. 2008. *Foodborne Microbial Pathogens- Mechanisms and Pathogenesis, Food Science text Series*, Springer International, New York, USA.
- Benwart, G.J. 1987. *Basic Food Microbiology*, CBS Publishers & Distributors, New Delhi.
- Deak, T. and Beuchat LR. 1996. *Hand Book of Food Spoilage Yeasts*, CRC Press, New York.
- Doyle, M.P. and Beuchat, L. R. 2007. *Food Microbiology- Fundamentals and Frontiers*, ASM Press.
- Garbutt, J., 1997. *Essentials of Food Microbiology*, Armold – International Students edition, London.
- Marriott, N.G. and Gravani R. B. 2006. *Principles of Food Sanitation, Food Science text Series*, Springer International, New York, USA.

Websites

- https://www.journals.elsevier.com/food-microbiology
- https://www.nature.com/subjects/food-microbiology
- https://www.frontiersin.org/journals/microbiology/sections/food-microbiology
- https://www.sciencedirect.com/journal/food-microbiology

I. Course Title : Bacteriophages

II. Course Code : MICRO 508

III. Credit Hours : 1+1

IV. Why this Course?

Bacteriophages are viruses that infect and reproduce in bacteria. Phages are inherently highly specific towards bacterial hosts. This characteristic has both negative and positive aspects in that it is beneficial in terms of avoiding negative effects on the host microbiota and a hindrance when it comes to detection and elimination of the target pathogen Course is formulated to demonstrate the complete sequence of host parasite reactions and provide a model by which virus –host cell reactions can be postulated for infection in higher plants and animals.

V. Aim of the course

To familiarize the students about phages and phage- bacterial interactions. Bacteriophages have been of intense value in elucidating many biological phenomena, including those concerned with genetics.

The course is organized as follows:

No.	Blocks	Units
1.	Bacteriophages	1. Historical prospective of bacteriophages 2. Biological processes of phage bacterial interaction 3. Life cycle of bacteriophages 4. Biotechnological Genetic manipulation

VI. Theory

Block 1: Bacteriophages

Unit 1: Historical prospective of bacteriophages.

Historical developments and classification of bacteriophages.

Unit 2: Biological processes of phage bacterial interaction

Physiology, biochemistry, enzymology and molecular biology of phage- bacterial interactions.

Unit 3: Life cycle of bacteriophages.

Structure, functions and life cycles of P2 phage, Lambda phage, M13 phage, ÕX174 phage.

Unit 4: Biotechnological Genetic manipulation

Phages in the development of molecular biology and genetic engineering.

VII. Practicals

- Titration of phages and bacteria.
- Absorption of phages.
- Preparation of phage stocks.
- Isolation of new phages and phage resistant bacteria.
- One step growth curve, phage bursts.
- Induction of lambda.
- Complementation of T_4*rII* mutantsetc.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in Practical

IX. Learning outcome

With this course the students are expected to be able to learn

– About different phages and phage- bacterial interactions.
– Intensible value Bacteriophage in elucidating many biological phenomena, including those concerned with genetics.
– Development of molecular biology and genetic engineering

X. Suggested Reading

- Birge EA. 2000. *Bacterial and Bacteriophage Genetics*. Springer-Verlag. Mathew CK. 1972. *Bacteriophage Biochemistry*. Am. Chemical Soc.
- Mathew CK, Kutter EM, Mosig G & Berget P. 1988. *Bacteriophage T4*. Plenum Press.
- Nancy T and Trempy J. 2004. *Fundamental Bacterial Genetics*. Blackwell. Stent SG. 1963. *Molecular Biology of Bacterial Viruses*. WH Freeman and Co.
- Winkler J, Ruger W and Wackernagel W. 1979. *Bacterial, Phage and Molecular Genetics - An Experimental Course*. Narosa.
- Winkler U and Rugr W. 1984. *Bacteria, Phage and Molecular Genetics*. ALA.

Websites

- https://www.nature.com/scitable/definition/bacteriophage-phage-293
- https://www.phe-culturecollections.org.uk/news/nctc-news/the-rise-and-rise-of-bacteriophages. aspx

- https://www.khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/bacteriophages

I. Course Title : Environmental Microbiology

II. Course Code : MICRO 509

III. Credit Hours : 2+1

IV. Why this Course?

This course deals with the study of composition and physiology of microbial communities in the environment. Diversity of microbial populations and their important roles in air, water, soils and sediments. Microbial community ecology and interactions with plants and animals. Microbial communities control nutrient cycles and transformation of compounds. Deeper understanding about the beneficial and harmful effects of microbial communities in the environment will help, so this course as been mandated.

V. Aim of the course

The course is designed to introduce students to diverse microbial population and their important roles in environmental processes in air, water, soils and sediments.types of microorganisms found in the air, terrestrial and aquatic environments. Interaction of microbial communities with plants and animals. Geochemically and environmentally significant processes that are contributed by the activities of microorganisms. Methods that are used to identify and enumerate bacteria in natural environments and also how specific microbial activities. Impact of microbial degradation of organic contaminants and xenobiotics.

The course is organized as follows:

No.	Blocks	Units
1.	Microbial ecology	1. Scope of Environmental microbiology and Ecological Niche 2. Microorganisms and their natural habitats 3. Extremophiles
2.	Microbial interaction	1. Biogeochemical cycles 2. Waste water and solid waste treatment 3. Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract

VI. Theory

Block 1: Microbial Ecology

Unit 1: Scope of Environmental microbiology and Ecological Niche

Scope of environmental microbiology,Microbial ecology: Microbial evolution and biodiversity – Ecological niches – Definitions, biotic and abiotic environment. Environmental segments. Composition and structure of environment. Concept of biosphere, communities and ecosystems. Ecosystem characteristics, structure and function. Food chains, food webs and trophic structures. Ecological pyramids.

Unit 2: Microorganisms and their natural habitats

Microorganisms and their natural habitats: Aeromicrobiology, Astrobiology, Methane and chlorates on Mars, terrestrial analogues. Biofilms and microbial mats, Aquatic ecosystems- Public Health Microbiology.

Unit 3: Extremophiles

Extremophiles: Definition and ecological aspects. Thermophiles, Xerophiles, Psychrophiles, Piezophiles, Alkaliphiles, Acidophiles- Halophiles and Barophiles. Environmental Distribution and Taxonomic Diversity, Physiology, Adaptive mechanisms, Enzymes, Applications.

Block 2: Microbial Interaction

Unit 1: Biogeochemical cycles

Biogeochemical cycling and its consequences. Global environmental problems.

Unit 2: Waste water and solid waste treatment

Microbiology of wastewater and solid waste treatment: - Waste-types-solid and liquid waste characterization, physical, chemical, biological, aerobic, anaerobic, primary, secondary and tertiary treatments. Anaerobic processes-Bioremediation of nuclear wastes. Bioconversion of Solid Waste and utilization as fertilizer. Bioaccumulation of heavy metal ions from industrial effluents. Biomining. Microbiology of degradation of xenobiotics in the environment, ecological considerations, decay behavior.

Unit 3: Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract.

Microbial upgradation of fossil fuels and coal gas. Microbial interaction in rumen and gastrointestinal tract.

VII. Practicals

- Determination of indices of pollution by measuring BOD/COD of different effluents.
- Analysis of natural waters.
- Quality control tests, waste treatment and anaerobic digestion; Demonstration of waste water treatment processes such as activated sludge processes, biofilter and fluidized bed process.
- Bacterial reduction of nitrate from ground waters.
- Isolation and purification of degradative plasmid of microbes growing in polluted environments.
- Recovery of toxic metal ions of an industrial effluent by immobilized cells.
- Utilization of microbial consortium for the treatment of solid waste [Municipal Solid Waste]
- Biotransformation of toxic metal ions into non-toxic metals ions.
- Microbial dye decolourization/adsorption.
- Biotrap based isolation of selective functional microbes.
- Thermophlic enzyme in biomass deconstructions.
- Halophilic microbes from salt lake-Pesticide degradation by microbes

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in practical

– Field visit
– Case studies

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Appreciate the diverse microbial communities in environment and will be able to isolate and enumerate them from different environment.
– Realise the significance of microbial communities in biogeochemical cycles and their beneficial aspects to plants.
– Role of microorganism which are involved for bioremediation of harmful xenobiotic compounds.

X. Suggested Reading

- Campbell R. 1983. *Microbial Ecology*. Blackwell.
- Hawker LE & Linton AH. 1989. *Microorganisms Function, Form and Environment*. 2nd Ed. Edward Arnold.
- Richards BN. 1987. *Microbes of Terrestrial Ecosystem*. Longman.
- Mitchell R. 1992. *Environmental Microbiology*. John Wiley & Sons.
- Baker K.H. and Herson D.S. 1994. *Bioremediation*. McGraw Hill Inc., N.Y.
- Metcalf and Eddy HP. 2004. *Waste Water Engineering - Treatment, Disposal and Re-use* Inc., Tata McGraw Hill, New Delhi.
- McEldowney S Hardman DJ and Waite S. 1993. *Pollution: Ecology and Biotreatment* Longman Scientific Technical.
- Mitchell R, and GuJi-Dong. 2010. *Environmental Microbiology*. John V, Wiley Sons. Inc.
- Waste Water Microbiology 2nd Edition. Bitton. Chemistry and Ecotoxicology of pollution. Edited by Des. W. Connell, G.J. Miller. Wiley Interscience Publications.
- Bitton G. 2010. *Waste Water Microbiology* 2nd Edition.
- Connell OW and Miller GJ. 1984. *Chemistry and Ecotoxicology of pollution*. Wiley Interscience Publications.
- Forster CF and John Wase DA. *Environmental Biotechnology*. Ellis Horwood Ltd. Publication.
- Trivedi RK. 1998. *Advances in Waste Water Treatment Technologies*. Volumes II and I Global Science Publication.
- Lawrence P, Wacekett C and Hershberger D. 2000. *Biocatalysis and Biodegradation: Microbial transformation of organic compounds*. ASM Publications.
- Hurst CJ. 2001. *A Manual of Environmental Microbiology*. 2nd Edition. ASM Publications.

Websites

- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Industrial Microbiology

II. Course Code : MICRO 510

III. Credit Hours : 2+1

IV. Why this Course?

The syllabus of industrial microbiology is oriented towards the industrial application of microorganisms and recent microbial products. After studying this course students will know the industrial aspects of microbiology.

V. Aim of the course

To expose the students to the commercial exploitation of microorganisms for production of useful products. Focus will be on understanding of the techniques involved and the application of microorganisms for agribusiness purpose.

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Industrial Microbiology	1. Historical account of microbes in industrial microbiology 2. Fermented Microbial products
2.	Bioplastics, Biopolymers & Biofuels	1. Biocontrol agents and Biopesticides 2. Industrial production of Bioplastics and biopolymers 3. Production of valuable products

VI. Theory

Block 1: Basics of Industrial Microbiology

Unit 1: Historical account of microbes in industrial microbiology

Introduction to Industrial Microbiology. Sources and characters of industrially important microbes; their isolation, purification and maintenance.
types of fermentation and fermenters. Microbial growth kinetics in batch, continuous and fed-batch fermentation process.

Unit 2: Fermented Microbial products

Bioreactors: Types and configuration. Microbiology and production of alcoholic beverages; Malt beverages, distilled beverages, wine and champagne; Commercial production of organic acids like acetic, lactic, citric, and gluconic acids Commercial production of important amino acids (glutamic acid, lysine and tryptophan), vitamins (riboflavin and vitamin A), enzymes, antibiotics and single cell proteins.

Block 2: Bioplastics, Biopolymers and Biofuels

Unit 1: Biocontrol agents and Biopesticides

Biocontrol agents and Biopesticides: Biocontrol agents and their scope in control of plant diseases, nematodes and insect pests. Role of bioagents in sustainable agriculture.

Unit 2: Industrial production of Bioplastics and biopolymers

Introduction & industrial production of Bioplastics: Microorganisms involved in synthesis of biodegradable plastics and microbial pigments and biopolymers.Biosensors: Development of biosensors to detect food contamination and environment pollution. Biofuels: Production of ethanol, biogas and hydrogen from organic residues, fuels from algae; Mushroom cultivation.

Unit 3: Production of valuable products

Genetic engineering of microbes, Role of recombinant microbes in industrial sectors for enhanced production of valuable products. Mechanisms of pesticide degradation by microbes. Biomining: Coal, mineral and gas formation, prospecting for deposits of crude, oil and gas, recovery of minerals from low-grade ores.

VII. Practicals

- Isolation and purification of industrially important microbes (Bacteria, fungus and yeasts)
- Production of industrial compounds such as alcohol, beer, citric acid, lactic acid

acetic acids gluconic acid and their recovery
- Demonstration of biogas production
- Production and assay of enzymes, organic acids and pigments
- Mass production of biocontrol agent
- Visit to industries

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical
- Field visit/Industries/University lab
- Case studies

IX. Learning outcome

After studying this course students will know and will be able to learn

- The applied and industrial aspects of microbiology such as screening of microorganisms, strain improvement, microbial metabolites, fermented microbial products, microbial enzymes, Biofuels using microbes and microbial production of Biopolymers.
- The recent applications of the microbes for the human welfare.

X. Suggested Reading

- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology*. 2nd Ed. Pearson Prentice Hall Edu.
- Waites, M.J., Morgan, N.L., Rockey, J.S. and Higton, G. (2002). *Industrial Microbiology: An Introduction.* Blackwell Science Publishers.
- Crueger W and Crueger A. *Biotechnology: A Text Book of Industrial Microbiology* Panima Publishing Corporation.
- Reed G. 1999. *Prescott and Dunn's Industrial Microbiology*. CBS Publishers.
- Demain AL. 2001. *Industrial Microbiology and Biotechnology* IInd Edition. ASM Press, Washington.
- Stanbury PF, Whitaker W and Hall SJ. 1997. *Principles of Fermentation Technology* Aditya Books (P) Ltd., New Delhi.
- Baltz RH, Davies JE and Demain AL. 2010. *Manual of Industrial Microbiology and Biotechnology*. 3rd Edition, ASM Press.
- Forciniti D. 2008. *Industrial Bioseparations: Principles and Practice*. 1st Edition, Wiley-Blackwell.
- OkaferN. 2007. *Modern Industrial Microbiology and Biotechnology,* Scientific Publishers, Enfield, USA.
- Nduka O and Benedict OC. 2018. *Modern Industrial Microbiology and Biotechnology*, Taylor and Francis 465p.
- ElMansi EMT, Bryce CFA, Dahhou A, Sanchez S, Demain AL, Allman AR. 2012. *Fermentation Microbiology and Biotechnology* 3rd Ed. CRC Press, Taylor and Francis, Boca Raton.
- Stanbury AF and Whitaker A. 1984. Principles of Fermentation Technology –Oxford Pergamon press New York.
- Moses V and Cape RE. 1991. *Biotechnology* - The Science and the Business Harwood Academic Publishers, USA.
- Casida LE Jr. 1989. *Industrial Microbiology* Wiley Eastern Ltd., N. Delhi.
- Miller BM and Litsky W. 1976. *Industrial Microbiology*, McGraw Hill Co.,New York 451p.
- Crueger W and Crueger A. 1984. *Biotechnology – a Text book of Industrial Microbiology*. Science Tech. Inc., Madison.
- Glazer AN and Nikaido HN. 1995. *Microbial Biotechnology: Fundamentals of Applied Microbiology*, W.H.Freeman Co., New York.

- Demain AL and Solomon MA. 1986. *Manual of Industrial Microbiology and Industrial Microbiology*, American Society of Microbiology, Washington.
- Atkinson B and Marituna F. 1983. *Biochemical Engineering and Biotechnology* Handbook, McMillian Publishers.
- Jones DG. 1983. *Exploitation of Microorganisms*. Chapman & Hall, Oxford.
- Peppler HJ and Perlman D. 1979. Microbial technology Vol.1 Fermentation Tecnology, Vol.2, Academic Press.
- Rehm HJ and Reed G. 1995. *Biotechnology, a Comprehensive Treatise*, 8 Vols. (Reference Book) Verlag Chemie,Wienheim. Also refer Second edition, 12 vols,1995 (Rehm,H.J.: Reed, G.: Puhler,A; Stadler, P Eds)
- Moo-Young Y. 1985. *Comprehensive Biotechnology*- 5 vols. (Reference Book) Pergamon Press, Oxford.
- Arora DK. 1992. *Handbook of Applied Mycology* – 5 Vols. (Reference Book) Marcel Dekker, New York.
- Glick BR and Pasternak JJ. 2003. *Molecular Biotechnology-principles and applications of recombinant* DNA,ASM press,Washington,760 pp.

Also consult latest issues of:
- Advances in Applied Microbiology, Biotechnology Advances,
- Biotechnology & Genetic Engineering Reviews,Advances in Biochemical Engineering & Biotechnology, Advances in Microbial Physiology

Websites
- https://www.biomerieux.com/en/industrial-microbiological-control-0
- https://icar.org.in/content/food-and-industrial-microbiology

I. Course Title : Biofertilizer Technology

II. Course Code : MICRO 511

III. Credit Hours : 2+1

IV. Why this Course?

The exploitation of beneficial microbes as a biofertilizer is of prime importance in agriculture sector for their potential role in food safety and sustainable crop production. There is wide gap between nutrient removal and supplies. There is increase in cost of fertilizers due to deplete in the feed stock fossil fuels besides growing concern of environmental hazards due to chemical fertilizers. It is essential to exploit Biofertilizers having functional traits for enhancing plant growth and productivity, nutrient profile, plant defense and protection with special emphasis to its function to trigger various growth- and defense-related genes in signaling network of cellular pathways to cause cellular response and thereby crop improvement.

The syllabus Biofertilizers technology is oriented towards application of biofertilizer to trap atmospheric nitrogen to the soil and convert them into plant usable forms. They also convert the insoluble phosphate forms into plant available forms. They stimulate root growth by producing some hormones and antimetabolites. Improved Plants.

V. Aim of the course

To familiarize the students and farmers with mass scale production of different agriculturally important microorganisms which are being used as biofertilizers for maintaining the soil and plant health for sustaining crop productivity and their importance in organic farming.

The course is organized as follows:

No.	Blocks	Units
1.	Agriculturally important beneficial microorgansims	1. Agriculturally important beneficial nitrogen fixing microorganisms. 2. Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition 3. Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria 4. Agriculturally important biocontrol microbial inoculants 5. Economics of biofertilizer production.
2.	Production of Biofertilizer	1. Production and quality control of biofertilizer

VI. Theory

Block 1: Agriculture Important Beneficial Microorganisms

Unit 1: Agriculturally important beneficial nitrogen fixing microorganisms.

Different agriculturally important beneficial microorganisms: Chemical Vs Biofertilizers: Current Scenario in biofertilizer technology in world-In India-List of biofertilizers-their applications in agriculture.

Brief introduction about Agriculturally beneficial microorganisms (free living, symbiotic (rhizobial, actinorhizal), associative and endophytic nitrogen fixers including phosphobacteria, cyanobacteria, their types and importance taxonomic classification, Nitrogen fixing biofertilizers: nodule formation, competitiveness and quantification of N_2 fixed and their use. Mechanism of phosphorous solubilization by photobacteria. BIS standards of biofertilizers

Unit 2: Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition

Different agriculturally important beneficial microorganisms: phosphate solubilizing bacteria and fungi, including mycorrhiza; Mechanism of phosphorous solubilization by phosphobacteria. Bacteria for potassium, Sulphur and Zinc nutrition.

Unit 3: Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria.

Different agriculturally important beneficial microorganisms: plant growth promoting rhizobacteria. FCO norms and biofertilizer production and usage at national and international levels

Unit 4: Agriculturally important biocontrol microbial inoculants

Different agriculturally important beneficial microorganisms: Biocontrol microbial inoculants. Requirements for establishing bioinoculants production unit Economics of biofertilizers production Constraints in biofertilizers production and usage

Unit 5: Economics of biofertilizer production

Different agriculturally important beneficial microorganisms for recycling of organic waste and compositing, bioremediators and other related microbes.

Block 2: Production of Biofertilizer

Unit 1: Production and quality control of biofertilizer

Different agriculturally important beneficial microorganisms - selection, establishment, competitiveness, crop productivity, soil & plant health, mass scale production and quality control of bio inoculants. Biofertilizer inoculation and microbial communities in the soil. Different formulations of biofertilizers. Advantages and limitations of Liquid formulations.

VII. Practicals

- Isolation of phosphate solubilizing microorganisms.
- Development and production of efficient microorganisms,
- Determination of beneficial properties in important bacteria to be used as biofertilizer, Nitrogen fixing activity, indole acetic acid (IAA), siderophore production etc,
- Bioinoculant production and quality control.
- Population dynamics in broth and carrier materials during storage.
- Development of cultures from starter.
- Preparation of broth for large scale cultivation in fermenter/ large containers. Inoculation and development of culture.
- Mass production of carrier based and liquid biofertilizers. Mass production of important two or three biocontrolagents (*Trichoderma viride, Pseudomonas fluorescens* and *Metarhiziumanisopliae*).
- Form, dose and method of application.
- Mass production of AM fungi in pot and root organ culture.
- Quality control and BIS standards.
- Mass production of Azolla and BGA.
- Visit to a biofertilizer production plant

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

IX. Learning outcome

After successful completion of this course, the students are expected to be able to learn:

- Agriculturally important beneficial microorganisms for fixation of various important elements and compounds.
- Biofertilizer production and usage at national and international levels.
- Requirements for establishing bioinoculants production unit, economics (solid liquid carrier) production, constraints in biofertilizers production and usage.
- A complete exposure to all kinds of agriculture important biofertilizers along with their functions and properties,
- Helps to develop as entrepreneur.

X. Suggested Reading

Books

- Alexander M. 1977. *Soil Microbiology*. John Wiley.
- Bergerson FJ. 1980. *Methods for Evaluating Biological NitrogenFixation*. John Wiley & Sons.
- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology*. 2nd Ed. Pearson Prentice Hall Edu.
- Van Elsas JD, Trevors JT and Wellington EMH. 1997. *Modern Soil Microbiology*. CRC Press.
- Panwar JDS and Jain AK. 2016. *Organic farming scope and use of biofertilizers*. Pub: NIPA, New Delhi.
- Gaur AC. 2010. *Biofertilizers in Sustainable Agriculture*, ICAR, New Delhi.
- Chanda P and Srivathsa RSH. 2005. *Liquid Biofertilizers*. Ministry of Agriculture Department of Agriculture & Cooperation, GOI.
- DeshMukh AM, Khobragade RM and Dixit PP. 2007. *Handbook of Biofertilizers & Biopesticides*. Oxford Book Company, Jaipur, India.
- Gupta RP, Kalia A and Kapoor S. 2007. *Bioinoculants a Step towards Sustainable Agriculture* .NIPA, New Delhi.
- Somani LL, Shilkar P and Shilpkar D. 2011. *Biofertilizers Commercial Production Technology & Quality Control*. AgroPublishing Acadamy, Udaipur.
- Srivastava HS and Singh RP. 1995. *Nitrogen nutrition in higher plants*. Associated Publishing Company, New Delhi.
- Kannaiyan S and Kumar K. 2005. *Azollabiofertiliser for sustainable Rice Production*. Daya Publishing House, Delhi.
- Kannaiyan S, Kumar K and Govindarajan K. 2010. *Biofertilizer Technology*. Scientific Publishers (India), Jodhpur.
- Vora MS, Shelat HN and Vyas RV. 2013. *Handbook of Biofertilizers & Microbial Pesticides*.
- Chanda JK. 2008. *Biofertilizer Statistics 2006-07*. The fertilizer Association of India, New Delhi.

Journals

- *Journal of Biofertilizer& Biopesticides*
- *Journal of Botanical Sciences*

Websites

- Biofertilizer in organic Agriculture (www.Journalphytology.com)
- Microbial biofertilizers (www.Boffinaccess.com)
- Biofertilizer as a prospective input for sustainable agriculture in India. http://www.krishisewa.com/articles/organic-agriculture/115-biofertilizers.html
- Handbook of Microbial Biofertilizers M. K. Rai, PhD Editor Pub: Food Products Press, NY.
- Bio fertilisers https://www.worldcat.org/search?q=biofertilisers&fq=dt%3Abks&dblist=638&qt =sort&se=yr&sd=desc&qt=sort_yr_desc

I. Course Title : Cyanobacterial and Algal Biotechnology

II. Course Code : MICRO 512

III. Credit Hours : 2+0

IV. Why this Course?

Cyanobacteria and algal biomass contribute major role in carbon cycle in turn influencing the climate. The blooms of cyanobacteria and algae in different ecosystems is worth exploiting due to their wide biodiversity. They play an important role in agriculture by contributing to the fertility of soil in terms of biomass, biofertilizer, and act as herbicides, insecticides and in bioremediation. Their physiological and biochemical properties disclose their significant potential for colorants, polysaccharides, pharmaceutical & nutraceutical compounds, and valuable biomolecules of industrial importance. With the population explosion and scarcity of land, these can provide better feed stock due to their high protein content, easy cultivation, and versatile growth and easy to harvest. It is challenging for designing bioreactor and utilizes waste waters for growing and harvesting cyanobacteria and algae for these purposes. They are capable of producing and accumulating lipids which can be the source for biodiesel in future.

This course will help the student to understand taxonomy and molecular biology methods of cyanobacteria. The course will give knowledge on cyanobacterial and algal fuels,

V. Aim of the course

The aim is togive exposure on the potential applications of cyanobacteria and algae in Agriculture, Industry and Environment; to inculcate knowledge on algal mass production techniques and their valuable products of commercial importance and to introduce the R&D and entrepreneurial opportunities algae. Students will learn about biodiversity of cyanobacteria and their classification, the biotechnological applications in agriculture – biofertilizers, biocontrol, bioenergy and bioprocessing, their applications in pharmaceuticals, production of antioxidative enzymes and pigments, as source of food, etc.

The course is organized as follows:

No.	Blocks	Units
1.	Importance of cyanobacteria and algae	1. Ecology and evolution of algae and cyanobacteria
2.	Physiology and culturing of cyanobacteria and algae	1. Algal pigments, storage products 2. Metabolism of carbon and nitrogen 3. Culturing methods.
3.	Role of cyanobacteria and algae in agriculture and their products of industrial importance	1. Importance as fuels, neutraceuticals and industrial importance 2. Role of algae related to environment

VI. Theory

Block 1: Importance of Cyanobacteria and Algae

Unit 1: Ecology and evolution of algae and cyanobacteria

Introduction to cyanobacteria and algae. Definition, occurrence and distribution, thallus structure, reproduction, life cycles, origin and evolution of cyanobacteria, molecular evolution; role of algae in evolution of land plants and horizontal transfer of genes. Brief classification of algae: different classes, occurrence and distribution.

Block 2: Physiology and Culturing of Cyanobacteria and Algae

Unit 1: Algal pigments, storage products.

Algal pigments, storage products, physiology and metabolism including photosynthesis.

Unit 2: Metabolism of carbon and nitrogen

Ecology of algae –primary colonizers and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism carbon metabolism.

Unit 3: Culturing methods

Algal culturing and cultivation. Culture types, culture conditions, culture vessels, culture media, sterilization, culture methods, synchronous cultures, photobioreactors, algal density and growth, seaweed cultivation.

Block 3: Role of Cyanobacteria and Algae in Agriculture and their Products of Industrial Importance

Unit 1: Importance as fuels, neutraceuticals and industrial importance.

Cyanobacterial and algal fuels, Fine chemicals (restriction enzymes etc.) and nutraceuticals from algae; UV absorbing pigments Industrial products from macro algae - seaweed biotechnology, sustainable aquaculture. Ecology of algae- distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism.

Unit 2: Role of algae related to environment.

Algae in pollution control - as pollution indicators, eutrophication agents and role in Bioremediation and reclamation of problem soils. Cyanobacterial and algal toxins, allelopathic interactions, Algae in global warming and environmental sustainability. Cyanobacteria and selected microalgae in agriculture – biofertilizers &algalization; soil conditioners; reclamation of problem soils.

VII. Teaching methods/activities

- Lecture
- Assignment (reading/writing)
- Publication review
- Student presentation
- Group discussion
- Case analysis and case studies
- Guest lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Types of cyanobacteria and algae along with their physiological and biochemical properties that provides base for selection for further exploitation of industrial use.
- Algal culturing and cultivation. Culture types, culture conditions, synchronous cultures, photobioreactors, algal density and growth, seaweedcultivation.
- Production of cyanobacterial and algal fuels
- Industrial products from macro algae – seaweed biotechnology, sustainable aquaculture.
- Ecology of algae – distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water.

IX. Suggested Reading

- Ahluwalia AS. 2003. *Phycology: Principles, Processes and Applications*. Daya Publ.
- Barsanti L and Gualtieri P. 2006. *Algae: Anatomy, Biochemistry and Biotechnology*. Taylor & Francis, CRC Press.
- Carr NG and Whitton BA. 1982. *The Biology of Cyanobacteria*. Blackwell.
- Herrero A and Flores E. 2008. *The Cyanobacteria Molecular Biology,Genomics and Evolution*. Calster Academic Press

- Kumar HD. 2005. *Introductory Phycology*. East West Press. Linda E Graham & Lee W Wilcox. 2000. *Algae*. Prentice Hall.
- Andersen RA. 2005. *Algal Culturing Techniques*. Academic Press.
- Venkataraman LV and Becker EW. 1985. *Biotechnology and Utilization of Algae: the Indian Experience*. DST.
- Das MK. 2010. *Algal Biotechnology*. Daya Publishing House.
- Tiwari. 2014. *Cyanobacteria: Nature, Potentias and Applications*. Daya Publishing House.
- Khattar JIS, Singh DP, Kaur G. 2009. *Algal Biology and Biotechnology*. I.K. International Publishing HousePvt. Ltd.
- Bhatnagar SK, Saxena A, Kraan S. 2011. *Alga Biofuels*. Stadium Press (India) Pvt. Ltd.
- Sahoo D and Kaushik BD. 2012. *Algal Biotehcnolgoy and Environment*. I.K. International Publishing HousePvt. Ltd.

Journals

- *Journal of Phycology*
- *Journal of Applied Phycology*
- *Frontiers in Microbiology*

Websites

- Cyanbacterial and algal Biotechnology
- https://www.worldcat.org/search?q=cyanobacterial+and+algal+biotechnology&qt=results_page#%2528x0%253Abook%2Bx4%253Aprintbook%2529format
- www.cyanosite.bio.purdue.edu
- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.bbsrc.ac.uk/organisation/policies/reviews/scientific-areas/1107-algal-research.aspx
- http://asulightworks.com/resources/videos/arizona-center-algae-technology-and-innovation.html

Course Title with Credit load
Ph.D. in Microbiology

Course Code	Course Tittle	Credit Hours
MICRO 601*	Improvement in fermentation Technology	2+1
MICRO 602	Microbial physiology and regulation	2+0
MICRO 603*	Recent development in soil microbiology	2+0
MICRO 604	Recent approaches in environmental microbiology	2+0
MICRO 605*	Plant microbe interactions	2+1
MICRO 691	Doctoral seminar I	1+0
MICRO 692	Doctoral seminar II	1+0
MICRO 699	Doctoral Research	75

*Core Courses

Course Contents
Ph.D. in Microbiology

I. Course Title : Improvements in Fermentation Technology
II. Course Code : MICRO 601*
III. Credit Hours : 2+1

IV. Why this Course?

This course aims to introduce technological advancement of fermentation and bioprocess for industrial applications. Microorganisms are capable of growing on a wide range of substrates and can produce a remarkable spectrum of products. This course will enlighten the students on basics of fermentation, metabolic engineering, fermenter design and downstream processing. The economics of industrial products are introduced to understand commercialization of microbial products.

V. Aim of the course

The aim is to teach students regarding fermentation industry using industrially useful microorganisms including yeast technology. To introduce the students to broad coverage of a diverse field of fermentation technology, provide an understanding of the exploitation of microorganisms in the manufacture of bio products and provide the students with skill in operation of fermenter.

The course is organized as follows:

No.	Blocks	Units
1.	Rise of Fermentation Technology	1. Development in Fermentation 2. Types of Fermenters
2.	Fermenter	1. Component of fermenter and use
3.	Fermentation process	1. Types of Fermentation
4.	Recombinant Strategies Followed	1. Strategies for isolation of industrially important microbes

VI. Theory

Block 1: Rise of Fermentation Technology

Unit 1: Development in Fermentation

Definition of fermentation – rise of fermentation technology –current trends in fermentation industry – scope and importance of fermentation technology.

Unit 2: Types of fermenters

Continuous, batch and fed batch culture –anaerobic fermentation - range of fermentation process – microbial growth cycle – diauxic growth – growth kinetics – substrate uptake kinetics (Jacob and Monod) - primary and secondary metabolites – future prospects of fermentation microbiology

Block 2: Fermenter

Unit 1: Components of fermenter and use

Peripheral parts and accessories – alternative vessel designs –containment in fermentation – fermenter preparation and use - aeration and agitation – instrumentation and control – biosensors in monitoring – computer applications in fermentation technology

Block 3: Fermentation Process

Unit 1: Types of Fermentation

Solid state and submerged fermentation – acidic/alcoholic fermentation - recovery of product – effluent treatment – Economics of fermentation

Block 4: Recombinant Strategies Followed

Unit 1: Strategies for isolation of industrially important microbes

New strategies for isolation of industrially important microbes and their genetic manipulations; Antibiotic fermentation research; steroid transformation; Yeast technology – classification, genetics, strain improvement for brewing, baking and distilleries

VII. Practicals

- Studying the various components of fermenter
- exposure to different types of fermenter
- sterilization and operating procedures
- designing the production medium
- isolation and purification of industrially important microbes
- Genetic manipulations in microbes
- Fermentation by improved strains of yeast for production of alcohol
- microbial production of enzymes by solid state fermentation
- Microbial production of important antibiotics
- Bioremediation of industrial effluents

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Students should have an understanding of the variety of fermentation and subsequent processing approaches available for the manufacture of biological products and the design and operation of these systems.

X. Suggested Reading

- Stanbury PF, Whitaker A and Hall SJ. *Principles of fermentation technology*, Second edition
- Patel AH. *Industrial Microbiology*
- ElMansi EMT and Bryce CFA. *Fermentation Microbiology and Biotechnology*

- Srivastava ML. *Fermentation Technology*
- Singh T and Purohit SS. *Fermentation Technology*
- ElMansi EMT, Bryce CFA, Demain AL and Allman AR. *Fermentation Technology – Microbiology and Biotechnology*
- Peppler HJ and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Reed G. 1987. *Presscott& Dunn's Industrial Microbiology*. 4th Ed. CBS.
- Stanbury PF and Whitaker A. 1987. *Principles of Fermentation Technology*. Pergamon Press.
- Wiseman A. 1983. *Principles of Biotechnology*. Chapman & Hall.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.scribd.com/doc/46151150/Fermentation-Technology
- http://www.chalmers.se/en/areas-of-advance/lifescience/research/Pages/Fermentation-Technology.aspx

I. Course Title : Microbial Physiology and Regulation

II. Course Code : MICRO 602

III. Credit Hours : 2+0

IV. Why this Course?

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favorable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and biosynthesis and how do they respond to the changes in environment

V. Aim of the course

To acquaint students with current topics in molecular microbiology. Course imparts thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.

The course is organized as follows:

No.	Blocks	Units
1.	Historical evaluation of microbial physiology	1. Molecular aspects of various cell component
2.	Regulation and pathways	1. Regulatory Pathways 2. Regulatory control 3. Current topics

VI. Theory

Block 1: Historical Evaluation of Microbial Physiology

Unit 1: Molecular aspects of various cell component

Origin, evolution, structure, function and molecular aspects of various cell components. Differentiation in bacteria, slime molds, yeasts. Molecular biology of bioluminescence, bacterial virulence. Heat shock response. Extracellular protein secretion in bacteria.

Block 2: Regulation and Pathways

Unit 1: Regulatory Pathways

Regulation of initiation, termination and anti-termination of transcription. Global regulation and differentiation by sigma factor. Regulatory controls in bacteria - inducible and biosynthetic pathways. Oxidative stress control. Fermentative and respiratory regulatory pathways.

Unit 2: Regulatory control

Ribosomal RNA and ribosomal proteins regulation under stress condition. Specific regulatory systems; SOS regulatory control; Antisense RNA regulation of gene expression.Biosynthesis of micromolecules (Nucleotides and Aminoacids) macromolecules (DNA, RNA, Proteins) Global nitrogen control and regulation of nitrogen fixation

Unit 3: Current topics

Topics of current interest in Molecular microbiology and regulatory systems.

VII. Teaching methods/activities

– Class room Lecture
– Assignment (Reading/Writing)
– Student presentation
– Seminar presentation by students

VIII. Learning outcome

With this course, the students are expected to be able to learn
– Current topics in molecular microbiology.
– Thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.
– About the synthesis of biomolecules in microorganisms by various pathways and their regulation.

IX. Suggested Reading

Websites

- https://www.frontiersin.org/journals/microbiology/sections/microbial-physiology-and-metabolism
- https://www.sciencedirect.com/bookseries/advances-in-microbial-physiology
- https://www.researchgate.net/journal/0065-2911_Advances_in_Microbial_Physiology
- https://bmb.psu.edu/undergraduate/courses/course-archive/2016/fall-2016/microbiology-micrb/micrb-401-fall-2016/micrb-401-microbial-physiology-and-structure
- Selected articles from journals.

I. Course Title : Recent Developments In soil microbiology

II. Course Code : MICRO 603*

III. Credit Hours : 2+0

IV. Why this Course?

Directly or indirectly the waste of human and other animals, their bodies, and the tissues of plants are dumped onto or buried in the soil. It is the microbes that make these changes –the conversion of organic matter in to simple organic substances that provide the nutrient material for the plant and agriculture world. Thus microorganisms play a vital role in maintaining life on earth. The prerequisite for this class is SOIL. To be completely prepared for this class a course taken in Microbiology is very useful.

V. Aim of the course

To make students learn the latest trends in soil microbiology like diversity, biological control and bioremediation.

The course is organized as follows:

No.	Blocks	Units
1.	Recent developments in soil microbiology	1. Ecology and microorganisms diversity 2. Role of microorganisms in soil 3. Bioremediation

VI. Theory

Block 1: Recent Developments in Soil Microbiology

Unit 1: Ecology and microorganisms diversity

Molecular ecology and biodiversity of soil microorganisms; Survival and dispersal of microorganisms. Interaction between agricultural chemicals, pollutants and soil microorganism

Unit 2: Role of microorganisms in soil

successions and transformation of organic matter; Role of microorganisms in soil fertility. Soil health and quality: Microbial indicators

Unit 3: Bioremediation

Bioremediation of polluted soils; Biological control. Other topics of current interest.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Seminar presentation by students.
- Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

- Latest trends in soil microbiology like diversity, biological control and bioremediation.

IX. Suggested Reading

Websites

- https://www.springer.com/in/book/9789811073793
- https://www.researchgate.net/publication/322952969_Advances_in_Soil_Microbiology_Recent_ Trends_and_Future_Prospects_Volume_2_Soil-Microbe-Plant_Interaction
- Selected articles from journals.

I. Course Title : Recent Approaches in Environmental Microbiology

II. Course Code : MICRO 604

III. Credit Hours : 2+0

IV. Why this Course?

The activities of the microorganisms at large in nature/ environment are considered in this course. Microbes play far more important roles in nature than their small sizes would suggest. In order to evaluate the roles of microorganisms in ecosystems, it is essential to understand the precise natural habitats and how their activities can be explored.

V. Aim of the course

To apprise the students about the role of microbiology in environment management for sustainable eco-system and human welfare.

The course is organized as follows:

No.	Blocks	Units
1.	Recent environmental issue	1. Basic concepts and environmental issues 2. Methodology of environmental management 3. Microbial waste treatment.
2.	Energy harnessing from organic waste	1. Pollution through conventional fuel 2. Renewable sources of energy.
3.	Treatment of waste for safe disposal.	1. Disposal of domestic and industrial wastes 2. Global environmental problems

VI. Theory

Block 1: Recent Environmental Issue

Unit 1: Basic concept and environmental issues

Types of environmental pollution; problems arising from high-input agricultural residues. Air and water pollution.

Unit 2: Methodology of environmental management

Waste water treatment -physical, chemical, biological and microbial processes; need for water and natural resource.

Unit 3: Microbial waste treatment

Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of Xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides & toxic chemicals, detergents, etc.; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc.); anaerobic processes: digestion, filtration, etc.

Block 2: Energy Harnessing from Organic Waste

Unit 1: Pollution through conventional fuel

Conventional fuels and their environmental impact.

Unit 2: Renewable sources of energy.

Energy from solid waste; ; biogas; land filling, microbial hydrogen production; use of agro-industrial waste, agricultural waste for sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture, etc.

Block 3: Treatment of Waste for Safe Disposal

Unit 1: Disposal of domestic and industrial wastes.

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms.

Unit 2: Global environmental problems

Ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; Microbial and biotechnological approaches for the management of environmental problems.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Seminar presentation by students.
– Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

– Latest trends in environmental microbiology like Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms
– Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; land filling, microbial hydrogen production

IX. Suggested Reading

- Evans GM and Furlong JC. 2002. *Environmental Biotechnology: Theory and Application*. Wiley International.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

Websites

- https://www.springer.com/series/11961
- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Plant Microbe Interactions

II. Course Code : MICRO 605*

III. Credit Hours : 1+1

IV. Why this Course?

In the course, interactions between plants and microbes are discussed on general and detailed level for both pathogenic and symbiotic interactions. This course will be helpful in imparting knowledge to student about Infection mechanisms, defense of plants and stress responses and a large number of important problems within agriculture, horticulture and forestry

V. Aim of the course

The aim is to familiarize the students with the biochemical and biophysical mechanisms, genetics, genomics, proteomics and advanced microscopy, spectroscopy of different interfaces of beneficial and pathogenic plant microbe interactions. Molecular analysis of relevant factors in the plant and microbes, and components that modulate plant-microbe interactions for soil and plant health for sustaining crop productivity.

The course is organized as follows:

No.	Blocks	Units
1.	Types of ecosystem and microbial interaction	1. Different interfaces of interactions 2. Ecosystem- Concept and Dynamics.
2.	Signaling and interaction among microbes	1. Microbial interaction.
3.	Genomic and proteomic study in plant microbe interaction	1. Methodology/resources in plant-microbe interaction.

VI. Theory

Block 1: Types of Ecosystem and Microbial Interaction

Unit 1: Different interfaces of interactions

Plant-microbe, microbe-microbe, soil- microbe, soil-plant-microbe interactions leading to symbiotic (rhizobial and mycorrhizal, *Azolla-Anabaena*), associative, endophytic and pathogenic interactions.

Unit 2: Ecosystem- Concept and Dynamics

Types of ecosystems: Concept and dynamics of ecosystem, Food chain and energy flow, Microbial communities in the soil. Community dynamics and population interactions employing DGGE, TGGE, T-RFLP.

Block 2: Signaling and Interaction among Microbes

Unit 1: Microbial interaction

Quorum-sensing in bacteria, flow of signals in response to different carbon or other substrates and how signals are recognized.

Block 3: Genomic and Proteomic Study in Plant Microbe Interaction

Unit 1: Methodology/resources in plant-microbe interaction

Methodology/resources to study plant-microbe interaction, biosensors, transcriptome profiling, metabolic profiling, genomics, and proteomics Induced systemic resistance against pathogens and tolerance against abiotic stress: Molecular basis; Molecular diversity of microbes, plants and their interactions including transgenic microbes and plants

VII. Practicals

- Phylochip based microbial community analyses-
- Endophytic and phyllosphere microbial community
- PCR-DGGE-Rhizosecretion
- secretome -FT-IR, HPLC
- Multifunctional protein identification and characteriation-2DE, MALDI-TOF.
- Examination of mycorrhizal infection in roots of different plants.
- Characterization of PGPR; Quantification of siderophores, HCN and IAA

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Publication Review
– Student presentation

– Group discussion
– Case Analysis and case studies
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Better understanding of soil – plant – microbe interaction and how the plant/ microbial system select their host. In addition this course will also provide new insight about the various biomolecules secreted by the plant root as well as microbes which forms the basis for their intimate association and exert multiple benefits to the plants.

X. Suggested Reading

- Kosuge T and Nester, E.W. 1989. *Plant Microbe Interactions: Molecular and Genetic Perspectives*, Vol.I-IV, McGraw Hill.
- Paul Eldor, A. 2007. *Soil Microbiology, Ecology and Biochemistry*
- Robert L. Tate III. 1995. *Soil Microbiology*, John Wiley & Sons, INC.
- Sylvia David, M., Fuhrmann, T.A., Hartel, P.G. and Zuberer, D.A. 2005. *Principles and Applications in Soil Microbiology* (II nd Edition).
- Verma, D.P.S. and Kohn, T.H. 1984. *Genes involved in Microbe-Plant Interactions*, Springer-Verlag
- Jaya Kumar Arjun, Kumarapillai Harikrishnan. 2011. Metagenomic analysis of bacterial diversity in the rice rhizosphere soil microbiome. *Biotechnol. Bioinf. Bioeng*. 1(3): 361-367
- Andrea Porras-Alfaro and Paul Bayman.2011. Hidden Fungi, Emergent Properties: Endophytes and Microbiomes. *Annu. Rev. Phytopathol*. 49: 291-315.
- Eleonora Rolli *et al*. 2014. Improved plant resistance to drought is promoted by the root-associated microbiome as a water stress-dependent trait. *Environmental Microbiology*. doi: 10.1111/1462-2920.12439
- Roeland L. Berendsen, Corne´ M.J. Pieterse and Peter A.H.M. Bakker. 2012. The rhizosphere microbiome and plant health. *Trends in Plant Science*, Vol. 17, No. 8.
- Josep Penuelas and Jaume Terradas. 2014. The foliar microbiome. *Trends in Plant Science*. http://dx.doi.org/10.1016/j.tplants.2013.12.007

Journals

- *Advances in Microbial Physiology*
- *Annual Review of Genetics/Biochemistry*
- *Annual Review of Microbiology*
- *Applied and Environmental Microbiology*
- *Biology and Fertility Soils*
- *Indian Journal of Microbiology*
- *Journal of Bacteriology*
- *Journal of Basic Microbiology*
- *Microbiology and Molecular Biology Reviews*
- *Nature/Science/EMBO Journal*
- *Reviews in Microbiology and Biotechnology*
- *Soil Biology and Biochemistry*
- *Trends in Biotechnology*
- *Trends in Microbiology*
- *Trends in Plant Sciences*

Websites

- http://testweb.science.uu.nl/pmi/
- popups.ulg.ac.be/1780-4507/index.php?id=7578
- www.researchgate.net/...The_rhizosphere_microbiome_and_plant_health...
- journal.frontiersin.org/Journal/10.3389/fpls.2013.00165/abstract

- http://www.aw-bc.com/microplace/
- http://www.personal.psu.edu/jel5/micro/index.htm
- http://microbiology.ucsc.edu/
- http://www.suite101.com/links.cfm/microbiology
- http://www.microbeworld.org/resources/links.aspx
- http://www.asm.org/
- http://www.microbiologyiworld.com/
- http://www.sciencemag.org/cgi/collection
- http://www.latrobe.edu.au/microbiology/links
- www.uwstout.edu/lib/subjects/microbi
- http://www.aemtek.com

Journal related to Microbiology

- http://www.fems-microbiology.org/website/nl/default.asp
- http://www.blackwellpublishing.com/journal
- http://www.springer.com/
- http://www.e-journals.org/microbiology/
- http://pubs.nrc-cnrc.gc.ca/
- http://www.elsevier.com/
- http://www.academicjournals.org/ajmr/
- http://www.horizonpress.com/gateway/journals.html
- http://www.scielo.br/bjm
- http://www.jmb.or.kr/
- http://microbiologybytes.wordpress.com/
- http://www.topix.net/science/microbiolog

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Plant Physiology

Preamble

The last decade witnessed phenomenal progress in science and technology resulting in the accruement of significant new scientific developments in plant sciences, more specifically on plant growth, development and productivity. This necessitates restructuring the curriculum and the syllabus to enable graduate students to be abreast with the developments through providing comprehensive exposure to the M.Sc and Ph.D. students, on new developments in different areas of plant sciences. With this background the structure of curriculum for M.Sc. and Ph.D. program and syllabi for the courses needs to be developed keeping in view the mandate of agriculture universities and crop specific ICAR institutes.

Genetic enhancement to achieve crop improvement is the major mandate of state agricultural universities (SAU) and crop specific institutes. The emphasis has systematically shifted towards improving specific physiological traits and mechanisms to enhance crop productivity, yield potentials, adaptation to stresses, etc. Yet another major mandate is to optimize agronomic inputs for yield enhancement to rationalize utilization of natural resources. As the crop improvement success heavily depends on improving physiological processes, plant/crop physiology will immensely contribute to the envisaged goals. With this background the M.Sc and Ph.D. students must be provided with adequate exposure and trainings on plant/crop physiology to complement national and state level crop improvement and crop production programs. The focus is to restructure the course content and syllabi of physiology courses to achieve these objectives. While restructuring and modifying the course curriculum it is necessary to take into cognisance the recent developments in molecular biology, genomics and phenomics which provide options to identify traits and their genetic enhancement. Besides potential interventions, the restructured courses should provide insight based on sound physiological process which now provided options to regulate the plant growth and productivity. Therefore, emphasis is on,

- Providing basic knowledge on plant physiological processes and plant responses to environment and other constraints
- Providing exposure to undertake programs for crop improvement by exploiting well characterized physiological processes
- Provides exposure on potential interventions based on principals of plant physiology to improve growth and productivity

M.Sc courses

Twelve courses for M.Sc have been developed, out of which 8 are the meticulous modification of existing courses, and rest 4 courses are newly designed with focus on applications of physiological process for crop improvement and crop productivity.
For M.Sc. Programme – emphasis is on four aspects:

I. Basic Plant Physiology Courses (PP 501, PP 502, PP 503)

These fundamental courses give exposure on basic principles of plant physiology, water relations, plant metabolic processes and on developmental biology. Also provides exposure on recent developments on plant growth and development, and aspects related to photomorphogenesis, photoperiodism, fruit ripening and senescence. Attempts were made to remove redundancy from UG programme and add new recent concepts and developments.

II. Physiology courses that provide insights on plant responses to environmental and internal factors (PP 504, PP 505, PP 506)

Plant Phenome is a reflection of genetic makeup, interaction with environment and internal factors. Therefore, basic aspects of plant responses to abiotic stresses and stress tolerance mechanisms form the basis for improving adaptation of crops to stress. Phytohormones are major internal factors and signaling molecules to regulate plant growth, differentiation and development. Mineral nutrients are essential for plant metabolic processes besides being essential constituents of many macromolecules. Emphasis is to introduce new emerging concepts and molecular mechanisms.

III. Crop physiology courses related to crop productivity (PP 507, PP 508, PP 509, PP 510)

Agronomic inputs and environmental factors enhance crop growth through optimizing photosynthesis processes and canopy photosynthesis and net carbon gain drives the crop growth rates. Further, components of growth and yield structure with environmental interaction forms the basis for crop modeling.

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Therefore, physiological aspects of crop growth and productivity of specific field and horticultural crops needs to be discussed.

The physiological aspects that need to be discussed should focus not only to address basic growth and developmental aspects of these crops but also emphasis should be given on the major production constraints and the physiological approaches to overcome.

IV. Student ready courses – application of physiological processes for crop improvement and crop production (PP 511, PP 512)

The mandate of SAUs and crop specific institutes of ICAR is crop improvement and crop production. These "*student-ready*" courses provide exposure on quantifying relevant physiological processes and capturing genetic variability, which complement breeding programs aimed at improving specific plant traits. Further, many physiological processes can now be exploited to improve growth and productivity. Several interventions that alter the developmental growth processes can be exploited to bring in synchronization of flowering, soilless cultures, pollen biology, light regulation in polyhouses, etc. Emphasis is to complement the crop improvement and productivity approaches.

Ph.D. courses

In PhD programme, 10 courses are finalized, out of which 7 are the thorough modification of existing courses, and rest 3 courses are newly designed. From the existing syllabus, one course is shifted to MSc programme with comprehensive modification.

For Ph.D. Programme – emphasis is on five aspects:

I. Exposure to the genomic tools and genetic resources (PP 601, PP 602, PP 603)

Focus is on identifying genes regulating the specific mechanisms/traits. Objective is to provide comprehensive exposure on different approaches and technologies to assess the functions of genes regulating plant physiological processes and biochemical mechanisms. It is well documented that plant response to external and internal factors is mainly through signal perception and amplification leading gene expression which bring in altered metabolism regulating physiological and biochemical processes and finally plant processes and growth. There is need to provide sufficient information on diverse receptors, ligand-receptor interactions and the role of secondary messengers in signal amplification leading to gene expression.

Phenomenal progress in understanding the basic physiological mechanisms that determine crop performance and "physiological traits" that have enormous relevance to improve yield potentials as well as adaptation to various biotic and abiotic stresses have been enumerated, well studied and documented. Although most of the physiological traits have been considered as complex and hard to breed, recent advances in understanding the sub-components of most of the major mechanisms coupled with the progress made in "phenotyping" to capture genetic variability in such subcomponent traits, have paved way for the adoption of "trait-based breeding" approaches. Finally, assess the relevance of physiological processes/mechanisms and develop options to combine/introgress them.

II. To characterize and capture the genetic variability in plant traits and adaptive mechanisms (PP 604, PP 605)

Phenotyping plant traits is the crucial input to complement the progress made in genomics. Phenomenal progress made in genomics cannot be exploited for improving plant traits/mechanisms unless phenotyping technologies are developed to capture genetic variability. Several technologies have been developed to quantify the traits and assess genetic variability. Genetic enhancement of specific plant traits is now "Pheno-centric".

Further, techniques, tools and instrumentation facilities drive the research in modern biology. These courses address recent developments related to phenotyping and phenomics and advances made in quantification methods based on novel methodologies and instruments. Emphasis on recent concepts on high throughput phenotyping options for crop improvement.

III. Predicting climate change, causative factors, their quantification, and effect on plant growth and development (PP 606)

Main focus is prediction of climate change, mitigation options and adaptive mechanisms. Predicting climate change variability, causative factors and their quantification and finally effects on plant growth and development is the main emphasis.

IV. Comprehensive insight and options to address major constraints in crop improvement (PP 607, PP 608)

Yield level reached plateau in many crops. Improving yield potential and crop growth rate forms the basis for further improvement in productivity. Photosynthesis and the establishing sink capacity are crucial processes to achieve this goal. Comprehensive exposure is needed as progress made in deciphering the molecular mechanisms to regulate several photosynthetic processes at cellular and canopy level, and also sink development processes.

Seed as a propagule is an important input for agriculture. From this context aspects related to seed development, its dormancy and viability etc. assumes significance. Besides seed is the major source of nutrition to mankind, hence quantitative and qualitative differences in seed constituents and their modification and improvement has been the area of focus in recent years. Emphasis on new conceptual approaches to enhancing yield potential and qualitative traits of seeds and fruits.

V. Plant interaction with biotic factors (Pathogens, Insects and weeds) (PP 609, PP 610)

Besides the genetic makeup expression of the phenotype is regulated by environment and the plant microbe interaction especially the endophytes. Besides it is relevant to understand the plant pathogen and plant insect interactions to improve tolerance mechanisms by altering specific physiological and biochemical processes. Weeds are one of the major biotic factors that affects yield in agricultural crops. Besides understanding weed biology and reproductive strategies of weeds recent concepts in developing selective herbicides based on mode of action and herbicide tolerance mechanisms provided greater insights in weed management. Genome editing options to develop herbicide tolerant transgenics is an exciting option.Implemntation of the revised syllabus needs a sanction of an approximate recurring budget of ₹ 20 lacs per annum in addition to aone time equipment and maintenance grant of ₹ 2 crores.

Course Title with Credit Load
M.Sc. (Ag) in Plant Physiology

Course Code	Course Title	Credit Hours
PP 501*	Principles of Plant Physiology-I: Plant Water Relations and Mineral Nutrition	2+1
PP 502*	Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation	2+1
PP 503*	Plant Developmental Biology: Physiological and Molecular Basis	2+1
PP 504	Physiological and Molecular Responses of Plants to Abiotic Stresses	2+1
PP 505	Hormonal Regulation of Plant Growth and Development	2+1
PP 506	Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions	2+1
PP 507	Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling	2+1
PP 508	Physiology of Field Crops	2+0
PP 509	Physiology of Horticulture Crops	2+0
PP 510*	Seed Physiology	2+1
PP 511	Phenotyping Physiological Processes	2+0
PP 512	Crop Growth Regulation and Management	2+0
PP 591	Master's Seminar	1+0
PP 599	Master's Research	30

Course Contents
M.Sc. (Ag) in Plant Physiology

I. Course Title : Principles of Plant Physiology I - Plant Water Relations and Mineral Nutrition

II. Course Code : PP 501*

III. Credit Hours : 2+1

IV. Why this Course?

Plant's growth and development and therefore, agricultural productivity depends on two major inputs like water and nutrients. In this regard, this course being a fundamental course will acquaint the students with the basic concepts of plant water relations and mineral nutrition. The course provides a basic knowledge on water and nutrient acquisition and their transport throughout the phenological stages. Further, it also provides hands on experience in assessing the plant and soil water status besides nutrient acquisition by plants.

V. Aim of the Course

The aim of this course is to impart knowledge in the field of water relations and mineral nutrition and how plants acquire water and transport it under different soil water regimes and also make use of the water in an effective way to maximize use efficiency. In addition, the other aim is to impart knowledge of how plants minimize water loss under stress conditions besides educating the students of how plants make use of nutrients in a best possible way.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Water Relations	1. Soil and Plant Water Relations 2. Water Absorption and Translocation 3. Transpiration and Evaporative Cooling 4. Water Productivity and Water Use Efficiency 5. Moisture Stress and Plant Growth
2.	Mineral Nutrition	1. Nutrient Elements and their Importance 2. Nutrient Acquisition 3. Concept of Foliar Nutrition

VI. Theory

Block 1: Plant Water Relations

Unit 1: Soil and Plant Water Relations

Water and its importance; Molecular structure of water; Properties and functions of water. Concept of water potential; Plant cell and soil water potential and their components; Methods to determine cell and soil water potential; Concept of osmosis and diffusion. Soil physical properties and water availability in different soils;

Water holding capacity and approaches to improve WHC; Concept of FC and PWP; Water holding polymers and their relevance.

Unit 2: Water Absorption and Translocation

Root structure and functions; Root architecture and relevance in water mining; Mechanism of water absorption and translocation; Theories explaining water absorption and translocation; Aquaporins. Mycorrhizal association and its relevance in water mining.

Unit 3: Transpiration and Evaporative Cooling

Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration; Concept of CCATD and its relevance. Energy balance: Solar energy input and output at crop canopy level. Stomata- its structure, functions and distribution; Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure; Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure. Antitranspirants and their relevance in agriculture.

Unit 4: Water Productivity and Water Use Efficiency

WUE and its relevance in water productivity; Transpiration efficiency, a measure of intrinsic WUE; Approaches to measure WUE; Stomatal and mesophyll regulation on WUE; Passioura's yield model emphasizing WUE.

Unit 5: Moisture Stress and Plant Growth

Physiology of water stress in plants; Effect of moisture stress at molecular, cellular, organ and plant level. Drought indices and drought tolerance strategies. Drought tolerance traits.

Block 2: Mineral Nutrition

Unit 1: Nutrient Elements and Their Importance

Role of mineral nutrients in plant's metabolism; Essential elements and their classification; Beneficial elements; factors influencing the nutrients availability; critical levels of nutrients. Functions of mineral elements in plants. Deficiency and toxicity symptoms in plants.

Unit 2: Nutrient Acquisition

Mechanism of mineral uptake and translocation; Ion transporters; genes encoding for ion transporters; localization of transporters; xylem and phloem mobility; Nutrient transport to grains at maturity; Strategies to acquire and transport minerals under deficient levels. Role of mycorrhiza, root exudates and PGPRs in plant nutrient acquisition.

Unit 3: Concept of Foliar Nutrition

Foliar nutrition; significance and factors affecting total uptake of minerals; Foliar nutrient droplet size for effective entry; role of wetting agents in entry of nutrients.

VII. Practicals

- Standard solutions and preparation of different forms of solutions
- Studies on the basic properties of water
- Demonstration of surface tension of water and other solvents
- Measurement of plant water status: Relative water content and rate of water loss

- Determination of water potential through tissue volume and Chardakov's test
- Determination of water potential using pressure bomb, osmometer, psychrometer
- Determination of soil moisture content and soil water potential
- Use of soil moisture probes and soil moisture sensors
- Measurement of transpiration rate in plants; use of porometry
- Measurement of CCATD and its relevance
- Demonstration and use of anti-transpirants to reduce transpiration
- Influence of potassium and ABA on stomatal opening and closing respectively
- Deficiency and toxicity symptoms of nutrients
- Effect of water stress on plant growth and development

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

- comprehend the fundamental concepts of plant physiological processes associated with water relation and mineral nutrition.
- describe the physiological mechanisms of water relation and mineral nutrition.
- recognize and describe how plants respond to mineral deficiency and toxicity.

X. Suggested Reading

- Vilalta JM and Forner NG. 2017. *Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydricconcept Plant, Cell and Environment* 40, 962–976
- Mangrich AS, Cardoso EMC, Doumer ME, Romão LPC, Vidal M, Rigol A, Novotny EH. *Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation*. Chapter 16, pp 339–354.
- McElrone AJ, Choat B, Gambetta GA and Brodersen CR. 2013. *Water Uptake and Transport in Vascular Plants. Nature Education Knowledge* 4(5): 6
- Hodson RC and J Acuff. 2006. *Water transport in plants: anatomy and physiology*. Pages 163-183, *Tested Studies for Laboratory Teaching*, Volume 27 (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.
- Chater CCC, Caine RS, Fleming AJ, Gray JE. 2017. *Plant Physiology,* 174 (2) 624-638; DOI: 10.1104/pp.17.00183
- Dietrich P, Sanders D, Hedrich R. 2001. *The role of ion channels in light dependent stomatal opening, Journal of Experimental Botany*, Volume 52, Issue 363, Pages 1959–1967, https://doi.org/10.1093/jexbot/52.363.1959
- Sreeman SM, Vijayaraghavareddy P, Sreevathsa R, Rajendrareddy S, Arakesh S, Bharti P, Dharmappa P, Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem*. 6, 92.
- Seyed Yahya Salehi-Lisar Hamideh Bakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp 1-16
- Pandey R. 2015. *Mineral Nutrition of Plants*. 10.1007/978-81-322-2286-6_20.
- Barker AV and DJ Pilbeam. 2015. Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.
- Vatansever R, Ozyigit II and Filiz E. 2017. *Essential and beneficial trace elements in plants, and their transport in roots: a review. Applied biochemistry and biotechnology* 181(1), 464-482..

- Tahat MM and Sijam K. 2012. *Arbuscularmycorrhizal fungi and plant root exudates bio-communications in the rhizosphere. African Journal of Microbiology Research*, 6(46), 7295-7301.
- Rajasekar MD, Nandhini DU and Suganthi S. 2017. *Supplementation of Mineral Nutrients through Foliar Spray – A Review. Int.J.Curr.Microbiol.App.Sci.* 6(3): 2504-2513.https://doi.org/10.20546/ijcmas.2017.603.283
- Tarek A and Hassan ER. 2017. *Foliar application: from plant nutrition to biofortification.* Environment, Biodiversity and Soil Security. 10.21608/jenvbs.2017.1089.1006.

General Source of Information

- Taiz T, Zeiger E and Max Mller IM, 2018, *Fundamentals of Plant Physiology*
- Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6th Ed
- Salisbury FB and Ross C. 1992 (4th Ed.) *Plant Physiology*
- Epstein E and Bloom AJ. 2004. *Mineral nutrition of plants: principles and perspectives*.2nd Ed.
- Hopkins WG and Huner NPA. 2004. *Introduction to Plant Physiology*
- Kramer, P. J., *Water relations of plants*
- Kirkham, M. B., *Principles of soil and plant water relations*
- Hopkins WG, 2008, *Introduction to Plant Physiology*

I. Course Title : Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation

II. Course Code : PP 502*

III. Credit Hours : 2+1

IV. Why this course?

Mechanisms associated with growth and development determine crop performance under any given condition. Metabolic and growth processes are quite sensitive to environmental factors and hence comprehensive understanding of the physiological basis of growth and development would be essential.

V. Aim of the course

This course will impart knowledge on cellular structure and function that determine of carbon and nitrogen metabolism, lipids, enzymes and secondary metabolites in plants. Relevance of metabolic processes on growth and development leading to productivity will be dealt.

The course is organized as follows:

No.	Blocks	Units
1.	Metabolic processes and growth regulation	1. Carbon Metabolism–Photochemical Processes 2. Carbon Metabolism: Biochemical Processes 3. Carbon Metabolism: Respiration 4. Product Synthesis and Translocation Leading to Crop Growth 5. Nitrogen Assimilation and Protein Synthesis 6. Lipid Metabolism and Secondary Metabolites 7. Hormonal Regulation of Plant Growth and Development 8. Synthetic Growth Promoters 9. Morphogenesis and Reproductive Phase

VI. Theory

Block 1: Metabolic Processes and Growth Regulation

Unit 1: Carbon Metabolism – Photochemical Processes
- Chloroplast ultrastructure with special mention of lamellar system
- Excitation, electron and proton transfers and their relevance in energy conservation
- Concepts of pigment systems and generation of powerful reductant and oxidant
- Water oxidation, Water-water cycle and other aspects of electron transfer

Unit 2: Carbon Metabolism: Biochemical Processes
- CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis
- RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabolite fluxes
- Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration
- Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation
- Ecological aspects of $C_4$and CAM photosynthesis
- Product synthesis, Starch and Sucrose biosynthesis

Unit 3: Carbon Metabolism: Respiration
- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitETC.
- Relevance of growth and maintenance respiration
- Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC

Unit 4: Product Synthesis and Translocation Leading to Crop Growth
- Phloem loading and sugar transporting, concepts of bi-directional transport of sugars and other metabolites
- Source-Sink relationship and modulation of photosynthesis
- Concepts and definitions of Growth and Differentiation
- Growth and yield parameters, NAR, CGR, HI and concepts of LAI, LAD

Unit 5: Nitrogen Assimilation and Protein Synthesis
- Developments in d-nitrgen fixation
- Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis
- Inter-Dependence of carbon assimilation and nitrogen metabolisms

Unit 6: Lipid Metabolism and Secondary Metabolites
- Storage, protective and structural lipids.
- Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids.
- Secondary metabolites and their significance in plant defense mechanisms.

Unit 7: Hormonal Regulation of Plant Growth and Development
- Growth promoting and retarding hormones: biosynthesis, transport, conjugation
- Mode of action of these hormones and their application in plant physiology

Unit 8: Synthetic Growth Promoters
- Different synthetic hormones: Salicylic acid, strigolactones etc
- Roles and biological activities of various synthetic hormones
- Commercial application of hormones to maximize growth and productivity

Unit 9: Morphogenesis and Reproductive Phase

- Photoperiodism: Phytochromes, their structure and function
- Circadian rhythms,
- Blue light receptors: Cryptochrome and morphogenesis.
- Vernalization and its relevance in germination.

VII. Practicals

- Radiant energy measurements
- Separation and quantification of chlorophylls
- Separation and quantification of carotenoids
- O_2 evolution during photosynthesis
- Anatomical identification of C_3 and C_4 plants
- Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
- Measurement of respiration rates
- Estimation of reducing sugars, starch
- Estimation of NO_3, free amino acids in the xylem exudates, quantification of soluble proteins
- Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
- Demonstration of photoperiodic response of plants in terms of flowering

VIII. Teaching methods/activities

- – Lecture
- – Assignment (Reading/Writing)
- – Student presentation
- – Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

- – figure out the fundamental metabolic processes in plant
- – describe the physiological mechanisms and metabolic events associated with regulation of plant growth

X. Suggested Reading

- Kirchhoff H. 2019. *Chloroplast ultrastructure in plants*, New Phytologist. Doi.org/10.1111/nph.15730
- Jafari T, Moharreri E, Amin A, Miao R, Song W and Suib S. 2016. *Photocatalytic water splitting—the untamed dream: a review of recent advances. Molecules*, *21*(7), 900.
- Jensen E, Cle´ment R, Maberly SC, Gontero B. 2017. *Regulation of the Calvin –Benson–Bassham cycle in the enigmatic diatoms: biochemical and evolutionary variations on an original theme. Phil. Trans. R. Soc. B* 372: 20160401. doi.org/10.1098/rstb.2016.0401
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General Text books

- *Taiz, Lincoln, Zeiger. 2007 Plant Physiology, Eduardo Original American edition Sinauer Associates, Inc., 2006; 4th ed., XXVI, ISBN: 978-3-8274-1865-4; © Springer.*
- *Plant Physiology* Frank Boyer Salisbury and Cleon Ross.
- *Introduction to Plant Physiology* (Wie)by William G. Hopkins.

I. Course Title : Plant Developmental Biology: Physiological and Molecular Basis

II. Course Code : PP 503*

III. Credit Hours : 2+1

IV. Why this Course?

From the conventional description information on plant growth and development based on morphology and anatomy, phenomenal changes and leads taken place in the last one and half decade to address these processes at physiological, biochemical and molecular levels. This basic understanding has provided options to regulate these processes genetically using genetic and molecular tools and by interventions using chemicals and external factors. To give an example on flowering, the progress made regarding the molecular players that regulate flowering, initiation, the photoreceptors like phytochromes and their regulation by the photoperiod-short and long days has provided options to manipulate the flowering time to bring in synchrony, etc. Phenomenal progress also made in several other processes like germination, viability, root development and pollination, etc. The other major area of contribution is in tissue culture where is understanding of plant developmental biology has been put o practical use and knowledge on morphogenesis is exploited to maximum. It is very essential that the students get exposed on these aspects to complement the research programs on crop improvement.

V. Aim of the course

To explain about basic physiological and molecular processes concerning various facets of growth and development of plants. It provides knowledge on basic physiological processes governing developmental events in plants including senescence and fruit development and ripening. Development of vegetative tissue like shoot, leaf and root and morphogenetic phenomena like flower induction and development, factors associated with photoperiod and thermoperiod response. Regulation of morphogenesis would be studied at the molecular level providing information on genes involved. In addition, students will study how to apply the knowledge on plant development and morphogenesis using tissue culture.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Developmental Biology	1. Evolutionary Development of Plants and Role of Environment 2. Physiological and Molecular Determinants of Seed Biology 3. Vegetative Growth and Organ Development 4. Physiological and Molecular Aspects of Reproductive Growth and Development 5. Ripening and Senescence 6. Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature
2.	Practical application of morphogenesis	1. Tissue culture and micro-propagation 2. Application of in-vitro techniques for crop improvement

VI. Theory

Block 1: Plant Developmental Biology

Unit 1: Evolutionary Development of Plants and Role of Environment

Plant development and plasticity, evolution, Biodiversity. Novel features of plant growth and development, Concept of plasticity-evolution and biodiversity, Model plants for study; Environment and development. Developmental stages and program; Cell-cycle, totipotency and regeneration.

Unit 2: Physiological and Molecular Determinants of Seed Biology

Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation. Seed dormancy- Physiological and molecular mechanism of seed dormancy regulation. Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination.

Unit 3: Vegetative Growth and Organ Development

Regeneration and totipotency- organ differentiation and development – role of hormones- developmental control genes in crop plants. Meristems in plant development. Shoot, Leaf, Trichome and stomate development and differentiation. Axillary shoot branching; Bud dormancy and growth**.** Root development; Nodule development; Tuber development- hormonal control, signaling and molecular regulation- genes involved. Vascular bundle development- xylem and phloem differentiation

Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development

Floral Induction and Development: Molecular and physiological mechanism of transition -vegetative to reproductive phase- floral organ initiation and development their controls. Development of male and female gametophyte; gametophytic mutants: pollen-stigma interaction- Pollen germination and tube growth; role of imprinting; Male sterility: and fertility restoration; Self incompatibility; Sterility and fertility restoration, Maternal gene effects, Zygotic gene effects. Sex determination in plants, mate choice in plants. Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes

Unit 5: Ripening and Senescence

Fruit development, enlargement, maturation and ripening; climacteric and non-climacteric fruit ripening mechanism. Hormonal, biochemical & Molecular aspects of fruit ripening. Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature

Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution. Molecular mechanisms of light perception, signal transduction and gene regulation. Photoperiodism and its significance, vernalization and hormonal control. Circadian rhythms-biological clocks and their genetic and molecular determinants. Thermomorphogenesis- Thermoperiodism

Block 2: Application of Morphogenesis and its Practical Application

Unit 1: Tissue culture and micro-propagation

Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants. Micro-propogation, tip and axillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 2: Application of *in-vitro* techniques for crop improvement

Development of somoclones, identification and exploitation of somoclonal variants.

Haploid production, pollen/anther, ovule/ovary culture. Production of secondary metabolites by tissue culture, concept of bio-fermenters. Plant transformation, development of transgenic plants and their characterization. Germplasm storage, cryopreservation and regulation

VII. Practicals

- Studying shoot apical meristem, floral meristem development and pollen tube development
- Phenotyping photomorphogenesis: (a) Studying effect of day length (short day and long day) in regulating floral induction/ flowering time in short day/long day/day neutral plants and (b) effect of light on seed germination in light-sensitive and -insensitive seeds.
- Studying effect of temperature on– (a) thermomorphogenesis- measuring hypocotyl elongation under different temperature conditions and (b) sex determination using cucurbits/sesame plants.
- Measure physiological paramters of fruit ripening and study the expression of key genes regulating ripening.
- Study the effect of ethylene, its inhbibitor and scruber on ripening (tomato).
- Study different sterilization techniques, prepare media stocks and plant hormones.
- Inoculate explant (seed and leaf tissue) of model plant for callus induction.
- Subculture the callus and standerdize regeneration protocol for shoot and root induction using callus and leaf explant.
- Micro-propagation using meristem tip and axillary node culture.
- Standerdize anther/ pollen culture for haploid production in model/crop/horticultural plant.
- Isolation of protoplast from Arabidopsis/tobacco and its culturing
- Study about selectable marker, reporter gene, PCR, southern and northern blotting techniques.
- Transformation of tobacco callus or leaf explant by *Agrobacterium tumefacines* and *Agrobacterium rhizogenes* for production of transgenic
- Molecular characterization of transgenic- PCR, southern blotting, gene expression.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular basis of plant growth and development. The student will develop critical insight in physiological aspects of vegetative growth and reproductive development at molecular level.

X. Suggested Reading

- Niklas KJ. *Plant Evolution- An Introduction to the History of Life.*
- Bahadur *B et al.* (eds.), *Plant Biology and Biotechnology:* Volume I: Plant Diversity, Organization, Function and Improvement
- Jong MD and Leyser O. *Developmental Plasticity in Plants.* Cold Spring Harbor Symposia on Quantitative Biology. 63-73.
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- J. Derek Bewley *et al*., Seeds-Physiology of Development, Germination and Dormancy.
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- Franklin KA and Wigge PA. *Temperature and Plant Development*. Wiley Blackwell.
- Franklin KA *et al*. 2014. *Interaction of light and temperature signaling. Journal of Experimental Botany*. 65(11): 2859–2871.
- Bhojwani SS and Razdan MK. *Plant tissue culture: theory and practice, a revised edition*. Elsiver publication.
- Bhojwani SS, Dantu SS and Kumar P. *Plant Tissue Culture: An Introductory Text*.
- George EF and Hall MA. *Plant Propagation by Tissue Culture* 3rd Edition.
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General Source Information

- Eng-Chong Pua and Michael R.Davey: *Plant Developmental Biology - Biotechnological Perspectives.*
- B. Bahadur *et al.* (eds.), *Plant Biology and Biotechnology*: Volume I: Plant Diversity, Organization, Function and Improvement.
- Bewley JD *et al.*, *Seeds-Physiology of Development, Germination and Dormancy.*
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I. Course Title : Physiological and Molecular Responses of Plants to Abiotic Stresses

II. Course Code : PP 504

III. Credit Hours : 2+1

IV. Why this course?

With the changing climate, plants are being more frequently exposed to abiotic stresses like, water, salinity, temperature, nutrient, radiation, etc. limiting the productivity. This will not only affect livelihoods of individual farmers but also the food security. Concerted efforts have been made to grow crops under resource limited/stressful environmental conditions and advances in physiology, molecular biology and genetics have significantly helped in this endeavor. In recent years, our understanding of the physio-morphological, biochemical and molecular adaptation of plants to resource limited/stressful environment is phenomenal. This course will outline different abiotic stresses, their impacts on agricultural productivity, stress tolerance mechanisms, stress mitigation strategies, crop improvement approaches and traits for stress tolerance.

V. Aim of the course

This course aims to describe students the abiotic-stress physiology and their effects on plant growth and productivity. This will also help students gain insights into latest developments in stress physiology and stress tolerance mechanisms, approaches for crop improvement under stressful environment.

The course is organized as follows:

No.	Blocks	Units
1.	Abiotic Stresses	1. Introduction to Abiotic Stresses
2.	Drought Stress	1. Moisture Stress Responses in Plants 2. Stress Perception and Molecular Responses of Plants to Drought Stress 3. Plant Adaptive Mechanisms to Drought 4. Approaches to Improve Drought Tolerance
3.	Salt, Heavy Metal, Water Logging, Temperature and Light Stress	1. Salt Stress 2. Heavy Metal Stress and Water Logging 3. Temperature and Light Stress

VI. Theory

Block 1: Abiotic Stresses

Unit 1: Introduction to Abiotic Stresses

Abiotic stresses major constraints to realize potential yields of crop plants, yield losses. Drought prone areas in India- Frequency of occurrence of drought, Rainfed-kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming.

Block 2: Drought Stress

Unit 1: Moisture Stress Responses in Plants

Drought-characteristic features; water potential in the soil-plant-air continuum. Physiological and biochemical processes affected by drought.Oxidative stress-generation of ROS and other cytotoxic compounds, their effect on cellular process. Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages.

Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress

Stress perception andsignal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms.

Unit 3: Plant Adaptive Mechanisms to Drought

(a) Escape and desiccation avoidance mechanism

Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters. Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes. Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.

(b) Desiccation tolerance- Concept of acquired tolerance

Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo-protection of chlorophylls.

Unit 4: Approaches to Improve Drought Tolerance

Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression.

Block 3: Salt, Heavy Metal, Water Logging, Temperature and Light Stress

Unit 1: Salt Stress

Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance.

Unit 2: Heavy Metal Stress and Water Logging

Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve. Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve.

Unit 3: Temperature and Light Stress

High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes. High light and high ionizing radiation- photo oxidation and photo-inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

VII. Practicals

- Measurement of soil and plant water status.
- Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements.
- Determination of water use efficiency as a drought resistant trait.
- Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress.
- Approaches to quantify root characters
- Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity.
- Determination of Salinity Tolerance Index.
- Studying acclimation response - Temperature induction response.

- Heat tolerance and membrane integrity- Sullivans heat tolerance test.
- Quantification of osmolytes – proline under stress.
- Oxidative stress imposition- Quantification of oxidative stress
- Quantification of ROS under stress.
- Estimation of ABA content in leaf and root tissues under stress.
- Determination of Sodium and Potassium in plant tissue grown under salt stress.
- Estimation of antioxidant enzymes.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular responses of plants to abiotic stresses. The student will develop critical insight in adaptive mechanisms of plants against various abiotic stresses.

X. Suggested Reading

- *Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.*
- Plant Physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury, Frank B
- Pereira A. 2016. *Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci*. 7: 1123. doi: 10.3389/fpls.2016.01123
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I. Course Title : Hormonal Regulation of Plant Growth and Development

II. Course Code : PP 505

III. Credit Hours : 2+1

IV. Why this Course?

Many plant growth and developmental processes are regulated by phytohormones.

It is important to understand the hormone biosynthesis, structure, function, signal transduction and their practical application. It is also important to provide basic knowledge on manipulating growth and developmental processes using plant hormones.

V. Aim of the course

It provides knowledge on the fundamentals of hormone biosynthesis, homeostasis, transport and signaling and the role in regulating basic physiological processes governing developmental events in plants.The role of classical hormones on developmental processes from germination, shoot and root apical meristem differentiation, flowering, seed maturation and senescence. The aim of this course is to appraise the students about structure and function of plant growth regulators. The course is organized as follows:

No.	Blocks	Units
1.	Plant Growth and Development: Hormonal Regulation	1. Introduction to Plant Hormones 2. Plant Hormones - Discovery and Metabolism 3. Physiological Role of Hormones in Plant Growth and Development 4. Endogenous Growth Substances other than Hormones 5. Hormone Signaling 6. Key Genes Regulating Hormone Levels and Functions 7. Crosstalk of Hormones in Regulation of Plant Growth and Development Processes 8. Practical Utility of Growth Regulators in Agriculture and Horticulture

VI. Theory

Block 1: Plant Growth and Development: Hormonal Regulation

Unit 1: Introduction to Plant Hormones

Growth, differentiation and development regulated by plant growth substances, Definition and classification of growth regulating substances: Classical hormones, Definition and classification of growth regulating substances: Endogenous growth substances other than hormones, Synthetic chemicals.

Unit 2: Plant Hormones – Discovery and Metabolism

Discovery, biosynthetic pathways and metabolism of Auxin, Discovery, biosynthetic pathways and metabolism of Gibberellins, Discovery, biosynthetic pathways and metabolism of Cytokinins, Discovery, biosynthetic pathways and metabolism of Abscisic acid, Discovery, biosynthetic pathways and metabolism of Ethylene, Discovery, biosynthetic pathways and metabolism of Brassinosteroids, Discovery, biosynthetic pathways and metabolism of Strigolactones.

Unit 3: Physiological Role of Hormones in Plant Growth and Development

Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Cytokinins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Abscisic acid and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Ethylene and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Brassinosteroidsand Strigolactones and use of mutants and transgenic plants in elucidating the physiological functions, Discovery, biosynthetic pathways metabolism and physiological roles of Salicylic acid and Peptide hormones.

Unit 4: Endogenous Growth Substances other than Hormones

Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins, Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricontanol, Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone, Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level, Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricontanol at physiological and molecular level.

Unit 5: Hormone Signaling

Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid), Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate, Brassinosteroids and strigolactones), Advances in elucidating the structure and function of receptors and signaling components of important hormones.

Unit 6: Key Genes Regulating Hormone Levels and Functions

Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.

Unit 7: Crosstalk of Hormones in Regulation of Plant Growth and Development Processes

Crosstalk of Hormones in Regulation of Plant Growth and Development Processes: Floral transition, reproductive development, Shoot and root apical meristem development

Unit 8: Practical Utility of Growth Regulators in Agriculture and Horticulture

Practical Utility of Growth Regulators in Agriculture and Horticulture: Rooting of cuttings, Vine and brewing industry, Promotion of gynoecious flowers, hybrid rice production, induction of flowering in pine apple, cucurbits, Practical Utility of Growth Regulators in Agriculture and Horticulture: Delaying of senescence and ripening, Production of dwarf plants for ornamental purpose, As herbicides, Reduction in flower and fruit drop.

VII. Practicals

- Extraction of Auxins from plant tissue
- Separation and detection of Auxins by GC / GC-MS / HPLC / Immunological technique
- Bioassay of auxin- effect on rooting of cuttings
- Extraction of abscisic acid (ABA) from plant tissue
- Separation and detection of ABA by HPLC/Immunological technique
- ABA bioassays- effect on stomatal movement

- Preparation of samples for ethylene estimation in plant tissue
- Estimation of ethylene in plant tissues using gas chromatography
- Ethylene bioassays, estimation using physico-chemical techniques- effect on breaking dormancy in sunflower and groundnut
- Extraction of Gibberellins from plant tissue- GC / GC-MS / HPLC
- Separation and detection of GA by GC / GC-MS / HPLC/Immunological technique
- GA bioassays- effect on germination of dormant seeds
- Cytokinin- extraction from plant tissue
- Separation and detection of cytokinin by GC / GC-MS / HPLC
- Cytokinin bioassays- effect on apical dominance and senescence / stay green

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– acquire basic knowledge about plant hormones and plant growth regulators.
– understand the physiological roles and mechanisms of actions of plant hormone.
– obtain practical knowledge about application of plant growth regulators in agricultural and horticulture.

X. Suggested Reading

- Davies P.J. 2004, *Plant Hormones: Biosynthesis, Signal Transduction and Action,* 2nd Edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Hedden, P. and Thomas, S.J. 2006. *Plant Hormone Signalling*, Blackwell Publishing Ltd., Oxford, UK.
- Osborne, D.J. and McManus, M.T. 2005. *Hormones, Signals and Target Cells in Plant Development*. Cambridge University Press, New York, USA.
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- Buchanan B B, Gruissem W and Jones R L. *Biochemistry and Molecular biology of Plants*, 2nd Edition
- Lincoln Taiz and Eduardo Zeiger. *Plant Physiology and Development*, 6th Edition.
- *Teaching Tools in Plant Biology*, The American Society of Plant Biologists
- *The Arabidopsis* Book(http://www.arabidopsisbook.org/)

I. Course Title : Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions

II. Course Code : PP 506

III. Credit Hours : 2+1

IV. Why this course?

In both basic and applied plant sciences, an understanding of the mineral nutrition of plants is of fundamental importance. Nutrient element forms the skeleton of any organic molecule in the organism vis-à-vis plant. Apart from the conventional information on criteria of essentiality, nutrient uptake pathways, function of essential elements and their deficiency and toxicity symptoms, remarkable advances have been made at physiological and molecular level. Exploration of the physiological mechanisms adopted by plants to tolerate the deficiency of specific nutrient element provides an opportunity alter the plants' ability to cope with the low nutrient condition. Identification and functional validation of various transporters involved in nutrient uptake and distribution, deciphering the sensing and signaling of nutrient starvation response and their regulatory network provides options to develop nutrient uptake and utilization efficient crops. In the era of Omics, 'ionomics' provides the total elemental composition of the plant and is a powerful approach to the functional analysis of its genes and the gene networks. Besides, it is also essential to expose the students to various conventional and high-throughput phenotyping techniques to identify the nutrient efficient 'donors', traits and QTLs/ candidate genes to complement the research program on crop improvement.

V. Aim of the course

It provides knowledge on basic physiological processes governing nutrient uptake, physiological role of elements, factors influencing uptake, internal remobilization of nutrient element during starvation and adaptation strategies. Regulation of nutrient uptake and translocation would be studied at the molecular level providing information on genes and other signaling factors involved. The aim of this course is to make the students understand the physiological and molecular basis of nutrient uptake, translocation and utilization and to apply this knowledge in genetic improvement of crop plants.

The course is organized as follows:

No.	Blocks	Units
1.	Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity	1. Mineral Elements: Classification, Function, Deficiency and Toxicity 2. Nutrient Availability at Rhizosphere
2.	Nutrient Uptake, Translocation and Acquisition	1. Ion Uptake Mechanisms 2. Ion Transport to Shoot and Grains 3. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients 4. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients 5. Microbes, Fungal Association for Nutrient Acquisition 6. Nutrient Delivery
3.	Nutrient Efficiency of Crop	1. Improving Nutrient Acquisition and Efficiency of Crops

VI. Theory

Block 1: Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity

Unit 1: Mineral Elements: Classification, Function, Deficiency and Toxicity

Classification based on mobility and characteristic features; physiological role in regulating plant growth, metabolism, development and human health- Regulatory Dietary Allowance (RDA), Deficiency and toxicity of macro, micro and beneficial elements, Tolerance of plants to nutrient toxicity, hyper-accumulators of nutrients: Concept of phytoremediation.

Unit 2: Nutrient Availability at Rhizosphere

Biological and chemical reactions influencing nutrient availability near the root system, interaction between ions in the rhizosphere, Rhizosphere chemistry in relation to plant nutrition- chemical reactions, root exudates to mobilize nutrients.

Block 2: Nutrient Uptake, Translocation and Acquisition

Unit 1: Ion Uptake Mechanisms

Mineral salt absorption- chemical potential of solute- Nernst equation- passive uptake- diffusion, ion exchange-Donnan Equilibrium, mass flow of ions, Mediated transport- Facilitated diffusion-ionophores; membrane transport proteins- active transport-ion channels, Primary and secondary transport- carriers and pumps.

Unit 2: Ion Transport to Shoot and Grains

Long distance transport in plants - Mechanism of xylem and phloem transport, Radial movement of ions across the root, Mechanism of phloem transport, remobilization of mineral nutrients - phloem loading, phloem unloading.

Unit 3: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients

Molecular structures of LAT and HAT, their localization and regulation by various external factors, Nitrate transporters and their functional regulation - Nitrate transporters (NRT1, NRT2, dual-affinity nitrate transporter NRT1.1/CHL1), Phosphate transporters and their functional regulation - PT1/PHT1, PHT2, PHT3, PHT4, Potassium transporters and their functional regulation - KT/HAK/KUP family Ion transporters involved in transport of multiple elements, for example, sulphate transporter for Selenate transport, phosphate transporter for Arsenate transport, etc.

Unit 4: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients

Plant Strategies: Different Strategies I & II adopted by plants for uptake of Fe under Fe deficient condition, Transporters and genes regulating uptake and transport of micronutrients, genes encoding transport/channel proteins, Examples of genes encoding mineral ion transporters for Zn, Fe, Mn, Cu, B, Mo, Ni, Cl, Na, Si, Se, Beneficial nutrients and their role in plant growth and development – Sodium, Silicon, and Cobalt.

Unit 5: Microbes, Fungal Association for Nutrient Acquisition

Microbes to improve nutrient availability – Bio-inoculation technology- P solubilizers and Zinc solubilizers in nutrient absorption, Microbial systems for biological nitrogen fixation – process of nodulation, biochemistry of N2-fixation, Endophytes to improve nutrient availability, Mycorrhiza- Mycorrhizal symbiosis on nutrient uptake by root. Role of AMF on nitrogen, phosphorus and zinc uptake.

Unit 6: Nutrient Delivery

Foliar application of nutrients, absorption and their compartmentation, Concept of slow release fertilizers and chelates (organic and inorganic), Soil less cultures- aeroponics, hydroponics, fertigation.

Block 3: Nutrient Efficiency of Crop

Unit 1: Improving Nutrient Acquisition and Efficiency of Crops

Concept of nutrient uptake and use efficiency- Genotypic differences- physiology and molecular mechanisms, Nutrient use efficiency in selected crops, Root system architecture (RSA), root characters associated with nutrient acquisition, Genes and QTLs to improve nutrient acquisition and efficiency for important nutrients in few crop species, Transgenic and molecular breeding approaches to improve traits associated with acquisition and efficiency – Case studies, Biofortification strategies – for micronutrients, agronomic approaches, Influence of nutrition status on plant response to biotic and abiotic stresses.

VII. Practicals

- Techniques to develop the deficiency symptoms of nutrients –Hydroponics/ Aeroponics- diagnosis of deficiency symptoms in agriculturally important crop plants
- Physiological and biochemical markers to identify nutrient deficiency levels
- Biochemical markers for essential elements: Assay of nitrate reductase activity for N
- Estimation of chlorophyll concentration in leaves of N deficient and N sufficient plants
- Collection of acid phosphatase from root exudates and enzyme assay for P
- Measuring anthocyanin and chlorophyll pigments concentration in leaves for P
- Collection of organic acid in root exudates, characterization and quantification for P
- Assay of carbonic anhydrase activity for Zn
- Assay of SOD Activity for Cu, Zn and Mn
- Estimation of nitrogen concentration in plant tissue - Kjeldhal and Dumas method
- Estimation of phosphorus concentration in plant tissue – colorimetric method
- Estimation of potassium, magnesium and sodium concentration in plant tissue – flame photometer
- Estimation of micronutrients (Zn, Cu, Fe, Mn, Co etc) concentration in plant tissue – atomic absorption spectrometer/ ICP-OES
- Measurement of simple root traits such as root length, angle, volume, surface area, etc. (using conventional methods or root scanner and WinRhizo)
- ‘Shovelomics’ in the field grown crops (for measuring root architecture) and using ‘ImageJ’ for analysis
- Non-invasive techniques to quantify nutrients – XRF (X-Ray Fluorescence) and hyper spectral reflectance.

VIII. Teaching methods/ activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

– comprehend the fundamental concepts of mineral nutrition of plant.
– describe the physiological and molecular mechanisms of acquisition and translocation of nutrient.
– describe the basis of differential nutrient efficiency.

X. Suggested Reading

- *Recommended Dietary Allowances*: 10th Edition (https://www.ncbi.nlm.nih.gov/books/NBK234932/pdf/Bookshelf_NBK234932.pdf)
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- Sarma, H., 2011. *Metal hyperaccumulation in plants: a review focusing on phytoremediation technology. Journal of Environmental Science and Technology*, 4(2), pp.118-138.
- Marschner H. *Mineral Nutrition of Higher Plants* 3rdEdn
- Zeiger and Taiz L. *Plant Physiology*
- *Mineral Nutrition of Plants*, *In: Plant Biology and Biotechnology*. B. Bahadur *et al*. (eds.), Volume I: *Plant Diversity, Organization, Function and Improvement*, DOI: 10.1007/978-81-322-2286-6_20, Springer India, Pp. 499-538.
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- Mitra GN. *Regulation of Nutrient Uptake by Plants: A Biochemical and Molecular Approach*
- Uraguchi, S., Kamiya, T., Sakamoto, T., Kasai, K., Sato, Y., Nagamura, Y., Yoshida, A., Kyozuka, J., Ishikawa, S. and Fujiwara, T., 2011. *Low-affinity cation transporter (OsLCT1) regulates cadmium transport into rice grains. Proceedings of the National Academy of Sciences*, 108(52), pp.20959-20964.
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I. Course Title : Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling

II. Course Code : PP 507

III. Credit Hours : 2+1

IV. Why this Course?

Agronomic inputs and environmental factors enhance crop growth by improving photosynthetic processes and photosynthate partitioning. Carbon metabolism is the most important physiological process that has a direct influence on crop growth and productivity which is quite sensitive to biotic and abiotic constraints. Hence a comprehensive understanding canopy photosynthetic process is crucial. This is an important component in crop improvement program, especially in the scenario of plateauing yields. These photosynthetic processes and their response to environmental factors form the basis for developing growth and yield predicting models.

V. Aim of the Course

The course provides a comprehensive theoretical and hands on experience and expertise to students on various aspects of photosynthesis including biophysical, biochemical and molecular regulations. While canopy photosynthesis drives crop growth rates, factors associated with sink activity and partitioning determine productivity. Hence, adequate emphasis would be given to canopy photosynthesis, translocation and its feedback regulation, Crop growth and yield structure analysis and their responses to environmental factors. Growth and yield prediction models and their relevance will be adequately discussed.

The course is organized as follows:

No.	Blocks	Units
1.	Photosynthetic Processes	1. Canopy Architecture and Energy Utilization 2. Photochemical Processes 3. Biochemical Processes 4. Product Synthesis and Translocation 5. Growth and Yield forming Mechanisms
2.	Yield Improvement and Modelling	1. Molecular Options to Improve Photosynthesis, Growth and Productivity 2. Fundamentals of Dynamic Simulation Models 3. Description of Well-established Yield Models 4. Examples of Robust Models Extensively Used

VI. Theory

Block 1: Photosynthetic Processes

Unit 1: Canopy Architecture and Energy Utilization

Parameters associated with canopy architecture that determine radiation interception and absorption, Energy absorption by primary and accessory pigments and energy utilization efficiency, Light distribution inside the canopy and concepts of light extinction coefficient.

Unit 2: Photochemical Processes

Ultrastructure of chloroplast: structure and composition of lamellar system, Components of electron transport, Water oxidation system and energy conservation processes, Pigment systems and the generation of a powerful oxidant and a powerful reductant, Chlorophyll fluorescence and fluorescence quenching: qN, qP, NPQ.

Unit 3: Biochemical Processes

CO_2 diffusion and resistances (g_s and g_m). Concept of Ci determining CO_2 diffusion. RuBisCO activation state, kinetics and catalytic properties, Carboxylation processes in C_3, C_4 and CAM plants and their relevance, CO_2 concentrating mechanisms and their importance in improving carbon assimilation, Ecological significance of C_4 and CAM photosynthesis, Photorespiration and Mitochondrial respiration and net carbon gain, Carbon isotope discrimination and its importance as a surrogate of Ci.

Unit 4: Product Synthesis and Translocation

Triose phosphate utilization and regulation of Calvin cycle mechanisms, Product synthesis and partitioning between starch and sucrose, Concepts of end-product inhibition or Pi-regeneration limitation, Phloem transport and factors that regulate phloem loading and un-loading.

Unit 5: Growth and Yield forming Mechanisms

Carbon gain and the concepts of Canopy photosynthesis. Relevance of LAI and LAD in determining total carbon gain and crop growth rates, Source: Sink relationship and its relevance in governing differences in crop growth rates and productivity. Concepts of HI and partitioning coefficient and remobilization of carbon from vegetative organs to reproductive structures, Growth analysis and parameters that explain growth rates: NAR, CGR, HI and their inter-dependence.

Block 2: Yield Improvement and Modelling

Unit 1: Molecular Options to Improve Photosynthesis, Growth and Productivity

Characteristic features of the Chloroplast genome: its structure and genes associated with various photosynthetic mechanisms, coordinated expression of chloroplast and nuclear genome for maintaining photosynthetic activities. Genomic and genetic resources such as specific genes and QTL associated with photosynthetic processes Transgenic options to enhance photosynthetic performance such as transferring genes to mitigate oxidative stress damage (SOD, APX, AKR etc), Theoretical concepts of crop improvement through inducing CCM in C_3 plants and reducing photorespiration.

Unit 2: Fundamentals of Dynamic Simulation Models

Collection of crop specific genetic coefficient, Crop, soil and historic weather data

Unit 3: Description of Well-established Yield Models

Application and limitations of modeling, Yield prediction models such as APSYM, PeanutGrowetc, Machine learning approaches and IoT for making informed on-farm decisions.

Unit 4: Examples of Robust Models Extensively Used

Duncan'syield prediction model, Passioura'smodelfor growth maximising.

VII. Practicals

- Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR. CGR, LAI, LAR, SLA portioning efficiency, HI.
- Measurement of light interception, light extinction coefficient, energy utilization efficiency based energy intercepted, and realized.
- Gas exchange: principles and uses to assess variations in CO_2 and water vapour transfer, determination of A/gs and intrinsic WUE
- Quantification of chlorophyll content by various methods: colorimetric and SPAD meter. The concept of SLN
- Chlorophyll fluorescence and quenching coefficients
- Theoretical aspects of carbon isotope fractional and its use in determining WUE
- Quantification of RuBisCO content by ELISA (if possible)
- Determination of RuBisCO activity and activation state using radioactive $CO\text{-}_2$
- CO_2 and light response curves and computation of carboxylation efficiency, quantum efficiency, relative limitations of photosynthesis at single leaf level.
- Adoption of crop models: Growth and yield prediction by Duncan's and Passioura's models

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

After completion of this course students are expected to have in depth knowledge on Photosynthetic processes associated with product synthesis and yield development. Students will also obtain current knowledge on various crop models.

X. Suggested Reading

- Goyne, P.J., Milroy, S.P., Lilley, J.M., and Hare, J.M. (1993). Radiation interception, radiation use efficiency and growth of barley cultivars. *Australian Journal of Agricultural Research*, 44(6), 1351-1366.
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- https://www.mdpi.com/1424-8220/18/8/2674/pdf
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- Splinter, W.E. (1974). Modelling of plant growth for yield prediction. *Agricultural Meteorology*, 14(1-2), 243-253.

General Source Information

- Blankenship RE. 2014. *Molecular mechanisms of Photosynthesis* 2nd Edition
- *Canopy Photosynthesis: From Basics to Applications*. 2016 Ed Hikosaka, Kouki, Niinemets, Ülo, Anten, Niels P.R.

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I. Course Title : Physiology of Field Crops

II. Course Code : PP 508

III. Credit Hours : 2+0

IV. Why this course?

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Genetic gain in productivity can be achieved only by improving plant physiological traits/adaptive mechanisms. Even crop management should be based on sound physiological principles. For example, crop's response to the increase in global warming has to be looked from thermo morphogenesis concept in terms of GDD and its effect on phenological processes in some of the important field crops exposure on crop specific physiological processes is necessary and has particular significance.

V. Aim of the course

This course provides a broad exposure on the physiological aspects of field crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of field crop plants. Besides, the emphasis is on unique crop specific features.

Broad categories of crops that can be selected for this course are as follows.

1. Cereals– Rice, Wheat, Maize etc.
2. Millets– Finger millet, Sorghum etc.
3. Pulse crops– Green gram, Black gram, Lentil, Pigeon pea, Chickpeas, Cowpea, Beans etc.
4. Oilseed crops– Groundnut, Rapeseed Mustard, Soybean etc.
5. Sugarcane
6. Fibre crops– Cotton, Jute, Ramie, Hemp etc.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Field Crops	1. Introduction 2. Crop Establishment, Crop Growth and Development 3. Reproductive Growth 4. Seed Nutrient Quality 5. Plant Nutrition 6. Abiotic Stress Response 7. Crop Specific Physiological Processes and Importance

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of field crops.

VII. Theory

Block 1: Physiology of Field Crops

Unit 1: Introduction

Origin- Variability in physiology of crop plants between wild species and cultivated. Adaptability to growing environments (ecosystems), Importance in food grain contribution.

Unit 2: Crop Establishment, Crop Growth and Development

Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand. Different crop growth stages, concept of source establishment and optimum LAI, Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.

Unit 3: Reproductive Growth

Photo and thermo-periodic response for flowering, sink development, sink source relationship, partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential.

Unit 4: Seed Nutrient Quality

Seed quality, seed as a source of nutrients, seed constituents and their improvement, concept of pathway engineering to improve seed quality.

Unit 5: Plant Nutrition

Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions, specific nutrient disorders.

Unit 6: Abiotic Stress Response

Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields. Global warming responses, thermomorphogenesis, approaches to overcome the constraints.

Unit 7: Crop Specific Physiological Processes and Importance

Choosing location specific crop species exposure will be given on physiological process as described above. Besides, emphasis is on providing information on crop specific features/productivity constraints.

Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

Suggested Reading

- *Grain Legumes*: Ed De Ron, Antonio M. (Ed.) 2015. Springer
- *Legumes under Environmental Stress: Yield, Improvement and Adaptations*. Eds MM Azooz P Ahmad and Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages. ISBN: 978-1-118-91708-4
- *Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance*. Ganeshan S, Gaur PM, Chibbar RN, Tuteja N, Gill SS, Tuteja R. chapter 17
- *Climate Change and Management of Cool Season Grain* Legume *Crops*. Eds Yadav GS, McNeil DL, Redden R, Patil SA. Springer
- *Nature's pulse power: legumes, food security and climate change.* Considine MJ, Siddique

KHM and Foyer CH,· 2017 *J Exp Bot*. 68(8): 1815–1818. Published online 2017 May 11. doi: 10.1093/jxb/erx099

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- Fahad S, Bajwa AA, Nazir U, Anjum SA, Farooq A, Zohaib A, Sadia S, Nasim W, Adkins S, Saud S and Ihsan MZ. 2017. *Crop production under drought and heat stress: plant responses and management options. Frontiers in Plant Science* 8(1147): 1-16.
- Pandey V and Shukla A. 2015. *Acclimation and Tolerance Strategies of Rice under Drought Stress. Rice Science* 22(4): 147-161.
- Kole C. 2006. *Cereals and millets. Genome Mapping and Molecular Breeding in Plants. Springer*.
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- Rinki, Mamrutha HM, Sareen S, Tiwari V, Singh GP. 2018. *Dissecting the physiological and anatomical basis for high yield potential in HD 2967. Vegetos*. 31: 121-124.
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- Tiwari R and Mamrutha HM. 2014. *Precision Phenotyping for Mapping of Traits for Abiotic Stress Tolerance in Crops. Biotechnology: Prospects and Applications.* Ed. Salar RK, Gahlawat SK, Siwach P and Duhan JS. Pp79-85. Publisher: Springer.
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- Reynolds *M. Wheat Physiological Breeding volume I and II (CIMMYT): Wheat Physiological Breeding: A Field Guide to Wheat Phenotyping*.
- Mamrutha HM *et al*. 2019. *Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat*. In: Rajpal V., Sehgal D., Kumar A., Raina S. (eds) *Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches*, Vol. I. Sustainable Development

and Biodiversity, vol 20. Springer, Cham
- Tiwari V. *et al*. 2017. *Managing Abiotic Stresses in Wheat*. In: Minhas P., Rane J., Pasala R. (eds) *Abiotic Stress Management for Resilient Agriculture*. Springer, Singapore

I. Course Title : Physiology of Horticulture Crops
II. Course Code : PP 509
III. Credit Hours : 2+0

IV. Why this Course?

Improving physiological processes forms the basis to enhance the productivity or to improve a specific growth processes. Several interventions based on principals of physiological processes provide options to enhance crop productivity. Basic insight on photoperiodic response is crucial for determining planting dates. Understanding the mechanisms of rooting for vegetative propagation has lead in developing rooting hormones etc., In view of this, a comprehensive exposure on growth and development of horticulture crops and providing insights on major production constraints and physiological approaches to overcome is highly essential.

V. Aim of the Course

This course should provide a broad exposure on the physiological aspects of horticulture crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of horticultural crop plants. To describe basic and applied physiology behind the production and productivity of horticultural crops and their pre and postharvest management, ideal storage conditions, quality retention, processing and value addition.

Broad categories of crops that can be selected for this course are as follows.

1. Fruit crops: Mango, Grapes, Apple, Banana, Citrus etc.
2. Vegetable crops: Tomato, Onion, Brinjal, Cauliflower, Okra etc.
3. Tuberous crops: Potato, Cassava, Sweet potato, Yam etc.
4. Plantation crops: Coconut, Oil palm, Cashew, Tea, Coffee, Rubber, Areca nut, Cocoa etc.
5. Floriculture crops: Rose, Marigold, Carnation, Chrysanthemum, Gladiolus, Orchids, Tuberose etc.
6. Other groups: Medicinal crops, Aromatic crops, Spices crops.

The course is organized as follows:

No.	Blocks	Units
1	Physiology of Horticultural Crops	1. Introduction 2. Crop growth and Development 3. Reproductive Growth 4. Pre and Post-harvest Physiology 5. Plant Nutrition and Abiotic Stress Responses 6. Specific Aspects and Unique Crop Features

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of horticultural crops.

VII. Theory

Block 1: Physiology of Horticultural Crops

Unit 1: Introduction

Origin, distribution and adaptability of crops to different agro-climatic conditions

Unit 2: Crop growth and Development

Internal factors (hormone, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth External factors (water, nutrition, temperature, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth, Propagation methods, grafting, cutting, budding, air layering. Physiology of pruning, dwarfing, branch bending, canopy management etc., Physiological and biochemical aspects of scion and root stock interaction and compatibility.

Unit 3: Reproductive Growth

Physiology of flowering, photo- and thermo-periodism and response to vernalization, Factors influencing reproductive growth, fruit and seed set/retention, physiology of flower sex ratio, Physiological processes governing source-sink relationship and productivity.

Unit 4: Pre and Post Harvest Physiology

Preharvest factors influencing postharvest physiology, Physiological and molecular mechanisms of ripening, Physiological and molecular mechanisms of senescence, Hormonal and chemical control of postharvest deterioration of fruits/vegetable/ flowers. Regulation of ripening at physiological and molecular levels, Regulation of senescence at physiological and molecular levels, Approaches to improve shelf life and storability. Approaches to improve postharvest management, Approaches to improve processing and value addition.

Unit 5: Plant Nutrition and Abiotic Stress Responses

Nutrient acquisition and requirement, plant phenology and nutrient requirement; Role of rootstocks in nutrient acquisition and in abiotic stress tolerance, Adaptive mechanisms and approaches to improve performances under drought and high temperature, Adaptive mechanisms and approaches to improve performances under frost, chilling and nutrient deficient conditions, Root physiology in abiotic stress tolerance.

Unit 6: Specific Aspects and Unique Crop Features

Specific aspects

Polyhouse cultivation, Hormones/PGRs for improving crop performance, Major and micronutrients for improving crop performance, Light interception, shade regulation, dwarfing root stocks, Chilling requirement for flowering, photoperiodic response, pollen viability, stigma receptivity, Flower (blossom) and fruit drop.

Unique crop features

Maturity and maturity indices, Source-sink relations, Vegetative propagation, Physiology of tuberization and rhizome initiation and formation, Virus free planting material, Bulbs/tubers dormancy, bud break, Physiological disorders, Storage, Packaging, Quality.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

IX. Suggested Reading

- Sethuraj MR and Raghavendra AS. 2012. *Tree Crop Physiology*. ISBN-13: 978-0444428417, ISBN-10: 0444428410, Elsevier Science Publishers.
- Bhatnagar P. *Physiology of Growth and Development of Horticultural Crops*, ISBN-10: 817754666X, ISBN-13: 978-8177546668
- Singh A. *Fruit Physiology and Production*, ISBN-10: 8127211788, ISBN-13: 978-8127211783, Kalyani Publishers; 5th edition (March 28, 2003).
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I. Course Title : Seed Physiology

II. Course Code : PP 510*

III. Credit Hours : 2+1

IV. Why this course?

Seeds are considered as propagule and as a major source of nutrition for humans and other animals. Therefore, all information concerning their nutritive value, chemical composition; storability, retention of viability are very important. Looking into the importance of seeds, emphasis has been given to produce high quality seeds with excellent genetic potential to improve seed germination and to produce vigorous seedlings. In fact, recently techniques are employed to raise healthy and vigorous seeds to obtain vigorous seedlings. Several hormones and chemicals are used to improve the oil, protein, and other economic attributes of seeds. Therefore, to give more insight into the development of quality seeds and also protecting them without losing much of nutritive value, this course has been proposed.

V. Aim of the course

This course will approach the subjects from two perspectives –physiology of seed development and seed germination. It aims to describe students the physiological processes involved in regulation and mechanism of seed development, dormancy and germination. Further, to provide an insight into physiological processes governing seed quality and its survival. Accordingly.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Seed Development	1. Introduction to Seed Physiology 2. Seed Development 3. Seed Maturation 4. Metabolism in Developing Seed
2.	Physiology of Seed Germination and Dormancy	1. Seed Germination 2. Seed Dormancy and Viability

VI. Theory

Block 1: Physiology of Seed Development

Unit 1: Introduction to Seed Physiology

Importance of seed as a propagule, seed structure and functions; chemical composition of seeds. Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development. Source-Sink relationship affecting seed yield and quality. Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds. Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination.

Unit 2: Seed Development

Physiology and molecular mechanisms of embryo, endosperm and seed coat development; cellularization during endosperm development; morphological and cellular changes during seed coat development, anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development.

Unit 3: Seed Maturation

Seed maturation and maturation indices; physiological and anatomical changes during seed maturation; Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance; role of ABA LEA's, HSP's, dehydrins and other stress proteins during seed maturation and drying, Seed abortion and approaches to reduce it.

Unit 4: Metabolism in Developing Seed

Chemical composition of seeds (carbohydrates, proteins, fats etc.), source of assimilates for seed development, pathways of movement of assimilates to developing seed, approaches to increase the chemical composition of seeds. Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds. Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis.

Block 2: Physiology of Seed Germination and Dormancy

Unit 1: Seed germination

Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination: seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed.

Environmental regulation of germination: hydro-time, thermal time and hydrothermal time models; Influence of environmental factors on germination; Role of plant hormones/PGR's during seed germination.

Unit 2: Seed Dormancy and Viability

Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments; Ecological perspective of seed dormancy. Seed viability: concept and physiology of seed viability, theories of seed ageing, seed storage and regulation of storage life of seeds; methods to prolong seed viability; Conservation of orthodox and recalcitrant seeds. Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour.

VII. Practicals

- Determination of seed reserves: carbohydrates, proteins and lipids
- Study of different seed structures
- Kinetics of seed imbibition; Seed germination test, enzymatic activities and respiration during germination and vigour testing methods etc.
- Accelerated ageing test to know the seed vigour and storability
- Measurement of seed moisture content
- Determination of amylase activity in germinating seeds
- Measurement of electrical conductivity in seed leachate
- Measurement of seed viability using tetrazolium chloride
- Determination of dehydrogenase activity
- Seed germination study- Determination of Germination Index and seedling growth
- Measurement ofseed vigour index
- Dormancy breaking treatments
- Seed priming techniques
- Effect of environmental stresses on seed germination and seedling growth
- Effect of hormones on seed germination

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

At the end of the course the students are expected to be able to understand the physiology of seed development and seed germination. The students will be able to identify the physiological processes involved in regulation of seed development, dormancy and germination.

IX. Suggested Reading

- Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). *Seeds: Physiology of Development, Germination and Dormancy*, Springer-Verlag.
- Larkins BA and Vasil IK (Ed), *Cellular and Molecular Biology of Plant Seed Development*, 2010, Springer.
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- http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/.
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I. Course Title : Phenotyping Physiological Processes

II. Course Code : PP 511

III. Credit Hours : 2+0

IV. Why this course?

One of the main mandates of SAU and crop specific institutes is crop improvement. Seed industry and academic institutes need contribution from physiologists on these aspects. Conceptual changes in breeding approaches in terms of breeding for specific physiological traits necessitates that the students develop conceptual approaches for phenotyping in different physiological processes. Characterizing the parents, germplasm accessions, segregating populations for specific physiological traits like flowering response, variation in root system architecture, etc is crucial for genetic enhancement of these traits. This student ready Course can contribute richly to research and development of the seed sectors and crop specific institutions where the major emphasis in recent years is genetic enhancement of traits.

V. Aim of the course

The major emphasis in this course is to phenotype well characterized physiological processes/plant traits associated with plant growth, development and productivity, besides, comprehensive approach to precise imposition of various abiotic stresses and capture genetic variability in adaptive traits. The aim is to employ these techniques for crop improvement programs.

The course is organized as follows:

No.	Blocks	Units
1.	Phenotyping Physiological Processes	1. Concept of Phenotyping 2. Phenotyping for Traits for Crop Establishment 3. Concept and Approaches to Identify Genotypes with Superior Growth Rate 4. Identifying Photo-insensitive Genotypes-options and Approaches 5. Identifying Thermo-insensitive Genotypes-options and Approaches 6. Yield Structure Analysis- Relevant Yield Attributes 7. Source-sink Relationship- Assessment of Limitation

No.	Blocks	Units
		8. Identify Genetic resources for Abiotic Stress Constraints

VI. Theory

Block 1: Phenotyping Physiological Processes

Unit 1: Concept of Phenotyping

Phenotyping technologies are essential component for assessing plant responses, identify superior trait donors, mitigation responses, trait introgression and trait based breeding.

Unit 2: Phenotyping for Traits for Crop Establishment

Seed viability, seed dormancy, seed hydration rates, seed density and weight, Seedling vigour in normal and adverse conditions.

Unit 3: Concept and Approaches to Identify Genotypes with Superior Growth Rate

Phenotyping for leaf expansion, leaf area index, light interception and crop extinction coefficient. Pigment quantification for nitrogen and chlorophyll status - SPAD, anthocyanin and flavonoids – Duolex. Growth rates by non-invasive techniques like NDVI, Concept of Net assimilation rate and DM/LAD; surrogates for photosynthetic traits; stomatal characteristic.

Unit 4: Identifying Photo-insensitive Genotypes-options and Approaches

Exposing to longer and shorter photoperiod by staggered sowing; extending the day length- light interception by red light; days to heading/ anthesis, approaches for synchronization of flowering.

Unit 5: Identifying Thermo-insensitive Genotypes-options and Approaches

Altering total degree days- staggered sowing at lower latitudes or by growth chambers; quantifying heading, anthesis, maturity and grain filling days, grain number and weight, grain filling rate.

Unit 6: Yield Structure Analysis- Relevant Yield Attributes

Pollen biology, stigma receptivity, spikelet sterility (cereals), floral abscission (other crops), fruiting points / productive tillers, number of grains/ fruits per panicle/ inflorescence and grain characteristic. Phenotyping for lodging- culm traits, intermodal length, lignification, Phenylalanine ammonia lyase (PAL) and Tyrosine ammonia lyase(TAL). Approaches to identify genetic resources with traits to improve yield potential.

Unit 7: Source-sink Relationship- Assessment of Limitation

Phenotyping for source-sink size, Concept of sink-source limitation- defloration and defoliation. Remobilization of stored metabolites and concept of stay green; estimation of water soluble carbohydrates; partitioning coefficient and harvest index.

Unit 8: Identify Genetic Resources for Abiotic Stress Constraints

Approaches for precise stress imposition to diverse stresses, Identify trait donor lines for different stresses: approaches by Stress Susceptibility Index (SSI), Stress Induction Response (SIR), Capturing variability for adaptive traits: root traits, stomatal factors/wax, osmolyte, surrogate approach for acquired tolerant traits, Flowering response, Spikelet fertility, Abscission and Senescence, Screening high density response-based on SSI – root adaptation and Shade Avoidance Response (SAR).

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

After completion of this course students are expected to develop clear concept and insight into phenotyping technologies associated with plant growth, development and productivity.

IX. Suggested Reading

- Kumar J, Pratap A and Kumar S. 2015. *Plant Phenomics: An Overview*. 10.1007/978-81-322-2226-2_1.
- Pratap A, Gupta S, Nair RM, Gupta SK, Schafleitner R, Basu PS, Singh CM, Prajapati U, Gupta AK, Nayyar H, Mishra AK, Baek KH. 2019. *Using Plant Phenomics to Exploit the Gains of Genomics. Agronomy* 9, 126.
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- Ouzounis, T., Rosenqvist, E., and Ottosen, C., 2015. *Spectral Effects of Artificial Light on Plant Physiology and Secondary Metabolism: A Review American Society Horticulture Science*. 50(8); 1128–1135 doi.org/10.21273/HORTSCI.50.8.1128
- *The Flowering Response of the Rice Plant to Photoperiod: A Review of The Literature* Fourth Edition.
- Sehgal A, Sita K, Siddique KH, Kumar R, Bhogireddy S, Varshney RK and Nayyar H. 2018. *Drought or/and Heat-Stress Effects on Seed Filling in Food Crops: Impacts on Functional Biochemistry, Seed Yields, and Nutritional Quality. Frontiers in Plant Science*, 9.
- Prasad, P. V., Bheemanahalli, R., andJagadish, S. K. 2017. *Field crops and the fear of heat stress—Opportunities, challenges and future directions. Field Crops Research* 200, 114-121.
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- Khobra R, Sareen S, Meena BK, Kumar A, Tiwari V and Singh GP. 2019. *Exploring the traits for lodging tolerance in wheat genotypes: A review. Physiology and Molecular Biology of Plants*, 1-12.

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  White, A. C., Rogers, a., Rees, M and Osborne, C.P., 2016. *How can we make plants grow faster? A source–sink perspective on growth rate Journal of Experimental Botany*, 67(1): 31–45.

  Ragheba, A., El-Shimyb, H and Raghebb, G. 2016. *Green architecture: a concept of sustainability, Procedia - Social and Behavioral Sciences* 216: 778 – 787.

- Wang H, Wu G, Zhao B, Wang B, Lang Z, Zhang C and Wang H. 2016. *Regulatory modules controlling early shade avoidance response in maize seedlings*, *BMC Genomics* **17**: 269, https://doi.org/10.1186/s12864-016-2593-6.
- Carriedo, L., Maloof, J and Brady, S. 2016. *Molecular control of crop shade avoidance. Current Opinion in Plant Biology*. 30. 151-158. 10.1016/j.pbi.2016.03.005.

I. Course Title : Crop Growth Regulation and Management

II. Course Code : PP 512

III. Credit Hours : 2+0

IV. Why this Course?

Besides crop improvement, the approach to regulate physiological processes for improving crop production made very good leads in recent years. The focus is to employ the basic knowledge of several physiological processes to manipulate the plant growth and specific processes like ripening, flowering to achieve higher economic yields. This dynamic course will address many of these technologies that are being developed for crop production based on principles of plant physiological processes. Training the students in this student ready coursewill provide the required practical knowledge which will be of immense relevance to contribute private agricultural sectors and for agri-based industries.

V. Aim of the Course

A comprehensive information needs to be provided in this course like light regulation in polyhouse cultivation, photoperiod responses by red/far red light for synchronizing flowering, techniques for soil less culture like aeroponics, pollen biology and hybrid production, chemical regulation of plant growth processes like flower initiation, flower sex, flower drop, fruit maturity, ripening and shelf-life, etc.

The course is organized as follows:

No	Blocks	Units
1	Propagation - Crop Establishment	1. Seed as a Propogule 2. Vegetative Propogule
2	Regulation of Plant Growth Processes	1. Regulation of Plant Growth and Flowering 2. Fruit Ripening and its Regulation 3. Concept of Senescence and its Retardation
3	Protective Cultivation–Stress Mitigation	1. Protective Cultivation Interventions to Alter Physiological Processes and Growth 2. Drought Mitigation Options and Approaches 3. Specific Plant Processes Regulated by Chemicals and Growth Hormones

VI. Theory

Block 1: Propagation - Crop Establishment

Unit 1: Seed as a Propogule

Concept of improving seed characteristics for crop establishment. Mechanisms of regulating seed dormancy, precocious germination, ways to control pre-harvest sprouting in crop plants. Seed viability and its regulation, factors to minimize loss of viability and improve seedling vigour. Concept of seed priming, techniques of priming, seed priming to induce tolerance to stresses. Role of media, nutrition and PGPR's on seedling vigour and subsequent crop establishment.

Unit 2: Vegetative Propogule

Chemical and hormonal regulation of vegetative propagation. Regulation of rooting, bud sprouting, Bulb/tuber dormancy. Chemical regulation of graft union. Concept of *in vitro* micropropogation.

Block 2: Regulation of Plant Growth Processes

Unit 1: Regulation of Plant Growth and Flowering

Chemical and hormonal regulation of plant architecture, tillering, branching, bud breaking, Regulation of flowering by photo and thermoperiod, nutrients, chemicals and hormones, concept of speed breeding, Flowering synchrony in hybrid seed production, Sex ratio alteration, flower and fruit thinning, Pollen viability in relation to environment, harvesting, storage and transportation, Prevention of abscission, flower and fruit drop, seed and fruit growth regulation- role of hormones.

Unit 2: Fruit Ripening and its Regulation

Approaches to improve shelf life – storage environment, water loss, respiration, Modified atmosphere, gaseous environment for storage, storage disorders, chilling injury.

Unit 3: Concept of Senescence and its Retardation

Physiology of senescence and options to regulate, Chemical regulation of senescence, maintenance of chlorophyll during storage, role of hormones/micronutrients in reducing senescence, Concept of stay green, advantages and limitations. Relevance of stay green traits in plant breeding for crop improvement.

Block 3: Protective Cultivation–Stress Mitigation

Unit 1: Protective Cultivation Interventions to Alter Physiological Processes and Growth

Spectral characteristics of light in polyhouse, light regulation to optimize plant photosynthetic and photomorphogenic processes and plant growth, LED sources of monochromatic light to regulate growth, etiolating and flowering, High temperature induced thermomorphogenic processes, Artificial growing media, soilless cultures, aeroponics, fogoponics, Concept of CO_2 fertilization. Effect of humidity on leaf expansion and growth.

Unit 2: Drought Mitigation Options and Approaches

Moisture conservation options at soil and plant level, Concept of increasing water holding capacity, role of Hydrogels – water and mineral nutrients release pattern. Approaches to improve transpiration over evapo-transpiration, stomatal and non-stomatal regulation of water loss, antitranspirants, Osmoprotectants, ROS scavengers, plant nutrients, Root stocks in improving tolerance, Chemical regulation of flower drop due to temperature, Chemicals to improve pollen viability during abiotic stress.

Unit 3: Specific Plant Processes Regulated by Chemicals and Growth Hormones

Rooting of cuttings, Wine brewing industry, Promotion of gynoecious flower, Hybrid rice production, Induction of flowering in pine apple, cucurbits, Delaying of senescence and ripening, Production of dwarf plant for ornamental purpose, Reduction in flower and fruit drop, Increase in berry size in grapes.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Suggested Reading

- Wu X, Ning F, Hu X and Wang W. 2017. *Genetic Modification for Improving Seed Vigor Is Transitioning from Model Plantsto Crop Plants. Front. Plant Sci.* 8: 8. doi: 10.3389/fpls.2017.00008
- William E. Finch-Savage and Steven Footitt. 2017. *Seed dormancy cycling and the regulation of dormancy mechanisms to time germination in variable field environments Journal of Experimental Botany*, 68, (4), 843 856, https://doi.org/10.1093/jxb/ erw477
- Afzal I, Ur Rehman H, Naveed M and ShahzadMaqsood, Basra A. 2016. *Recent Advances in Seed Enhancements* Intech.
- *Techniques and Experiments Plant Tissue Culture Techniques and Experiments* Elsevier Inc. 2013.
- Nanda AK and Melnyk CW. 2018. *The role of plant hormones during grafting. Plant Res.* 131(1): 49–58. doi: 10.1007/s10265-017-0994-5PMCID: PMC5762790
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- Sandarani, MDJC, Dasanayaka DCMCK and Jayasinghe CVL. 2018. *Strategies Used to Prolong the Shelf Life of Fresh Commodities. J AgriSci Food Res* 9: 206.
- Falagán, N and Terry LA. 2018. *Recent advances in controlled and modified atmosphere of fresh produce. Johnson Matthey Technology Review* 62(1), 107-117.
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- Bian, Z., Jiang, N., Grundy, S. and Lu, C., 2017. *Uncovering LED light effects on plant growth: new angles and perspectives-LED light for improving plant growth, nutrition and energy-use efficiency*. In *International Symposium on New Technologies for Environment Control, Energy-Saving and Crop Production in Greenhouse and Plant* 1227. 491-498.
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- Wang, P., Deng, Y., Li, X.Y., Wei, Z., Hu, X., Tian, F., Wu, X., Huang, Y., Ma, Y.J., Zhang, C. and Wang, Y. 2019. *Dynamical effects of plastic mulch on evapotranspiration partitioning in a mulched agriculture ecosystem: Measurement with numerical modeling. Agricultural and Forest Meteorology*, 268: 98-108.
- GernotBodner, Alireza, Hans-Peter *Management of crop water under drought: A review. Agronomy for sustainable development*. 2: 401-442

Course Title with Credit Load
Ph.D. Plant Physiology

Course Code	Course Title	Credit Hours
PP 601	Functional Genomics and Genes Associated with a Few Physiological Processes	2+0
PP 602*	Signal Perceptions and Transduction and Regulation of Physiological Processes	2+0
PP 603	Molecular Approaches for Improving Physiological Mechanisms Through Trait Introgression	2+1
PP 604	Plant Phenomics – Next Generation Phenomics Platforms	2+0
PP 605	Experimental Techniques to Characterize Plant Processes for Crop Improvement	0+2
PP 606	Global Climate Change and Crop Response	2+0
PP 607*	Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield	3+0
PP 608	Seed and Fruit Growth and their Quality Improvement	2+0
PP 609	Plant-microbe Interactions	2+1
PP 610	Weed Biology and Physiology of Herbicide Action	2+0
PP 691	Doctoral Seminar I	1+0
PP 692	Doctoral Seminar II	1+0
PP 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Plant Physiology

I. Course Title : **Functional Genomics and Genes Associated with a Few Physiological Processes**

II. Course Code : **PP 601**

III. Credit Hours : **2+0**

IV. Why this Course?

Agriculture in India faces tremendous challenges on multiple fronts. There is a need for targeted improvement of crops to meet the increasing food demand. Thorough understanding of the plant physiological processes, pathways and genes associated with the pathways are needed for speed breeding and trait improvement. With help of modern tools and techniques, in the genomic ear, a large amount of data on genomic resources has been developed. The post-genomic era concentrates on assigning functions to the every gene identified in plants. The PhD scholar working on plant biology and related field must be exposed to recent trends and developments in this new emerging area. The major emphasis would be on new developments in genomics to regulate plant growth.

V. Aim of the Course

The major goal is to expose the students of higher education program on functional genomic approaches, which is needed for crop improvement in a targeted way:

(i) Identify genes regulating the specific mechanisms/traits.

(ii) Assess the relevance of physiological processes/mechanisms and options to combine/ introgress them.

The course is organized as follows:

No.	Blocks	Units
1.	Functional Genomics and Genes: Physiological Processes	1. Gene Discovery 2. Genetic Tools for Plant Development 3. Gene Knock Out Approaches 4. Chemical Genomics 5. Gene Over Expression Approaches 6. Synthetic Biology and Interaction Studies 7. Case Studies

VI. Theory

Block 1: Functional Genomics And Genes: Physiological Processes

Unit 1: Gene Discovery

Finding genes in complex plant system, Constructing gene-enriched plant genomic libraries, Recent advancements in genome sequencing, RNA sequencing and expression, In Silico prediction of plant gene function, Quantitative Trait Locus analysis as a gene discovery tool, Gene expression analysis –micro-array and deep sequencing, small RNA and Degradome, Study of methylome and its significance

Unit 2: Genetic Tools for Plant Development

Understanding the importance of mutants in unrevealing the physiological processes, genome wide insertional mutagenesis – T-DNA insertion mutants, Gain in function, Transposon mutagens, Transposition, Physical and Chemical mutagenesis, Gene and Enhancer Traps for Gene Discovery, High-Throughput TAIL-PCR as a Tool to identify DNA Flanking insertions, High-Throughput TILLING for functional Genomics, Genome editing approaches for functional analysis of genes.

Unit 3: Gene Knock Out Approaches

PTGS-Antisense technology, Virus induced gene silencing (VIGS), Custom Knock-outs with Haripin RNA-mediated Gene Silencing and other silencing tools, Complementation studies.

Unit 4: Chemical Genomics

Reverse chemical genomic approaches for functional validation of genes, Protein structure prediction, homology modelling and virtual screening by using bioinformatic approaches to identify the small molecules and their validation through phenotyping assessment.

Unit 5: Gene Over Expression Approaches

Vector Construction for Gene Overexpression as a Tool to Elucidate Gene Function Transient expression, Transgenics, Targeted and conditional expression of transgene. Multiple gene expression by Nanostring technology, Co-expression analysis and gene networking to identify potential genes in the pathway (informatics), Epigenetics.

Unit 6: Synthetic Biology and Interaction Studies

Engineering microbial pathways in plants (eg, photosynthesis), DNA-protein & Protein-protein interaction studies, yeast hybrid system, Correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome, Multivariate analysis and identification of metabolite as biomarkers.

Unit 7: Case Studies

Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling photosynthesis and nutrient uptake, Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling respiration and photorespiration, Functional characterization of genes associated with important cellular processes influencing crop growth and development: fatty acid biosynthesis, seed protein quality and quantity, Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling flowering.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course students are expected to have in depth knowledge on the genetic tools for plant development.

IX. Suggested Reading

Regulation of Gene Expression in Plants*. Gatehouse JA. 1997. *Plant Biochemistry.

Plant genome sequencing, Fleury D, Langridge P. 2012. *Plant Biotechnology and Agriculture.*
Baxevanis, A. D. and Ouellette, B. F. F. (eds). 2001. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, Methods of Biochemical Analysis*, vol. 43, 2nd ed., New York: John Wiley and Sons, Inc.
Gene Expression Analysis: Methods and Protocols, Raghavachari N, Garcia-Reyero, N (Eds.) 2018. ISBN 978-1-4939-7834-2, Springer
Transcriptome Data Analysis: Methods and Protocols. Wang Y, Sun, M (Eds.), 2018. ISBN 978-1-4939-7710-9; Springer
Comparative Genomics: Methods and Protocols. Setubal, J C., Stoye, Stadler P (Eds.) ISBN 978-1-4939-7463-4; Springer

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- *Recombinant DNA Technology and Genetically Modified Organisms*. 2017. Nambisan P. An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology.
- He F, Zhang F, Sun W, Ning, and Wang GL. 2018. *A Versatile Vector Toolkit for Functional Analysis of Rice Genes* 11: 27.doi: 10.1186/s12284-018-0220-7.
- Kamburova VS, Nikitina EV, Shermatov SE, Buriev ZT, Kumpatla SP, Emani C and Abdurakhmonov EY. *Genome Editing in Plants: An Overview of Tools and Applications International Journal of Agronomy*. https://doi.org/10.1155/2017/7315351
- Bhardwaj R, Singh R. 2014. *Gene Silencing in Emerging Technologies and Management of Crop Stress Tolerance*, Volume 1.
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- Dejonghe W and Russinova E. *Plant Chemical Genetics: From Phenotype-Based Screens to Synthetic Biology*. *Plant Physiol*. 2017 May; 174(1): 5–20.doi: 10.1104/pp.16.01805
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- *Gene Overexpression in Cereals for Functional Genomics and Discovery of Useful Genes*, Abe K and Ichikawa H. 2016. *Front Plant Sci.* 7: 1359. doi: 10.3389/fpls.2016.01359
- *Gene Overexpression: Uses, Mechanisms, and Interpretation*, Prelich G. 2012. 190 no. 3 841-854; https://doi.org/10.1534/genetics.111.136911
- Wusheng Liu C. Neal Stewart Jr *Plant synthetic biology* https://doi.org/10.1016/j.tplants.2015.02.004, REVIEW| 20, 5, P309-317, 2015
- *Plant Synthetic Biology*: Quantifying the "Known Unknowns" and Discovering the "Unknown Unknowns" R. Clay Wright, Jennifer Nemhauser, 2019. DOI: https://doi.org/10.1104/pp.18.01222
- *Plant synthetic biology for molecular engineering of signalling and development.* Nemhauser JL and Torii KU. 2016. *Nat Plants* 2: 16010.doi: 10.1038/nplants.2016.10

I. Course Title : Signal Perceptions And Transduction And Regulation Of Physiological Processes

II. Course Code : PP 602*

III. Credit Hours : 2+0

IV. Why this course?

Biosignaling is emerging as an import fields in plant biology. Thorough understanding of signal perception, activation and cellular changes associated is needed for manipulation of specific traits or events in plants. The M.Sc. PhD scholar working on plant biology and related field must be exposed to this new emerging area. Plant response to external and internal factors is mainly through signal perception and amplification leading gene expression which brings in altered metabolism regulating physiological and biochemical processes and finally plant processes and growth. The course provides insights on the diverse receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression and finally regulating plant growth.

V. Aim of the course

Objective of this course is to provide comprehensive exposure on different signaling events and associated cellular changes in plants. The course will include lectures on the signalling mechanisms employed by plants to perceive and transduce environmental signals.

The course is organized as follows:

No	Blocks	Units
1	Signal Perceptions and Transduction: Regulation of Physiological Processes	1. Concept of Receptor and Ligands 2. Receptors – Signal Perception and Transfer 3. Hormone Signaling 4. Light Signaling 5. Abiotic Stress Signaling and Nutrient Signalling 6. Signaling Cascade during Developmental Events 7. Signal Perception and Transduction in Plant Defense Responses

VI. Theory

Block 1: Signal Perceptions and Transduction: Regulation of Physiological Processes

Unit 1: Concept of Receptor and Ligands

Signal, signal types, long (diffusible) and short (contact) range signaling and components of signaling. Types of receptors, nature of ligands, downstream components like primary, secondary signaling components.

Unit 2: Receptors – Signal Perception and Transfer

Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptors Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs), receptor two component systems. Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes. Downstream components- G-proteins, second messengers-Cyclic AMP, Adenylate cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factor).

Unit 3: Hormone Signaling

Hormone binding receptors-Transduction process. Effector molecules and gene expression. Specific signaling pathways of Auxins, Cytokinin, Gibberellins, Ethylene, ABA, Brassinosteroids, Salicylic Acid, Strigolactone, polyamines, Jasmonic acid, etc. which leads to formative effects. Cross talk in the signaling of different hormones-significance of studies with hormone action mutants.

Unit 4: Light Signaling

Perception of light-pigments involved- activation of phytochrome/cryptochrome (study of mutants). Light signal transduction. Multiple signaling cascades-identification of signaling components through mutant analysis-changes in gene expression.

Unit 5: Abiotic Stress Signaling and Nutrient Signalling

Sensing of environmental factors (Temperature-Osmotic-Ionic stress), Activation of specific molecules and secondary messengers, activation of downstream components-leading to stress gene expression, Case studies with different abiotic stresses, Retrograde signaling, Nitrogen fixation, nitrogen and phosphorus uptake, nutrient translocation.

Unit 6: Signaling Cascade during Developmental Events

Leaf senescence/fruit development and ripening, Tuberization, Sugar signaling. Signaling during seed germination.

Unit 7: Signal Perception and Transduction in Plant Defense Responses

General mechanisms to pathogen response, Role of salicylic acid and active oxygen species, Cross Talk Signaling- Stress matrix under field conditions, cross talk between abiotic-abiotic stress, biotic-abiotic stress signaling networks.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to:

1. comprehendvarioussignaling events and associated physiological changes in plants.
2. understand the diverse roles of receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression.

IX. Suggested Reading

- He, Y., Zhou, J., Shan, L. and Meng, X., 2018. *Plant cell surface receptor-mediated signaling–a common theme amid diversity*. J Cell Sci, 131(2), p.jcs209353.
- Hall, M.A., Smith, A.R., Novikova, G.V. and Moshkov, I.E., 1999. *Perception and transduction of ethylene. New Comprehensive Biochemistry*, 33, 475-490.
- Huber, A.E. and Bauerle, T.L., 2016. *Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge. Journal of Experimental Botany*, 67(7), 2063-2079.
- Pollard, T.D., Earnshaw, W.C., Lippincott-Schwartz, J. and Johnson, G., 2016. *Cell Biology* E-Book. Elsevier Health Sciences.
- Braun, Y., Smirnova, A.V., Weingart, H., Schenk, A. and Ullrich, M.S., 2007. *A temperature sensing histidine kinase—function, genetics, and membrane topology*. Methods In Enzymology: 423: 222-249. Academic Press.
- Unden, G., Wörner, S. and Monzel, C., 2016. *Cooperation of secondary transporters and sensor kinases in transmembrane signalling: the DctA/DcuS and DcuB/DcuS sensor complexes of Escherichia coli. In Advances in Microbial Physiology* (Vol. 68, 139-167). Academic Press.
- Ortiz-Urquiza, A. and Keyhani, N.O., 2016. Molecular genetics of *Beauveria bassiana* infection of insects. *Advances in Genetics* 94: 165-249). Academic Press.
- Snijders, L. and Naguib, M., 2017. *Communication in animal social networks: a missing link. Adv Study Behav*, 49, pp.297-359.

- Hedden, P. and Thomas, S.G. (eds.), 2008. *Annual Plant Reviews, Plant Hormone Signaling* 24. John Wiley and Sons.
- Eckardt, N.A., 2015. *The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk*.
- Chow, B. and McCourt, P., 2006. *Plant hormone receptors: perception is everything. Genes and development,* 2015, 1998-2008.
- Leduc, N., Roman, H., Barbier, F., Péron, T., Huché-Thélier, L., Lothier, J., Demotes-Mainard, S. and Sakr, S., 2014. *Light signaling in bud outgrowth and branching in plants. Plants*, 3(2), 223-250.
- Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. *Light-regulated plant growth and development. Current Topics in Developmental Biology* (91: 29-66). Academic Press.
- Coureux, P.D. and Genick, U.K., 2007. *Triggering and Monitoring Light Sensing Reactions in Protein Crystals. Methods in Enzymology* (422: 305-337). Academic Press.
- Wang, C.S., Hsu, S.W. and Hsu, Y.F., 2013. *New insights into desiccation-associated gene regulation by Lilium longiflorum ASR during pollen maturation and in transgenic Arabidopsis. International Review of Cell and Molecular Biology* (301: pp. 37-94). Academic Press.
- Ben-Ari, G. and Lavi, U., 2012. *Marker-assisted selection in plant breeding. Plant Biotechnology and Agriculture* (163-184). Academic Press.
- Peleg, Z.V.I., Walia, H. and Blumwald, E. 2012. *Integrating genomics and genetics to accelerate development of drought and salinity tolerant crops. Plant Biotechnology and Agriculture* 271-286. Academic Press.
- Zhu, J.K., 2016. *Abiotic Stress Signaling and Responses in Plants*. Cell, 167(2): 313-324.
- Pandey, G.K., Pandey, A., Prasad, M. and Böhmer, M., 2016. *Abiotic stress signaling in plants: functional genomic intervention. Frontiers in Plant Science*, 7, p.681.
- Inaba, T., Yazu, F., Ito-Inaba, Y., Kakizaki, T. and Nakayama, K., 2011. *Retrograde signaling pathway from plastid to nucleus. International Review of Cell and Molecular Biology* (Vol. 290, pp. 167-204). Academic Press.
- Khan, M.I.R., Reddy, P.S., Ferrante, A. and Khan, N.A. (eds.). 2019. *Plant Signaling Molecules: Role and Regulation Under Stressful Environments*. Woodhead Publishing.
- Sparks, E., Wachsman, G. and Benfey, P.N., 2013. *Spatiotemporal signalling in plant development. Nature Reviews Genetics*. 14(9), p.631.
- Becraft, P.W., 2002. *Receptor Kinase Signaling in Plant Development. Annual Review of Cell and Developmental Biology*, 18(1) 163-192.
- Sparks, E., Wachsman, G. and Benfey, P.N. 2013. *Spatiotemporal signalling in plant development. Nature Reviews Genetics* 14(9): p.631.
- Rabellino, D., Boyd, J.E., McKinnon, M.C. and Lanius, R.A. 2019. *The Innate Alarm System: A Translational Approach. Stress: Physiology, Biochemistry, and Pathology* 197-212. Academic Press.
- Newton, A.C., Torrance, L., Holden, N., Toth, I.K., Cooke, D.E., Blok, V. and Gilroy, E.M., 2012. *Climate change and defense against pathogens in plants. Advances in Applied Microbiology* (81: 89-132). Academic Press.
- Reverchon, S., Muskhelisvili, G. and Nasser, W., 2016. *Virulence program of a bacterial plant pathogen: the Dickeya model. Progress in Molecular Biology and Translational Science* (142, 51-92). Academic Press.
- Davies, P.J. ed., 2004. *Plant Hormones: Biosynthesis, Signal Transduction, Action*. Springer Science and Business Media.
- Dzhavakhiya, V.G. and Shcherbakova, L.A., 2007. *Creation of disease-resistant plants by gene engineering. Comprehensive and Molecular Phytopathology* (439-466). Elsevier.
- Dyakov, Y.T. and Ozeretskovskaya, O.L., 2007. *Vertical pathosystem: avirulence genes and their products. Comprehensive and Molecular Phytopathology* (181-215). Elsevier.
- Yamane, H., Konno, K., Sabelis, M., Takabayashi, J., Sassa, T. and Oikawa, H., 2010. *Chemical defence and toxins of plants*.

- Vinutha, T., Gupta, O.P., Prashat, G.R., Krishnan, V. and Sharma, P. 2014. *Molecular mechanism of Begomovirus evolution and plant defense response. Plant Virus–Host Interaction* (345-357). Academic Press.

General Source Information

- Bogre L and Beemster G. 2008. *Plant cell monographs. Plant Growth Signaling. Signals and Signal Transduction Pathways in Plants* Klaus Palme (Editor), 2012, Springer ISBN-13: 9789401041072
- Memon, A.R. and Durakovic, C., 2014. *Signal perception and transduction in plants. Periodicals of Engineering and Natural Sciences* (PEN), 2(2).
- Signal Transduction Mechanism: EduRev: https://edurev.in/studytube/Lecture-15-Signal-transduction-mechanisms/d82aff0d-53d8-4d71-a16c-185c6bdb517b_p
- Signaling and Communication in Plants, ISBN-10: 3540892273Springer; 2009 edition (March 18, 2009)
- Sopory SK Oelmuller R, Maheswari SC. 2012. (Ed) *Signal Transduction in Plants: Current Advances*; ISBN-13: 9781461355182
- Wang XY, Springer, 2016. *Plant Signalling Networks: Methods and Protocols* ISBN-13: 9781493961696
- *Developmental and Cell Biology Series: Hormones, Signals and Target Cells in Plant Development Series* Number 41, Osborne DJ, McManus MT, Cambridge University Press, ISBN-13: 9780521330763
- *How Plants Communicate* Machajewski S. 2018, Rosen Education Service, ISBN-13: 9781538301852
- *Signal Transduction in* Plants Aducci P (Ed), 2011, ISBN-13: 9783034899383
- *Reactive Oxygen Species: Signaling Between Hierarchical Levels in Plants*. Schmitt FJ. Allakhverdiev SI (Eds), 2017, Wiley-Scrivener ISBN-13: 9781119184881
- *Biocommunication: Sign-Mediated Interactions Between Cells and Organisms* Gordon R and Seckbach J (Ed). 2017. World Scientific Publishing Europe Ltd ISBN-13: 9781786340443
- *Annual Plant Reviews: Intracellular Signaling in Plants* Hedden P, Napier R, Yang Z (Ed) 2008, Wiley-Blackwell (an imprint of John Wiley and Sons Ltd) ISBN-13: 9781405160025

I. Course Title : Molecular Approaches for Improving Physiological Mechanisms through Trait Introgression

II. Course Code : PP 603

III. Credit Hours : 2+1

IV. Why this Course?

Phenomenal progress in understanding the basic physiological mechanisms that determine crop performance has been made in recent years. Extensive deciphering of the molecular and genetic basis of variations in these mechanisms has led to the enumeration of several "physiological traits" that have enormous relevance to improve yield potentials as well as adaptation to various biotic and abiotic stresses. Although most of the physiological traits have been considered as complex and hard to breed, recent advances in understanding the sub-components of most of the major mechanisms coupled with the progress made in "phenotyping" to capture genetic variability in such subcomponent traits have paved way for the adoption of "trait based breeding" approaches. The tremendous progresses made in genomics have also led to the development of extensive molecular and genetic resources that can be used for a focused "breeding by design".

V. Aim of the course

Deep understanding of modern translational research methods such as molecular breeding, transgenics, genome editing, grafting and reverse breeding approaches such as Doubled haploidization will be provided to the students. Contemporary developments in molecular approaches in accelerated crop improvement would be dealt with. Acquainting with the approaches and techniques is crucial for young students to groom themselves into focused and successful scientists in future. Theoretical and practical concepts of trait introgression (or trait pyramiding) will be discussed in this course so as to provide recent developments in this area of research. To acquaint with regulatory aspects of working with transgenic plants is crucial and will be discussed elaborately.

The course is organized as follows:

No.	Blocks	Units
1.	Trait Introgression through Molecular Breeding	1. Physiological Traits Relevant for Crop Improvement and their Phenotyping 2. Identification of QTL by Bi-parental Mapping Approach 3. Identification of QTLs by Association Mapping Approach 4. Trait Introgression by Molecular Breeding Approaches
2.	Trait Introgression through Transgenic Technology	1. Gene Discovery and Gene Constructs for Relevant Plant Traits/Adaptive Mechanisms 2. Trait Improvement or Pyramiding through Transgenic Technology 3. Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach 4. Characterization of Transformed Plants and Event Selection Strategies
3.	Other Approaches for Trait Introgression	1. Trait Introgression through Tissue Grafting and Asexual Propagation 2. Doubled haploids for Trait Introgression

VI. Theory

Block 1: Trait Introgression through Molecular Breeding

Unit 1: Physiological Traits Relevant for Crop Improvement and their Phenotyping

Physiological traits with relevance to growth, development, biotic/abiotic stress tolerance, nutrient acquisition, Concept of complex, multi-gene control of physiological traits, Concepts of trait introgression to augment crop productivity and/or stress adaptation.

Unit 2: Identification of QTL by Bi-parental Mapping Approach

Concepts of developing trait-specific mapping population and identification of contrasting parental lines through phenotyping, Mapping populations and their developments – F_2, RIL, doubled haploid populations, Accurate phenotyping of bi-parental mapping populations, Conventional Genotyping strategies using SNP and SSR markers, other rapid approaches like GBS, RADseq, QTLseq etc., Composite interval mapping and other approaches for QTL discovery.

Unit 3: Identification of QTLs by Association Mapping Approach

Concepts of assembling a "Panel" of germplasm amenable for association mapping based on molecular and phenotypic diversity, Concepts of linkage disequilibrium, LD decay and population structure, Concepts QTL discovery in structured populations. Phenotyping of the association mapping populations, Concepts of Genome wide association studies (GWAS).

Unit 4: Trait Introgression by Molecular Breeding Approaches

Strategies for QTL introgression and Marker Assisted Selection (MAS), Various breeding methods for trait introgression: Marker assisted backcross breeding (MABC), Marker assisted recurrent selection (MARS), Marker assisted phenotypic selection (MAPS), etc.

Block 2: Trait Introgression through Transgenic Technology

Unit 1: Gene Discovery and Gene Constructs for Relevant Plant Traits/ Adaptive Mechanisms

Map-based cloning to identify novel genes and their allelic variants, Identification of differentially expressed genes through transcriptome, metabolome and proteome analysis in contrasting genotypes, Gene identification through forward (inducing mutations with radiation, chemicals, or insertional mutagenesis)and reverse genetic approaches (site-directed mutagenesis, gene knockout or knockdown), Cloning full-length candidate genes, inducible promoters, Concepts of "codon optimization" to make constructs for specific crops.

Unit 2: Trait Improvement or Pyramiding through Transgenic Technology

Introduction to GMOs and its application in crop improvement, Gene stacking strategies for trait improvement, *Agrobacterium* and other methods of plant transformation including gene gun, *in planta*, etc.

Unit 3: Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach

Genome editing techniques: CRISPR/Cas9, Zinc finger nucleases, etc, CRISPR as tool to generate loss-of-function and gain-of-function transgenics.

Unit 4: Characterization of Transformed Plants and Event Selection Strategies

Molecular analysis bySouthern, qRT-PCR/Northern analysis, and immunoassays, Concepts of copy number and desirable number of independent events, Evaluation of transgenics based on empirical/physiological/biochemical processes under specific conditions – containment and confined field trials, Generation of T1 populations, event characterization, Molecular data as per regulatory requirements, Biosafety and Regulatory aspects of GMO.

Block 3: Other Approaches for Trait Introgression

Unit 1: Trait Introgression through Tissue Grafting and Asexual Propagation

Concept of identifying root stocks with superior traits, grafting, scion root stock interaction, compatibility, concept of chimeric grafting in transgenic technology involving a non-transgenic shoot to a transgenic root.

Unit 2: Doubled haploids for Trait Introgression

Concept of crossing trait donor lines and developing doubled haploids from the F1 anthers, Screening and identifying trait introgressed doubled haploids.

VII. Practicals

- Phenotyping approaches for the different physiological traits. Development of SSR, SNP and SCAR markers, resolution of polymorphism on agarose gels and PAGE, genotyping options for SSR markers using capillary and chip based fragment analysis systems. scoring of gels and assessment of polymorphism
- Statistical approaches to assess genetic variability, heritability and other parameters. Phylogenetic analysis and principle component analysis and construction of dendrograms. Construction of Linkage map, QTL maps, population structure, LD decay etc leading to identification of QTLs.
- Bioinformatics – sequence analysis, structure analysis, designing primers for SSR regions, SNP2CAPS approaches of genotyping.
- Molecular biology - genomic/plasmid DNA isolation, RNA isolation. Full-length gene cloning, vector construction with specific promoter, gene stacking and transient assays. Transformation in model system
- Crop transformation - *Agrobacterium* mediated transformation (in-planta and invitro), particle-gun transformation.
- Evaluation of transgenics – semiquantitative and quantitative RT-PCR, southern blot, northern blot, western blot and ELISA, biochemical/physiological assay based on the function of gene and testing LOD.
- Improvement of traits based on grafting options.
- Techniques in developing doubled haploids and characterization.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

1. comprehend the basic concepts of modern translational research methods such as molecular breeding, transgenics, genome editing, grafting etc.
2. describe reverse breeding approaches such as doubled haploidization
3. accumulate both theoretical and practical concepts of trait introgression

X. Suggested Reading

Reynolds MP. 2012. *Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation* Chapters 2, 3, 5: 153

Reynolds M and Langridge P. 2016. *Physiological Breeding*. Current Opinion in Plant Biology, 31: 162–17.1

Sheshshayee MS, Preethi NV, Rohini S, Sowmya HR, Smitharani A, Pooja B, Prathibha MD and Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem.*, 10.

Cossani M and Reynolds M. 2012. *Physiological Traits for Improving Heat Tolerance in Wheat. Plant Physiology*, Vol. **160**: 1710–1718

Payne T, Reynolds M and Skovmand B. *Searching genetic resources for useful variation in physiological traits* Chapter 5. *Physiological Breeding* I: Interdisciplinary Approaches to Improve Crop Adaptation Reynolds, M.P. (ed).

Bonnett D. *Optimizing marker-assisted selection (MAS) strategies for crop improvement*. Chapter 14: 153 Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation Reynolds, M.P. (ed).

- Breeding Rice for Drought-Prone Environments Edited by K.S. Fischer, R. Lafitte, S. Fukai, G. Atlin, and B. Hardy. 2003, IRRI. Section 4. What molecular tools are available for selection for drought tolerance?
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I. Course Title : Plant Phenomics-next Generation Phenomics Platforms

II. Course Code : PP 604

III. Credit Hours : 2+0

IV. Why this course?

Crop improvement in the present scenario is increasing focusing on trait based breeding. The phenomenal progress made in genomics cannot be exploited for improving plant traits/mechanisms unless phenotyping technologies are developed to capture genetic variability. Several technologies have been developed to accurately quantify genetic variability in specific traits.

V. Aim of the course

The course aims at providing cutting edge knowledge on the current progress made in various phenotyping techniques and approaches. The students will be versed with principles of various phenotyping approaches. The aim is to provide hands-on expertise in analyzing trait diversity. Exposure will be provided on Non-invasive imaging technologies that drive the phenomics platforms. The course provides comprehensive exposure on recent developments in phenomics platforms imaging tools/techniques and recent trends in designing specific phenomics platforms e.g. drought studies/root phenotyping etc.

The course is organized as follows:

No	Blocks	Units
1.	Concepts of High throughput Phenotyping and its Requirement	1. Concepts of Phenotyping 2. Physio-Morphological Traits Associated with Crop Performance 3. Features of Phenomic Platforms 4. Trends in Phenomics 5. Non-invasive Phenotyping Approaches
2.	Applications of the Phenomics Platforms	1. Basic Studies to Assess the Crop Response 2. Applied Studies Focused on Crop Improvement Programs

VU, Theory

Block 1: Concepts of High throughput Phenotyping and its Requirement

Unit 1: Concepts of Phenotyping

The concepts of "phene and trait" analogous to gene and allele. Genome-phenome relationship, definition of phenotyping, GxE interaction on phenome.

Unit 2: Physio-Morphological Traits Associated with Crop Performance

Overview of phenotyping needs to complement genomic resources, specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses). Need for high throughput precision phenotyping approaches for basic studies and to generate genetic and genomic resources.

Unit 3: Features of Phenomic Platforms

Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response, Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits, Concept of sensors, diverse sensors and their utility in precise quantification of environmental variables, soil moisture sensors, Imaging to capture plant traits, image acquisition. Automated big data access, processing, etc.

Unit 4: Trends in Phenomics

Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms. Platforms designed for specific needs i.e., root phenotyping, drought studies etc., Crop specific phenotyping, mobile and stationary platforms, Global trends in establishing major phenomics platforms, and their characteristic features and impact.

Unit 5: Non-invasive Phenotyping Approaches

The concept of non-invasive capturing of plant growth and health, Imaging technologies - image acquisition, segmentation and data analysis, Critical aspects of Visual, IR Thermal, Fluorescence, NIR, Hyperspectral imaging, Development and validation of models for deriving relevant physiological traits from image phenome. Concepts of Plants to sensors and sensors to plants, Stationary and ground based tractor mounted sensors/imaging tools, Unmanned aerial vehicle (UAV) sensors, Machine learning and its integration to analyze ground and aerial based images.

Block 2: Applications of the Phenomics Platforms

Unit 1: Basic Studies to Assess the Crop Response

Functional validation of genes, chemicals and other interventions, Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait.

Unit 2: Applied Studies Focused on Crop Improvement Programs

Characterizing the pre-released promising lines for productivity under defined environmental variables. Phenotyping germplasm accessions, mapping populations for specific traits for mapping, Concept of Phenome Wide Association Studies (PWAS). Genomic selection, gene-based crop models to predict complex traits, Impact of phenomics platform, progress made, case studies.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to understand the current progress made in various phenotyping techniques and approaches.

IX. Suggested Reading

- Pieruschka R and Poorter H. 2012. *Phenotyping plants: genes, phenes and machines. Functional Plant Biology*, 39(11), 813-820.
- Noah F, Gehan MA and Baxter I. 2015. *Lights, camera, action: high-throughput plant phenotyping is ready for a close-up. Current Opinion in Plant Biology* 24 2015: 93-99.
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- Costa C, Schurr U, Loreto F, Menesatti P and Carpentier S. 2018. *Plant Phenotyping Research Trends, a Science Mapping Approach. Frontiers in Plant Science*, 9.
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- Golzarian MR, Frick RA, Rajendran K, Berger B, Roy S, Tester M and Lun DS. 2011. *Accurate inference of shoot biomass from high-throughput images of cereal plants. Plant Methods*, 7(1), 2.
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- Hartmann A, Czauderna T, Hoffmann R, Stein N and Schreiber F. 2011. *HTPheno: an image analysis pipeline for high-throughput plant phenotyping. BMC bioinformatics*, 12(1), 148.
- Berger B, Parent B and Tester M. 2010. *High-throughput shoot imaging to study drought responses. Journal of Experimental Botany*, 61(13), 3519-3528.
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- Li, L, Zhang Q and Huang D. 2014. *A review of imaging techniques for plant phenotyping. Sensors* 14(11) 20078-20111.
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- Araus JL, Kefauver SC, Zaman-Allah M, Olsen MS and Cairns JE. 2018. *Translating high-throughput phenotyping into genetic gain. Trends in Plant Science* 23(5): 451-466.

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- Montes JM, Melchinger AE and Reif JC. 2007. *Novel throughput phenotyping platforms in plant genetic studies. Trends in Plant Science*, 12(10): 433-436.
- Development of high throughput plant phenotyping facilities at aberystwyth (ppt)
- Zhou J, Reynolds D, Websdale D, Le Cornu T, Gonzalez-Navarro O, Lister C and Clark M. 2017. *CropQuant: An automated and scalable field phenotyping platform for crop monitoring and trait measurements to facilitate breeding and digital agriculture*. BioRxiv, 161547.
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I. Course Title : Experimental Techniques to Characterize Plant Processes for Crop Improvement

II. Course Code : PP 605

III. Credit Hours : 0+2

IV. Why this Course?

Techniques, tools and instrumentation facilities drive the research in modern biology. The course addresses recent developments related to advanced quantification methods based on novel methodologies and instruments. Besides the emphasis is on new emerging trends in assessing physiological and biochemical processes based on surrogate methods. Several molecular biology techniques are now essential to comprehend physiological processes. The course provide comprehensive picture on these areas addressing recent developments in this area.

V. Aim of the course

Aim of this course is to provide exposure to phenotype very specific physiological processes which have direct relevance in crop improvement programmes. The course provides insight on recent techniques and methodologies on each of the major physiological processes like stress responses, photosynthetic process, hormone area, photo-morphogenesis and genomics aspects.

The course is organized as follows:

No.	Blocks	Units
1.	Characterization of Plant Processes: Experimental Techniques and Crop Improvement	1. Stress Responses 2. Photosynthetic processes 3. Hormonal Response on Specific Plant Growth Processes and Quantification 4. Nutrient Response Acquisition and Quantification 5. Photo and Thermo Morphogenesis 6. Recent Approaches for Functional Genomics

VI. Theory

Block 1: Characterization of Plant Processes: Experimental Techniques and Crop Improvement

Unit 1: Stress Responses

Thermal (reflectance) characters as a measure of water status and root characteristics, Oxidative stress induction and assessing the response on lipid peroxidation and quantification of ROS, RCC's, RNS, Fluorescence to assess the stress response, Water use efficiency quantification at leaf, plant level, surrogates for WUE, Tissue localization of ROS, RNS by qualitative staining and fluorescence-based methods.

Unit 2: Photosynthetic processes

Concept and approaches to assess of radiation utilization efficiency (RUE), Quantification of mesophyll and other diffusive resistances regulating photosynthesis. Carboxylation efficiency (light and CO_2 response curves), RuBiSCO activation status

Unit 3: Hormonal Response on Specific Plant Growth Processes and Quantification

Bioassays to assess the biological process regulated by hormones – new in-vivo assays, Promoter assays for hormone response- GUS/YFP/GFP based assays-expression of hormone responsive genes, Recent analytical tools and techniques to quantify hormones – GC-MS, LC-MS, Capillary electrophoresis.

Unit 4: Nutrient Response Acquisition and Quantification

Recent advances in soil less cultures to study the nutrient response- Hydroponics/

Aeroponics/Fogoponics, Noninvasive techniques to quantify nutrients – XRD (X-Ray Diffraction analysis) and hyper spectral reflectance.

Unit 5: Photo and Thermo Morphogenesis

Photo receptors, light and temperature regulation of plant growth and flowering, Thermal time, heat units, GDD, Concept and approaches for speed breeding.

Unit 6: Recent Approaches for Functional Genomics

In silico prediction of gene function, Flanking sequence identification in insertional (T-DNA/transposon) mutants, Concept of insertional mutagenesis and mutant experiments, Utilization of genetic resources for functional genomics – mutants and tilling, eco tilling, VIGS, RNAi, miRNA, Genome editing –CRISPR, Concept of chemical genomics for functional validation, Relevant molecular tools to assess gene expression or (to regulate the process and assign a function to gene), Multiple gene expression by Nano String technology, Cap analysis gene expression (CAGE) – to identify start point of transcription, Yeast hybrid interaction, Immunoprecipitation, Chip-PCR.

VII. Teaching methods/activities

- Practical Assignments
- Results presentation

VIII. Learning outcome

After completion of this course students are expected to develop practical skill and knowledge on various experimental techniques employed in crop improvement programme. Moreover, students will have experience with characterization of plant processes.

IX. Suggested Reading

- Costa, Miguel and Grant, Olga and Chaves M. 2013. *Thermography to explore plant-environment interactions. Journal of Experimental Botany* **64**. 10.1093/jxb/ert029.
- Padhi Jyotiprakash and K Misra R and Payero Jose. 2009. *Use of infrared thermography to detect water deficit response in an irrigated cotton crop.*
- Root Phenotyping for Drought Tolerance: A Review, Wasaya A, Zhang X, Fang Q and Yan Z. 2018. *Agronomy* 8, 241; doi: 10.3390/agronomy8110241
- Zhang Y, Menghong D and Zonghui Y. 2018. *Methods for the detection of reactive oxygen species. Analytical Methods* 10 (38): 4625-4638.
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- Sinclair TR and Muchow RC. 1999. *Radiation use efficiency. In Advances in Agronomy* 65: 215-265. Academic Press, 1999.
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- Ljung K, Sandberg G, Moritz T. 2010. *Methods of Plant Hormone Analysis*. Davies P.J. (eds) *Plant Hormones*. Springer, Dordrecht
- Šimura J, Antoniadi J, Tarkowská D, Strnad M, Ljung K and Novák O. 2018. *Plant hormonomics: Multiple phytohormone profiling by targeted metabolomics. Plant Physiology* 177 (2): 476-489.
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- Watson A, Ghosh S, Matthew JW, Cuddy WS, Simmonds J, Rey MD *et al*. 2018. *Speed breeding is a powerful tool to accelerate crop research and breeding. Nature Plants* 4 (1): 23.
- Kahl G and Khalid M (eds.). 2008. *The handbook of plant functional genomics: concepts and protocols.* John Wiley and Sons.
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- Sadhukhan A and Sahoo L and Panda S. 2012. *Chemical Genomics in Plant Biology*. *Indian Journal of Biochemistry and Biophysics*. 49. 143-154.
- Fung TH, WeiwenXue V, Koh SP, Chiu YM, Ng LP and Wong SC. 2017. *NanoString, a novel digital color-coded barcode technology: current and future applications in molecular diagnostics. Expert review of molecular diagnostics* **17** (1): 95-103.
- Rimantas K, Kojima M, Nishiyori H, Nakamura M, Fukuda S, Tagami M, Sasaki *D et al*. 2006. *CAGE: cap analysis of gene expression." Nature Methods* 3 (3): 211.

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- Mishra KB, Mishra A, Klem K and Govindjee. 2016. *Plant phenotyping: a perspective Ind J Plant Physiol*. DOI 10.1007/s40502-016-0271-y
- Sudhakar P, Latha P, and Reddy PV. 2016. *Phenotyping crop plants for physiological and biochemical traits*. Academic Press.
- Li L, Zhang Q and Huang D. 2014. *A Review of Imaging Techniques for Plant Phenotyping*. Sensors. 14, 20078-20111; doi: 10.3390/s141120078

I. Course Title : Global Climate Change and Crop Response

II. Course Code : PP 606

III. Credit Hours : 2+0

IV. Why this Course?

Present Indian agriculture encounters tremendous challenges due to rapid climate change. Climate change exerts remarkable negative impact on food, nutritional and ecological security. It significantly affects the plant physiological processes, hence yield is severely affected. Therefore students of plant physiology need to quip themselves with knowledge and skill sets required to navigate the climate change scenario and its impact on crops physiological processes. Hence, this course is designed .

V. Aim of the Course

The course is designed to provide basic knowledge on the subjects of crop responses to climate change. The aim of this course is to address both long-term and short-term effects of climate change on crops, natural vegetations and ecosystems.

The course is organized as follows:

No.	Blocks	Units
1.	Climate Change: Crop Response and Mitigation	1. Fundamentals of Climate Change 2. Manifestations of Climate Change 3. Major GHGs (CO_2, Methane, NO_2 etc.), their Production Rates, Monitoring and their Influence on Climate Change 4. Agricultural Practices on GHG Production 5. Direct and Indirect Effects of Climate Change on Plant Processes 6. Climate Change Scenario and Impact on Crops 7. Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth 8. Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems 9. Technologies for Climate Change Mitigation in Agriculture 10. Climate-resilient Agriculture 11. Climate Change: Technologies for Crop Response Studies 12. Politics of Climate Change Negotiations

VI. Theory

Block 1: Climate Change: Crop Response and Mitigation

Unit 1: Fundamentals of Climate Change

Definition of climate change, history and evidences of climate change and its implications. Natural and anthropogenic climate change. Sources of Greenhouse Gas (GHG) emission, Global Warming Potential of GHGs, accumulation of GHGs in the atmosphere and science behind climate change, industrial revolution and GHG build-up in the atmosphere, Energy-Emission-Economy Interactions, carbon intensity of economy, carbon equity/justice.

Unit 2: Manifestations of Climate Change

Impact on monsoons, occurrence of extreme weather events, hydrological cycle and water availability, effect on crop growing period in tropics, subtropics and temperate regions, shifts in distribution of flora and fauna, effects on biodiversity and migration of tropical plant species to higher latitudes and altitudes.

Unit 3: Major GHGs (CO_2, Methane, NO_2, etc.), their Production Rates, Monitoring and their Influence on Climate Change

GHGs: An Overview, - role of CO_2, methane and major uncertainties. Mechanism of their production and emission from various, source and sinks of GHGs; and contribution of GHGs to global warming. Techniques used in monitoring GHGs.

Unit 4: Agricultural Practices on GHG Production

Carbon footprint analysis of agriculture and various agricultural practices contribute to climate change. Impacts of natural factors and farming practices on greenhouse gas emissions. Sources of agricultural GHG emission- Agricultural Soil Management, enteric fermentation, manure management, other sources. Opportunities to reduce GHG emission from Agriculture.

Unit 5: Direct and Indirect Effects of Climate Change on Plant Processes

Problems and Prospects of Crops with changing temperature: Growth and Development of Crop plants, Thermo-morphogenesis, phenology, Physiological processes such as photosynthesis, Net carbon assimilation, C_3 and C_4 plants adaptation,Respiration, Nutrient acquisition and metabolisms, Plant water relations and Heat shock proteins, Grain/seed development: Grain Quality parameters and yield.

Unit 6: Climate Change Scenario and Impact on Crops

Different scenarios for temperature, rainfall in different agro-climatic zones of India and their impact on crop growth and productivity. Major climate change (temperature, CO_2, and rainfall) impact quantification using field or controlled environment experiments, meta-analysis and simulation models. Some examples of crop simulation models calibration and their application in short-term and long-term predictions.

Unit 7: Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth

Role of CFCs in ozone depletion, penetration of ionizing UV radiations and its implications on crop growth.

Unit 8: Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems

Response of natural ecosystems to increasingatmospheric CO_2 concentration and climate warming, effect of climate change on quality of feed i.e leaf and stored grains/seeds, its implications on pollinators and pests

Unit 9: Technologies for Climate Change Mitigation in Agriculture

Agricultural biotechnology to produce crop varieties with enhanced carbon uptake.
Nutrient management: Management of nitrogenous fertilizers.
Tillage/residue management: 1.Conservation tillage CO_2 mitigation technology; 2. Biochar: A potentialtechnique for carbon sequestration.
Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors.
Carbon sequestration potential, concept and measurement.

Unit 10: Climate-resilient Agriculture

Conventional and biotechnological approaches to improve the crop adaptation to climate change. Relevance of "Genome wide mutants" to identify genes/processes for improved adaptation to changing environments.

Unit 11: Climate Change: Technologies for Crop response studies

Temperature Gradient Chambers, Temperature Gradient Greenhouses, Soil plant atmosphere research system (SPAR), Infra-red warming Technology, Free Air temperature enrichment technology, Soil Warming system etc.

Unit 12: Politics of Climate Change Negotiations

IPCC, Major International conventions/treaties, Kyoto Protocol, Paris Agreement, Global initiatives on Carbon sequestration, carbon trading.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

After completion this course, students will be able to obtain in depth and basis knowledge on crop responses to climate change.

IX. Suggested Reading

- Uprety DC and Reddy VR. 2016. *Crop responses to Global warming*, Springer publication, ISBN 978-981-10-2004-9, pp 1-125 (2016)
- Torquebiau E. 2015. *Climate Change and Agriculture Worldwide* Springer Netherlands
- Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca. 2018. *Climate Smart Agriculture: Building Resilience to Climate Change.* Springer, FAO.
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- IPCC AR5 Reports WG I 2013
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- IPCC Special Reports
- UNFCCC website
- IPCC website
- NOAA website
- CCAFS website
- India's Second National Communication to UNFCCC

- INCCA Report, MoEF and CC
- MoEF and CC website

I. Course Title : Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield

II. Course Code : PP 607*

III. Credit Hours : 3+0

IV. Why this course?

Yield level reached plateau in many crops improving yield potential and crop growth rate forms the basis for further improvement in productivity. Photosynthesis and the establishing sink capacity are crucial processes to achieve this goal. Very good progress has been made in deciphering the molecular mechanisms to regulate several photosynthetic processes at cellular and canopy level. Similar insights now exist regarding establishing sink size (capacity). In the last five years, phenomenal conceptual approaches have been developed to understand the basic physiological and molecular mechanisms to enhance the source through photosynthetic processes. Besides, scientific insights in recent years provided leads in improving sink ie., yield associated traits. Yield plateau can be broken only by enhancing yield potential by structured improvement in source capacity and sink size.

V. Aim of the course

The course addresses the recent development in photosynthetic processes that can be exploited to improve yield potential. Besides, other major emphasis is to provide exposure on recent developments in regulating the sink characters ie., yield attributes at molecular level to achieve higher potential yields.

The course is organized as follows:

No.	Blocks	Units
1.	Source Size and Function- Basic Concepts, Physiological and Molecular Mechanisms, Genomic RESOURCES to Regulate Source Characters	1. Source Establishment 2. Source Function- Photochemical Reactions 3. Source Function- CO_2 Diffusion and Concentration 4. Source Function- Metabolic Engineering of CO_2 Fixation 5. Case Studies to Improve Source Capacity
2.	Improving Sink Size and Capacity	1. Sink Establishment 2. Increase the Sink Size by Enhancing the Relevant Constituent Traits 3. Genetic Genomic RESOURCES, Genes/QTLs, Genetic RESOURCES to Improve Sink Traits– Case Studies 4. Source to Support the Sink Capacity

VI. Theory

Block 1: Source Size and Function–Basic Concepts, Physiological and Molecular Mechanisms, Genomic Resources to Regulate Source Characters

Unit 1: Source Establishment

Maximize energy capture by improved light interception, light distribution and its utilization efficiency, concepts of shade avoidance response (SAR) and option to increase, Increase canopy size by vertical expansion – concept of increasing optimum LAI levels, Concepts of semi-tall varieties with resistance to lodging: traits associated with lodging resistance, Sustain net carbon gain with age – the relevance of stay green character, photon capture and achieve high CO_2 reduction to photon ratio under low light, Options for increasing canopy photosynthesis, Relevance of maintaining cell turgor and nutrient status.

Unit 2: Source Function- Photochemical Reactions

Maximize conversion efficiency of intercepted radiation by improving net carbon gain - Emerging solutions to increase carbon fixation rate, Improve efficiency of photochemical reaction by - Engineering the pigments to expand PAR spectrum into IR range; reduce antenna size, optimize energy dissipation mechanisms; optimize components of ETC and downstream acceptors; accelerate adaptation for shifting light intensities.

Unit 3: Source Function- CO_2 Diffusion and Concentration

Enhance stomatal conductance (g_s) and mesophyll conductance (g_m) – guard cell metabolism; concepts of leaf mesophyll tissue thickness (SLW), Concepts of VPD responses of g_s to enhance duration of photosynthesis during the day, Bicarbonate transports and aquaporins; achieve higher CCM - Engineering C4 cycle, CAM, cyanobacteria, carboxysomes, algal pyrenoids.

Unit 4: Source Function- Metabolic Engineering of CO_2 Fixation

RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO with enhanced specificity to CO_2, Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors, Increased activation state by improving stability and function of RuBisCOactivase; optimize RuBp regeneration – modulate specific enzyme levels. New concepts on photorespiratory synthetic bypass.

Unit 5: Case Studies to Improve Source Capacity

Genetic and genomic resources, genes/QTLs associated with specific yield potential traits and/or photosynthetic mechanisms, Genetic resources to improve source traits-case studies.

Block 2: Improving Sink Size and Capacity

Unit 1: Sink Establishment

Optimise duration of phenological stages related to sink establishment, genetic and environmental factors, GDD and phenology.

Unit 2: Increase the Sink Size by Enhancing the Relevant Constituent Traits

Role of hormones in regulating molecular mechanisms of yield structure development, Genomic and genetic resources developed for regulation/improvement of such traits. – Sink Size: Tillering associated traits, branching patterns/fruiting points, spikelet number, pod number, fruit number. – Sink development: Basic concepts and molecular mechanisms associated with pollination, fertilization, ovary development in determining the spikelet fertility/sterility components and strategies for engineering seed/fruit size in crop plants.

Unit 3: Genetic and Genomic Resources, Genes/ QTLs, Genetic Resources to Improve

Sink Traits- Case Studies. Progress and status in developing genomic and genetic resources of validated genes/ QTLs to improve sink traits- Specific case studies.

Unit 4: Source to Support the Sink Capacity

Canopy architecture to support sink requirements in cereals: plant height, tillering, leaf area, shading or senescence of lower canopy leaves, canopy photosynthesis, Canopy architecture to support sink requirements in Pulses: Leaf senescence, abscission, mobilization of N and other nutrients, Symbiotic N fixation to support sink size and capacity in pulses.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to:

1. comprehend the current development in photosynthetic research
2. know how to employ the theoretical concept of photosynthetic research in yield improvement programme
3. understand the mechanisms of source and sink establishment

IX. Suggested Reading

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- Sato T, Shimoda Y, Matsuda K, Tanaka A, Ito H. 2018. *Mg-dechelation of chlorophyll a by Stay-Green activates chlorophyll b degradation through expressing Non-Yellow Coloring in Arabidopsis thaliana. Journal of Plant Physiology* 222 (2018) 94–102
- Christophera M, Chenub NK, Jenningsa R, Fletchera S, Butlera D, Borrellc A, Christopher J. 2018. *QTL for stay-green traits in wheat in well-watered and water-limited environments. Field Crops Research* 217 (2018) 32–44
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- Narnoliya *et al*. *Transcriptional Signatures Modulating SAM Morphometric and Plant Architectural Traits Enhance Yield and Productivity in Chickpea, The Plant Journal.*

I. Course Title : Seed and Fruit Growth and their Quality Improvement

II. Course Code : PP 608

III. Credit Hours : 2+0

IV. Why this Course?

Seed as a propagule is an important input for agriculture. From this context, aspects related to seed development, its dormancy and viability etc. assumes significance. Besides, seed is the major source of nutrition to mankind and hence, quantitative and qualitative differences in seed constituents and their modification and improvement have been the area of focus in recent years. Several molecular approaches are now being adapted to improve the seed characters like longevity, vigour and seed quality. In addition to seed and fruit development, processes regulating the post-harvest deterioration of fruits and vegetables, increasing their self-life are another area that needs comprehensive intervention involving molecular biology tools and techniques. The course therefore addresses recent developments on these aspects.

V. Aim of the course

The major aim of the course is to train and educate the students about the importance of seeds and fruits as a source of nutrition for human health. Further, this course also addresses how to improve the nutritional status besides protecting the nutritive value of seeds and fruits. In addition, the other aim of the course is to address to regulate the post harvest deterioration of seeds and fruits to minimize the losses.

The course is organized as follows:

No.	Blocks	Units
1.	Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement	1. Physiology of Seed Growth and Development 2. Seed as a Propagule 3. Seed as a Source of Nutrition 4. Quality Deterioration during Storage 5. Fruit Growth and Development 6. Fruit as a Source of Phytochemicals: Nutraceuticals 7. Fruit Ripening, Post Harvest Deterioration and Shelf life

VI. Theory

Block 1: Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement

Unit 1: Physiology of Seed Growth and Development

Mechanism of seed development and different developmental stages; synthesis, mobilization and accumulation of stored reserves, Forms of stored reserves and their localization, Sink drawing ability (SDA) and its relevance in seed growth and development, Role of plant hormones in seed growth and development and SDA.

Unit 2: Seed as a Propagule

Seed as a propagation material; seed size and seed chemical composition and their relevance in seed germination, Physiological, biochemical and molecular mechanisms and approaches to regulate seed germination, seedling emergence and establishment and seedling vigour, Physiological, biochemical and molecular mechanisms and approaches to regulate seed priming and crop establishment: seed dormancy, precocious germination and controlling pre-harvest sprouting in crops, Physiological, biochemical and molecular mechanisms and approaches to regulate seed viability, improving the viability and storability of seeds.

Unit 3: Seed as a Source of Nutrition

Seed as a source of nutrition to humans: approaches to improve the quality of seeds through synthesis of seed storage reserves and other constituents, Genes/ QTL's regulating these processes and concept of pathway engineering to improve the quantity and quality of seed constituents, Carbohydrates- Amylose and amylopectin ratios for glycemic index, resistant and digestable starch, improving dietary fibre, alter gelatinisation, Protein content, modified proteins, essential amino acids, Oil content, fatty acid composition, Omega 3 fatty acids. Carotenoids and vitamins, Biofortification strategies to enhance the grain zinc, iron, other minerals and other essential compounds, Engineering for low protease inhibitors, phytic acid, tannins, phenolic substances, lectins, oxalates as anti-nutritional factors, Case studies of improving seed nutrition components by molecular breeding and transgenic approaches.

Unit 4: Quality Deterioration during Storage

Changes in chemical composition during storage; factors influencing the deterioration of nutritional quality of seeds during storage; approaches to minimize nutritional quality deterioration, Effect of quality deterioration on human and animal health

Unit 5: Fruit Growth and Development

Flower and fruit development; concept of parthenocarpy, Physiological and biochemical changes during fruit development and chemical composition, Molecular approaches to regulate flower and fruit drop/ abscission; Role of hormones.

Unit 6: Fruit as a Source of Phytochemicals: Nutraceuticals

Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Antioxidants, Flavanoids, anthocyanins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Vitamins- Vitamin C, Tocopherol, Carotenoids, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Alkaloids, Mangiferin, tomatins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of DigestableFiber lycopene, stillbeans, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Aroma, monoterpenoids and Fatty acid esters.

Unit 7: Fruit Ripening, Post Harvest Deterioration and Shelf life

Physiological and molecular mechanisms of fruit ripening, Postharvest deterioration of fruits; factors regulating fruit deterioration; hormonal and environmental aspects of reducing post harvest deterioration of fruits, Physiological and Molecular approaches to regulate fruit ripening and shelf life: Role of Ethylene and Ethylene response factors regulating specific processes of fruit ripening; Approaches to regulate specific shelf life characters, Improving fruit ripening and shelf life by molecular approaches-Case studies.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

1. comprehend the importance of seeds and fruits as a source of nutrition
2. describe how to improve the nutritional status of grains and fruits
3. know how to protect the nutritive value of seeds and fruits
4. detect the post harvest deterioration of seeds and fruits and to minimize the losses

IX. Suggested Reading

- Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). *Seeds: Physiology of Development, Germination and Dormancy*, Springer-Verlag
- Larkins BA and Vasil IK (Ed). 2010. *Cellular and Molecular Biology of Plant Seed Development,* Springer
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- Lee J, Nou IS, Kim HR. 2012. *Current status in calcium biofortification of crops, J Plant Biotechnol* 39: 23–32, DOI: http://dx.doi.org/10.5010/JPB.2012.39.1.023
- Sharma D, Jamr G, Singh UM, Sood S and Kumar A. 2017. *Calcium Biofortification: Three Pronged Molecular Approaches for Dissecting Complex Trait of Calcium Nutrition in Finger Millet (Eleusine coracana) for Devising Strategies of Enrichment of Food Crops*, doi: 10.3389/fpls.2016.02028
- Gemede HF and Ratta N. 2014. *Antinutritional factors in plant foods: Potential health benefits and adverse effects. International Journal of Nutrition and Food Sciences*, 3(4), pp.284-289.
- Vasconcelos IM and Oliveira JTA. 2004. *Antinutritional properties of plant lectins. Toxicon*, 44(4), pp.385-403.
- Kumar D and Kalita P. 2017. *Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries*. Foods, 6(1), p.8.
- Kawakatsu T, Hirose S, Yasuda H and Takaiwa F. 2010. *Reducing rice seed storage protein accumulation leads to changes in nutrient quality and storage organelle formation. Plant Physiology* 154(4), pp.1842-1854.
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- Wills R and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*. UNSW press.
- Siddiqui MW. ed., 2015. *Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance*. CRC Press.
- Corpas FJ and Palma JM. 2018. *Nitric oxide on/off in fruit ripening. Plant Biology*, 20(5), 805–807.doi: 10.1111/plb.12852

I. Course Title : Plant-Microbe Interactions

II. Course Code : PP 609

III. Credit Hours : 2+1

IV. Why this Course?

Plant microbe encounters can be friendly or hostile. Plants are associated with a variety of microorganisms, including endophytes, phylloplane and rhizosphere microbes which provide plants with mineral nutrients and other benefits. In contrast phytopathogens obtain nutrition from plants leading to reduction in plant growth and subsequent killing. Besides the genetic makeup expression of the phenotype is regulated by environment and the plant microbe interaction especially the endophytes. It is also relevant to understand the plant-pathogen and plant-insect interactions to improve tolerance mechanisms by altering specific physiological and biochemical processes. The combined effects of biotic and abiotic are another aspects of importance. Understanding how physiology of plants simultaneously exposed to abiotic stress and pathogens decides the outcome of their interactions is important. The course provides comprehensive information on these aspects. Plant-microbe interaction is an emerging area and PhD scholar must be exposed to this new knowledge which might help in manipulation plant traits and boost crop growth.

V. Aim of the Course

The objective of the course is to provide the understanding how beneficial microbes (endophyte/rhizosphere/phylloplane microbiome) play a role in boosting the plant immune system and thereby stimulate plant health and growth. The course also aims to understand how plant pathogens are able to infect plants and how resistant plants are able to defend themselves. The course covers comprehensive interactive information from physiology, microbiology and genomics.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Pathogen Interaction	1. Introduction to Plant Pathogen Interaction 2. Genetic Basis of Host Pathogen Interaction 3. Growth Regulators of Plant Defense and Susceptibility 4. Bioenergetics in Plant Pathogen Interaction
2.	Plant-Endophytes/ Rhizosphere/ Phylloplane Microbes Interaction	1. Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants 2. Role of Endophyte/ Rhizospheric/ Phylloplane Microbiota in Plant Physiological Processes 3. Endophyte/ Rhizospheric/ Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance 4. Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research
3.	Microbial Interaction with Plants in The Presence of Abiotic Factors	1. Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction 2. Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

VI. Theory

Block 1: Plant Pathogen Interaction

Unit 1: Introduction to Plant Pathogen Interaction

Introduction to plant microbe interaction and importance, the concepts of holobiome and hologenome, Differences between endophytes/ rhizosphere/phylloplane microbes and phytopathogens, Types of endophytes/rhizosphere/phylloplane microbes, and their classifications

Unit 2: Genetic Basis of Host Pathogen Interaction

Genetics of immune response, Signal perception, Host-pathogen interaction (bacteria, fungus and virus), Nature of resistance to diseases-pathogenecity genes *(pat)* in plant pathogens-disease specific genes *(dsp), avirulence genes (avr), avr gene – coded proteins-structure of avr genes,* Transmission of the alarm signal to host defense producers: signal transduction, pathogen elicitors, protein kinases, calcium ions, phosphorylases, phospholipases, ATPases, Accumulation of Phytoalexins as a Resistance mechanism-Biosynthesis and metabolism of Phytoalexins, Modes of action of Phytoalexins, Pathogenesis-Related proteins (PR) and Disease Resistance- intro-Characterization and biological functions of PR proteins, Biosynthesis of PR proteins.

Unit 3: Growth Regulators of Plant Defense and Susceptibility

Regulation of hormones countering the pathogen infection and toxins modulating the plant physiology, ABA-SA cross talk and role of JA during plant interaction biotrophic and necrotrophic pathogens respectively.

Unit 4: Bioenergetics in Plant Pathogen Interaction

An overview of energy-capture and energy-utilization processes in higher plant, Energy-capture and utilization process as affected by pathogenic infection, Molecular basis of pathogenesis and the process of interaction- classical examples of pathogens causing necrosis, wilts, tumours and soft rots, Role of primary metabolism in plant-pathogen interaction.

Block 2: Plant-Endophytes/ Rhizosphere/ Phylloplane Microbes Interaction

Unit 1: Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants

Approaches to study endophytic/ rhizosphere/ phylloplane microbes bacteria and fungi, Intracellular bacteria 'Cytobacts', Possible mechanisms of host plant genotype influence in recruitment of endophytic microbes vertical/ seed transmission, Inter-kingdom signaling regulating endophyte/ rhizosphere/phylloplane microbes development, Adaptation with respect to colonization of endophytes/ rhizosphere/ phylloplane microbes.

Unit 2: Role of Endophyte/ Rhizospheric/ Phylloplane Microbiota in Plant Physiological Processes

Phytohormones role in beneficial endophyte/rhizospheric/phylloplanerecruitment, Hormonal regulation of assimilate partitioning in plant-microbe interactions, Plant-Fungus-Bacteria, the three fold interaction for improved plant nutrition.

Unit 3: Endophyte/ Rhizospheric/ Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance

Importance in imparting stress (biotic and abiotic) adaptations, in the regulation of bioactive compound (alkamide) accumulation; acclimatization of root-interacting fungi for improved plant nutrition and stress tolerance, Cultivable versus uncultivable endophytes with respect to their extent of tissue colonization and diversity, Genetic engineering of endophytes for production of industrially important bioactive compounds, endophyte-enrichment technologies in crops for traits manipulation, Role of existing microbiome on introduced endophyte, symbiotic microbes and their interaction, Modern techniques for examining plant-microbe-insect interactions.

Unit 4: Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research

DBT biosafety regulations on working with microbial organisms associated with plants, Standard operating procedure (SOP), Committees dealing with biosafety and safe release of microorganisms.

Block 3: Microbial Interaction with Plants in the Presence of Abiotic Factors

Unit 1: Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction

Disease triangle involving plant-pathogen-environment and the importance of environmental stresses (drought, heat, humidity and soil factors) in influencing the resistance or susceptibility, Role of environmental factors in influencing establishment and sustenance of introduced beneficial microbes.

Unit 2: Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

Plant-water relations and changes in physiology in deciding the microbe interaction with plants, Metabolites in deciding the microbe interaction with plants, Hormonal cross talk, signal transduction, role of R-genes and other defense pathways during the simultaneous exposure to abiotic stress.

VII. Practicals

- *In-planta* bacterial/fungal multiplication in plant under drought stress
- Detection of plant pathogens using molecular tools
- Stomatal conductance in plants under drought stress and pathogen stress
- Apoplast isolation from plants subjected to bacterial infection
- Virus induced gene silencing in plants
- Acetylene reduction assays to check nitrogen fixation in plant (The effect of beneficial microbes in plant)
- Biochemical analyses of beneficial and pathogen-effector proteins
- Plant colonization and disease or growth promotion scoring
- In-vivo detection of plant immune responses and their inhibition by effectors
- Estimation of phytoalexins, PR proteins, ACC deaminase and growth hormones in pathogen challenged plants
- Effect of plant microbe interaction on plant physiological processes, viz. photosynthesis, chlroroplast, transpiration, etc.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

1. understand how beneficial microbes enhance the plant immune system
2. comprehend how beneficial microbes stimulate plant growth
3. describe plant-microbe interaction
4. understand plant defense and susceptibility

X. Suggested Reading

- Jones JDG and Dangl JL. 2006 *The plant immune system. Nature* Vol. 444, Pages 323–329
- Dodds PN and Rathjen JP. 2010. *Plant immunity: towards an integrated view of plant–pathogen interactions. Nature Reviews. Genetics.* Vol. 11, Pages 539–548
- Baker B, Zambryski P, Staskawicz B, Kumar SPD. 1997. Science. *Signaling in Plant-Microbe Interaction*. Vol. 276
- *The role of abscisic acid in plant–pathogen interactions.* Mani BM and Felix Mauch. *Current Opinion in Plant Biology*. 2005 8: 409-414 2005.
- Loake G and Grant M. 2007. *Salicylic acid in plant defence—the players and protagonists. Current Opinion in Plant Biology*.10: 466-472
- Kent AD and Triplett EW. 2002. *Microbial Communities and Their Interactions in Soil and Rhizosphere Ecosystems. Annual Review of Microbiology*. 56: 211-236
- Whipps JM. 2001. *Microbial interactions and biocontrol in the rhizosphere. Journal of Experimental Botany*. 52: 487–511.
- Vandenkoornhuyse P, Quaiser A, Duhamel M, Van AL, Dufresne A. 2015. *The importance of the microbiome of the plant holobiont. New Phytologist*. 206: 1196-1206 .

- Suzuki N, Rivero RM, Shulaev V, Blumwald E and Mittler R. 2014. *Abiotic and biotic stress combinations. New Phytologist*. 203: 32-4.
- Atkinson NJ and Urwin PE. 2012. *The interaction of plant biotic and abiotic stresses: from genes to the field. Journal of Experimental Botany*, 63: 3523–3543.

General Source Information

- Matveeva T, Provorov N, Valkonen JPT. *Cooperative Adaptations and Evolution in Plant-Microbe Systems*. Frontiers Media SA.
- Maheshwari, Dinesh K, Annapurna K. (Eds.). 2017. *Endophytes: Crop Productivity and Protection,* Ed. ISBN 978-3-319-66544-3; Springer.
- *Signaling in the Phytomicrobiome* Smith DL, Gravel V, Yergeau E. Frontiers Media SA
- Verma, Vijay C, Gange, Alan (Eds.) *Advances in Endophytic Research*. 2014, Eds: ISBN 978-81-322-1575-2; Springer
- Schulz, Barbara JE, Boyle, Christine JC, Sieber, Thomas N. (Eds.) *Microbial Root Endophytes,* Eds: 2004, ISBN 978-3-540-33526-9; Springer
- Choudhary, Devendra K, Varma, Ajit, Tuteja, Narendra (Eds.). 2016. *Plant-Microbe Interaction: An Approach to Sustainable Agriculture* Eds: ISBN 978-981-10-2854-0; Springer
- Miller, James R., Miller Thomas A. (Eds.) *Insect-Plant Interactions*, 1986, Eds.
- Ahmed S, Brattsten LB. *Molecular Aspects of Insect-Plant Associations*, ISBN 978-1-4613-1865-1 (Springer).
- Chandrakanth Emani. 2018. *The Biology of Plant-Insect Interactions: A Compendium for the Plant Biotechnologist* 1st Edn, ISBN 9781498709736 - CAT# K25008, CRC Press.
- Tejesvi MV, Pirttilä AM, Frank AC. *Emerging Tools for Emerging Symbioses—Using Genomics Applications to Studying Endophytes* by Frontiers Media SA
- Jyoti Shah, Linda Walling. *Advances in Plant-Hemipteran Interactions*, by Frontiers Media SA.
- Huang JS. 2009. *Plant Pathogenesis and Resistance* (*Biochemistry and Physiology of Plant-Microbe Interactions),* Kluwer Academic Publishers.
- Day PR. 1973. *Genetics of Host Parasite Interaction*,W.HFreeeman and Company.
- Sharma PD. 2006. *Plant Pathology,* Narosa Publishing House Pvt. Ltd.
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- Stainhaus EA. 1963. *Insect Pathology*, Academic Press, New York and London.
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- Bringel F and Couée I. 2015. *Pivotal roles of phyllosphere microorganisms at the interface between plant functioning and atmospheric trace gas dynamics. Front. Microbiol*. 6: 486. doi: 10.3389/fmicb.2015.00486.
- Lugtenberg B. (Ed.). 2015. *Principles of plant-microbe interactions***.** doi: https://doi.org/10.1007/978-3-319-08575-3.
- Velmourougane K, Saxena G, Prasanna R. 2017. *Plant-microbe interactions in the rhizosphere: mechanisms and their ecological benefits*. Singh D., Singh H., Prabha R. (eds) *Plant-Microbe Interactions in Agro-Ecological Perspectives*. Springer, Singapore. doi: https://doi.org/10.1007/978-981-10-6593-4_7.
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I. Course Title : Weed Biology and Physiology of Herbicide Action

II. Course Code : PP 610

III. Credit Hours : 2+0

IV. Why this course?

Weeds pose a serious threat to Crop production leading to a yield loss ranging from

30% to sometimes total failure. Weed management is a significant input on part of the producers. Chemical weed management through herbicides have been the most effective among various methods. Various herbicides with different modes of actions are used to control weeds. Prolonged chemical control has led to adverse environmental consequences and development of herbicide resistance. There is a need to understand the biology of weeds as well as herbicide actions at physiological and molecular levels for resistance management as well as development of more effective and less harmful chemicals for weed management. The aim of this course will be to apprise the students about these aspects of chemical weed control.

V. Aim of this course

The course is designed to provide both basic and applied knowledge on the weeds. It will help to understand the fundamental physiology, biochemistry, and molecular biology of herbicides and their effects on plants; To study the physiological and molecular mechanisms of herbicide resistance.

This course will provide knowledge on biology of weeds, classification and mode of action of herbicides, herbicide resistance and its management and environment friendly weed management strategies.

The course is organized as follows:

No.	Blocks	Units
1.	Weed Biology	1. Weed Biology and its Importance in Weed Management 2. Life Cycle and Population Dynamics of Weeds 3. Crop Weed Competition
2.	Physiology of Herbicide Action	1. Introduction to Herbicides 2. Mechanism of Action of Herbicides 3. Herbicide Resistance and its Management

VI. Theory

Block 1: Weed Biology

Unit 1: Weed Biology and its Importance in Weed Management

Introduction to weeds, Classification of weeds, Yield losses caused by weeds, Environmental impacts of invasive weed species, Aspects of Weed biology, Germination, Dormancy and growth behaviour of weed species, Effect of environmental factors on weeds, Adaptation of weeds to different ecologies

Unit 2: Life Cycle and Population Dynamics of Weeds

Growth duration and reproductive potential of weed species, Population dynamics, Weed Shift due to weed management, weed Seed Bank,

Unit 3: Crop Weed Competition

Understanding the nature of crop-weed competition, critical stages of crop weed competition, growth stages of weeds for improved control by herbicides

Block 2: Physiology of Herbicide Action

Unit 1: Introduction to Herbicides

Introduction, Chemistry and classification of herbicides by mechanism of action, HRAC Classification, Site of Actions, Application techniques, doses, active ingredients, formulations, Absorption and translocation of soil and foliar applied herbicides, Methods to increase the efficiency of soil and foliar applied herbicide – role of membranes, adjuvants, surfactants, synergists,

Unit 2: Mechanism of Action of Herbicides

Physiological and biochemical effects of herbicides: Effects on membrane structure and functions, cell division and cell development, Effects on chloroplast, photosynthesis, respiration, protein synthesis, synthesis of lipids, Molecular mechanism of action, Molecular mechanisms of herbicide resistance in relation to chloroplast gene expression,

Unit 3. Herbicide Resistance and its Management

Herbicide resistance-Definition, history, magnitude; Mechanisms of resistance: Target site and non-target site, cross and multiple resistances, Role of management practices on resitance development, Resistance management: Strategies; HR crops, Super weeds,

VII. Teaching methods/activities

– Lectures
– Assignment (Reading/Writing)
– Text Books / reference books and materials
– Student presentations

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Understand the importance of weed biology in weed management
– Understand the mechanism of herbicide action
– Understand the problem of herbicide resistance development
– Appreciate and suggest sustainable weed management strategies

IX. Suggested Reading

- Inderjit (Ed). 2004. *Weed Biology and Management*. Springer Netherlands
- Monaco, TJ, Weller SC, Ashton FM. 2002. *Weed Science: Principles and Practices*. John Wiley and Sons Inc., New York
- De Prado R, Jorrin J, and Garcia-Torres L. 1997. *Weed and Crop Resistance to Herbicides*. Kluwer academic Publishers, The Netherlands.
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Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Biotechnology and Bioinformatics

– Bioinformatics
– Molecular Biology and Biotechnology

Contents

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– Bioinformatics

Executive Summary
(Bioinformatics)

- Bioinformatics has emerged as an interdisciplinary and integrated scientific discipline, which links the computational and statistical sciences with life sciences. A big hurdle in the development of Bioinformatics in India is the limited availability of trained human resource, faculty and Ph.D. scholars in the field. However, with the constant efforts put forth by ICAR and SAUs in recruiting ARS scientists/ Assistant Professors in bioinformatics, the problem of faculty shortage has been reduced to some extent. Also, the students from this discipline get motivated with such employment opportunities. Wherever the new recruitments take time, the faculty drawn from computer science, statistics, biotechnology, biochemistry disciplines may be sent for training in bioinformatics within India or at abroad. In order to reach the unreached discoveries and innovations through bioinformatics, one should have a reasonably good infrastructure with high-end servers, high-speed internet connectivity, CPU/GPU based high performance computing system, high storage, smart classrooms, open source software, Linux-Apache-MySQL-Perl/PHP (LAMP) technology, etc. The need of the hour is to deploy advanced techniques of artificial intelligence, machine learning and big data analytics to unravel the underlying mechanisms and factors involved in complex biological phenomena and thus, the syllabus has been revised in this light. Recent developments in bioinformatics have become indispensable for use in omics and systems biology approaches. Thus, these developments have now been made part of the syllabus as follows.
- Five new courses have been added including (i) “Non-Coding RNAs”, (ii) “Comparative and Functional genomics”, (iii) “Systems Biology”, (iv) “R and high dimensional genome data” and (v) “Big data analytics” to prepare the students for meeting the challenges arising out of complex genomes.
- Emphasis has been laid on disassociating the overlaps in the existing courses, incorporating the new concepts in the courses like network modelling and systems biology, machine learning techniques in bioinformatics, parallel programming and algorithm development so that any student after completing his M.Sc. degree in bioinformatics can discharge his duties both as bioinformaticist and bioinformatician.
- More emphasis was given on practicals so that the students can efficiently deal with the high dimensional data sets of Next Generation Sequencing (NGS), Genotype-By-Sequencing and Genome Wide Association Studies (GWAS) with special skills.
- The revised syllabus addresses the recent advances and modern concepts of AI, Machine Learning in analyzing big data coming from genomics, transcriptomics, proteomics and other omics researches.
- The demand for trained manpower in bioinformatics is increasing in private sector, which is a healthy sign for the PG students. Care has been taken while devising the syllabus to incorporate more practicals on computer programming and high-dimensional genome data analysis software.

Preamble

Driven by the recent developments in high throughput Genomics, Bioinformatics is taking an ever-increasing role in Agri-genomics. In a similar way, advances in information technology and computational methods are driving the mathematical sciences forward. Artificial Intelligence and Big Data analytics have revolutionized the bioinformatics-based genome data analysis. Now with the availability of next generation sequencing technologies, a high volume of both structured and unstructured data is available. Further, data is also available from many genome data repositories like GenBank at National Centre for Biotechnology Information in the public domain. All these have led to the availability of the huge amount of data from different agricultural organisms that need to be analyzed and elicit the hidden information for knowledge discovery to unravel the underlying complex biological phenomena.

In order to achieve the goals of bioinformatics: (i) designing of algorithms for handling and analysis of genomic big data (ii) development of statistical-computational methods and techniques, automated pipelines, tools for high dimensional genome data analysis (iii) accessing the existing databases and sharing the developed tools and databases in public domain; planning strategies and human resources are to be developed in genomics research to solve the national level problems and issues. To mention a few, the priority areas are: (i) plant and animal improvement through genomics-assisted breeding and genomic selection (ii) climate smart crop production for food security (iii) metagenome wide association study of soil microbiome with crop productivity by machine learning (iv) GWAS, PheWAS and phenomics aided improvement programmes (v) artificial intelligence (AI); machine learning – an approach to achieve AI; and deep learning– a technique for implementing machine learning; for knowledge discovery through agri-genomics (vi) blockchain technology and data science for agricultural value chain (vii) role of microbiota in plant and animal health care and expression of economically important traits (viii) designing and development of Agri-Encyclopedia of DNA Elements (A-ENCODE) (ix) identification of bioremediation bacteria and probiotics from Indian river system for pollution remediation (x) improved and efficient algorithms for robust genome assembly from data generated under different Next Generation Sequencing platforms. Possessing expertise and skills in computer programming languages like R and python is essential for bioinformaticians, who are developers of bioinformatics tools and pipelines in the system. Above all, there exists always a rapidly increasing demand for individuals to be trained in bioinformatics with special skills and knowledge to handle high dimensional genomic data. The emerging trends in genomic research, need for human resources for teaching and application of bioinformatics in genomic research for crop improvement, shrinking job opportunities in the public sector etc would warrant students to possess the technical knowledge and skills in bioinformatics coupled with good practical and management skills, to be competitive for both public and private sectors. Hence a thorough restructuring of course curriculum and delivery system is needed.

In this revised course curriculum of Bioinformatics, the BSMA sub-group organized a series of meetings to develop the courses for M.Sc. and Ph.D. programs for the NAREE system. The meetings were focused on keeping different courses on AI/ML/DL, programming languages, big data analytics in the curriculum without compromising on the quality and the content in terms of imparting the requisite up to date knowledge to the students. Thus, the basic platform courses are kept as core courses that need to be taken by all the students irrespective of the subject specialization from which they entered the PG education. The course curriculum also targets the M.Sc. and Ph.D. students separately by providing two sets of courses and advanced courses to the Ph.D. students only. Also, substantial inputs were provided by the experts to introduce recent developments in the advanced courses so that the concepts are ingrained when the M.Sc. graduates enter to the Ph.D. system. An additional input received during discussion was on enabling the SAUs and Deemed-to-be Universities to have reasonably good infrastructure that helps students to have comprehensive knowledge with hands on training. This will help the students build confidence in becoming entrepreneurs in bioinformatics, get employment in R&D companies so that the gains in education gets translated to the end user, the produccers, processors and the consumers.

The opinions and suggestions invited from the institutions, eminent scientists and other stakeholders were revived by the BSMA sub-committee. The new look and restructured PG programme in bioinformatics has been designed by considering the needs of private sector, modern statistical and computational methods, algorithms, artificial intelligence and machine learning, and big data science to enhance the global competitiveness and employability of the students. Thus, considerable and markable efforts have gone into the preparation of the present revised course curriculum of Bioinformatics.

Course Title with Credit Load
M.Sc. in Bioinformatics

Course Code	Course Title	Credits (L+P)
	Major: 20 credits	
	(12 credits of core plus 8 credits of optional)	
BI 501	Introduction to Bioinformatics & Computational Biology*	2+1
BI 502	Statistical Genomics*	2+1
BI 503	Genome Assembly and Annotation	1+1
BI 504	Biomolecular Modelling and Simulation*	2+1
BI 505	Transcriptomics and Metagenomics	2+1
BI 506	Biological Data Management*	2+1
BI 507	Biological network modelling and analysis	2+1
BI 508	Computer programming in bioinformatics	2+1
BI 509	Machine Learning Techniques in bioinformatics	2+1
	Minor (8 credits)	
	Molecular Biology and Biotechnology	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Any other related discipline	
	Supporting (6 credits)	
	Statistics	
	Mathematics	
	Computer Science	
	Any other appropriate discipline	
	Common courses	5
BI	Seminar	0+1
BI 500	Research	0+30
	Total	70

*Core courses

Courses Contents
M.Sc. in Bioinformatics

I. Course Title : Introduction to Bioinformatics and Computational Biology

II. Course Code : BI 501

III. Credit Hours : 2+1

IV. Aim of the course

To provide theoretical and practical knowledge about handling and processing of genomic data, optimization and data mining techniques used in bioinformatics.

V. Theory

Unit I (15 Lectures)

Overview of available genomic resources on the web; NCBI/ EBI/ EXPASY etc; Nucleic acid sequence databases; GenBank/EMBL/ DDBJ; Database search engines: Entrez, SRS. Overview/concepts in sequence analysis; Pairwise sequence alignment algorithms: Needleman and Wunsch, Smith and Waterman; BLAST, FASTA; Scoring matrices for Nucleic acids and proteins: PAM, BLOSUM, Multiple sequence alignment: PRAS, CLUSTALW. Sequence based gene prediction and its function identification.

Unit II (5 Lectures)

Preprocessing of gene expression data; Data Normalization techniques, Data quality control: Modelling of errors, Imputation etc; High-throughput screening.

Unit III (6 Lectures)

Optimization Techniques: concept and applications, Simulated Annealing, Genetic Algorithms: *Ab initio* methods for structure prediction; Information theory, entropy and relative entropy.

Unit IV (6 Lectures)

Foundations for Machine learning Techniques: Unsupervised and Supervised Learning, Cross Validation Techniques, Markov Model, Bayesian Inference: concepts and applications, Hidden Markov Model and applications, Introduction to WEKA package.

VI. Practicals

Database Similarity Searches, Multiple sequence alignment, Genome databases, Structural databases, Derived databases, Gene annotation, Gene prediction software. Analysis of DNA microarray experiments, Expression profiling by microarray/gene chip, Proteomics, Pattern recognition, Hidden Markov Models, Gibbs Sampling, Analysis of single and multiple DNA or protein sequences.

VII. Suggested Reading

- Baldi, P. and Brunak, S. 2001. *Bioinformatics: The Machine Learning Approach*. MIT Press.
- Baxevanis, A.D. and Francis, B.F. 2004. *Bioinformatics: A Practical Guide to the Analysis of*

Genes and Proteins. John Wiley.
- Wang JTL, Zaki MJ, Toivonen HTT and Shasha D. 2004. Data Mining in Bioinformatics.Springer.
- Amaratunga D and Cabrera J. 2004. *Exploration and Analysis of DNA Microarray and Protein Array*. John Wiley.
- Gupta GK. 2006. *Introduction to Data Mining with Case Studies*. Prentice Hall of India, New Delhi.
- Han J and Kamber M. 2006. *Data Mining: Concepts and Techniques*. Morgan Kaufman.
- Hand DH, Mannila P Smyth. 2001. *Principles of Data Mining*. Prentice Hall of India, New Delhi.

I. Course Title : Statistical Genomics

II. Course Code : BI 502

III. Credit Hours : 2+1

IV. Aim of the course

This course builds the basic understanding of statistical methods used in genetics and genomics.

VI. Theory

Unit I (14 Lectures)

Fundamentals of Population genetics: Hardy –Weinberg law, Effect of systematic forces on changes in gene frequency; Principles of Quantitative genetics: Values, Means and Variances, Detection and Estimation of Linkage, Inbreeding, Selection, Genetic Parameter Estimation, Variance component estimation, BLUP, G x E interaction, Path Analysis

Unit II (10 Lectures)

Molecular Marker based classification: similarity measures, clustering methods, bootstrapping; QTL mapping: Detection and Estimation of QTL, Single Marker Analysis, Interval Mapping and MQM;

Unit III (8 Lectures)

Design and Analysis of Expression Data; Genome Selection; Genome Prediction, Genetic Markers, Association Mapping; Genome Wide Association Analysis

VII. Practicals (16 Lectures)

Population genetics: Hardy-Weinberg law, Estimation of linkage, Inbreeding, Selection, Genetic parameter estimation, Variance component estimation, BLUP, Path analysis, Molecular marker based classification, Estimation of QTL, Single marker analysis, MQM, Analysis of gene expression data, Genome selection and Genome prediction.

VIII. Suggested Reading

- Xu, Shizhong. 2013. *Principles of Statistical Genomics*. Springer
- Ben Hui Liu. 1997. *Statistical Genomics: Linkage, Mapping, and QTL Analysis.*
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics.* Springer.
- Ben HL and Leming MS. 2013. *Statistical Genomics and Bioinformatics.*

I. Course Title : Genome Assembly and Annotation
II. Course Code : BI 503
III. Credit Hours : 2+1

IV. Aim of the course

The primary objective of this course is to develop practical understanding of techniques and tools used in genome assembly with emphasis on issues and challenges of its structural and functional annotation.

V. Theory

Unit I (6 Lectures)

Types and methods of genome sequence data generation; Shot gun sequencing method; Problems of genome assembly, Approaches of genome assembly: Comparative Assembly, DE novo Assembly; Read coverages; Sequencing errors, Sequence Quality Matrix, Assembly Evaluation; Challenges in Genome Assembly.

Unit II (5 Lectures)

Various tools and related methods of genome assembly: MIRA, Velvet, ABySS, ALLPATHS-LG, Bambus2, Celera Assembler, SGA, SOAP*denovo,* etc.

Unit III (5 Lectures)

Basic concepts of genome annotation; Structural and Functional Annotation; Identification of open reading frame (ORF) and their regularization, Identification of gene structure, coding regions and location of regulatory motifs

VI. Practicals (16 Lectures)

Genome assembly methods for data from various sequencing platform, Sequencing error determination, Sequence quality matrix; Various tools for genome assembly: MIRA, Velvet, ABySS, ALLPATHS-LG, Bambus2, Celera Assembler, SGA, SOAP *denovo*, etc. Structural and functional Genome annotation.

VII. Suggested Reading

- Jung, S., Paul, Gordon, M.K., Sensen, C. W. 2012. *Genome Annotation*. Chapman and Hall/ CRC
- Venter, J. C., 2000. *Annotation of the Celera Human Genome Assembly*. Celera.
- Mark Menor. 2007. *Multi-genome Annotation of Genome Fragments Using Hidden Markov Model Profiles*
- Carson Hinton Holt. 2012. *Tools and Techniques for Genome Annotation and Analysis*
- Alistair G. Rust, Emmanuel Mongin and Ewan Birney Loraine A.E and Helt G.A. 2002. *Genome annotation techniques: new approaches and challenges. Drug Discovery Today*. 570-576 p.
- Weizhong Li and Adam Godzik. 2002. *Discovering new genes with advanced homology detection. Trends in Biotechnology*, 20: 8, 315-316 p.

I. Course Title : Bio-molecular Modelling and Simulation
II. Course Code : BI 504
III. Credit Hours : 2+1

IV. Aim of the course

The course aimed to develop understanding of bio molecular modelling techniques and simulation.

V. Theory

Unit I (8 Lectures)

Methods for 3D Structure Prediction: Homology modeling of protein 3D structures – approaches to loop building, energy considerations and evaluation of the accuracy of the model. *ab initio* approach to 3D structure prediction; Threading approach to 3D structure prediction. A Comparison of protein structure prediction methods: CASP

Unit II (8 Lectures)

Basic principles of modeling, modeling by energy minimization technique, concept of rotation about bonds, energy minimization by basic technique for small molecules, Ramachandran plot, torsional space minimization, energy minimization in Cartesian space, molecular mechanics-basic principle

Unit III (8 Lectures)

Basic concepts of Simulation Modelling: Units and derivatives, Force field and energy landscape, Truncation of non-bonded interactions, Introduction to solvation, Periodic boundary condition, Wald summation, implicit solvent model and continuum electrostatics, Monte Carlo simulation on parallel computers. Replica-exchange simulations, Restraint potentials, Free energy calculations, Membrane simulations

Unit IV (8 Lectures)

Energy Minimization: Concept of energy minimization - hypersurface, local and global energy minima, statement of problem. Derivative minimization methods - first derivative methods: the steepest descents method, line search in one dimension, arbitrary step approach, conjugate gradients minimization. Second derivative method – the Newton-Raphson method. Applications of energy minimization.

VI. Practicals: (16 Lectures)

Protein structure databases: PDB, MODBASE, Structure visualization – Rasmol and PyMol, Structural analysis- classification, CATH, SCOP, Protein geometry – bond length, bond angle, torsion angle, calculation of surface area, volume and radii: Swiss PDB Viewer. Small molecule generation - peptides and nucleic acids: ISIS draw / ChemSketch, Selection of query sequence, template selection: pdbBLAST, Comparative 3D structure prediction – SWISSMODEL, Model generation - building side chains and loops using Modeller, Threading, *ab initio* modeling, Structure validation - generation and analysis of Ramachandran plot using PROCHECK, WHATCHECK via SAVS server, Force field calculation and energy minimization, Structure refinement - loop building, removing non-bonded contacts, adding missing side chains via WhatIf interface, Scoring structural similarity - 3D structure alignment - RMS superimposition – VMD, Molecular dynamics simulation using Tinker. Simulation dynamics, Monte carlo simulation on parallel computers. Replica exchange simulation, free energy calculation. Docking

VII. Suggested Reading

- Schlick T. 2010. *Molecular Modeling and Simulation: An Interdisciplinary Guide*. Science.
- Gunsteren WF, Weiner PK, Wilkinson AJ. 1997. *Computer Simulation of Biomolecular Systems: Theoretical and experimental application*. Springer.
- Martin JF. 2007. *A Practical Introduction to the Simulation of Molecular Systems*. Cambridge University Press.
- Leach AR. 2001. *Molecular Modeling: Principles and Applications*. Prentice Hall. 784p.

- Bourne PE and H Weissig. 2003. *Structural Bioinformatics*. Wiley-Liss. 650 p.
- Marx D and Hutter J. 2009. *Ab Initio Molecular Dynamics: Basic Theory and Advanced Methods*. Cambridge University Press. 578p.

I. Course Title : Transcriptomics and Metagenomics

II. Course Code : BI 505

III. Credit Hours : 2+1

IV. Aim of the course

The course aims to teach basic concepts of metagenomics and various techniques used in the analysis of metagenomic data

V. Theory

Unit I (8 Lectures)

Microarrays, RNA-seq, Chip-Seq, EST-clustering, differential expression analysis

Unit II (6 Lectures)

Taxonomic and genetic annotation of high throughput sequence data, microbial diversity analyses, analyses of microbial community composition and change and metabolic reconstruction analyses.

Unit III (9 Lectures)

Comparison between Metagenomics and AL, EC, Comparison between LCS and Metagenomics, Symbiotic Evaluations: SANE, Comparison between SANE and Metagenomics, Horizontal Gene Transfer: Microbial GA.

Unit IV (9 Lectures)

Metagenome Sequencing, Single Cell Analysis, Host-Pathogen Interaction; Shotgun metagenomics; High-throughput sequencing; Comparative metagenomics; Community metabolism; Metatranscriptomics.

VI. Practicals (16 Lectures)

Meta genome annotation, Analyses of microbial community composition and change and metabolic reconstruction analyses; Metatranscriptomics; Comparative metagenomics. Microarray data analysis; RNA-seq, chip-seq, EST-clustering.

VII. Suggested Reading

- Diana marco. 2010. *Metagenomics: Theory, Methods and Applications*. Ceister academic press
- Streit WR and Daniel R. 2010. *Metagenomics: Methods and Protocols*. Springer protocols.
- Yeh WK, Yang H, McCarthy JR. 2010. *Enzyme Technologies: Metagenomics, Evolution, Biocatalysis and Biosynthesis*.wiley
- Muthukumar V. 2003. *Metagenomics for the Identification of Plant Viruses*. ProQuest.

I. Course Title : Biological Data Management

II. Course Code : BI 506

III. Credit Hours : 2+1

IV. Aim of the course

The course aims at teaching database management system and familiarizing with the techniques of data sources, data curation and integration of data sources

V. Theory

Unit I (6 Lectures)

Database Management System (DBMS): Need for DBMS - File system vs Database system, Advantages of DBMS - DBMS Architecture – DBMS services - Data abstraction - Overview of Data Models: Hierarchical Model - Network Model - Entity-Relationship (E-R) Model: Symbols - Components of E-R Model: Entities, Attributes, Relationships - Relational Model, Object-oriented Model.

Unit II (8 Lectures)

Overview of Relational Database Objects – Relation – Tuple - Cardinality – Attribute – Degree - Domain - Primary key – Foreign key - Relational data structure – Relational Data Integrity and Constraints: Domain constraints, Entity integrity, Referential Integrity, Operational constraints - Codd's Rules – Normalization: 1NF, 2NF, 3NF, BCNF, 4NF and 5NF.

Unit III (8 Lectures)

Structured Query Language (SQL): Overview of SQL – SQL Data types and Literals – SQL Commands: Data Definition Language (DDL), Data Manipulation Language (DML), Data Querying Language (DQL), Data Control Language (DCL), Data Administration Statements (DAS), Transaction Control Statements (TCS), SQL Operators: Arithmetic, Comparison, Logical and Set Operators – SQL Query, Nested Query - SQL Aggregate functions.

Unit V (10 Lectures)

Curation of genomic, genetic, proteomic data, High-throughput screening, array, qPCR data sets; Quality management of data: tools and techniques. Biological data sources, Data granularity, Schema modelling, architecture, query design, extraction, transformation and loading, Long term data management, storage and security. Bio-chip information system, visualization and reporting, Risk factors for data quality management. Un-structured or noSQL database; AI and BIG data Analytics

VI. Practicals (16 Lectures)

Understanding the data sources, Data granularity, Data modeling and architecture, development of database, Storage, Security, Visualization and reporting.

VII. Suggested Reading

- Kozak K. 2010. *Large scale data handling in biology*. Ventus Publishing ApS. ISBN 978-87-7681-555-4.
- Harold, E. and Means W.S. 2004. *XML in a Nutshell*, Third Ed. O'Reilly, Sebastopol, CA
- Witten, I.H. and Frank E. 2005. *Data Mining: Practical Machine Learning Tools and Techniques* (WEKA), 2nd Ed. San Francisco, Morgan Kaufmann,
- Lodish, H. *et al*. 2000. *Molecular cell biology*. New York: Freeman & Co.
- Kaneko K. 2006. *Life: An Introduction to Complex Systems Biology*. Springer.

I. Course Title : Biological Network Modelling and Analysis

II. Course Code : BI 507

III. Credit Hours : 2+1

IV. Aim of the course

This course aims to develop basic understanding of system biology through biological network modelling and its analysis.

V. Theory

Unit I (12 Lectures)

Introduction to biological networks, Graph theoretic modelling and analysis of biological networks, Discrete Dynamic modelling (Boolean networks, Petri nets), Continuous dynamic modelling (ODEs, stochastic simulation, etc.)

Unit II (12 Lectures)

Probabilistic modelling (Probabilistic Boolean networks, Bayesian networks, Mutual Information), Network inference from experimental data, Genome-scale modelling and network integration

Unit III (8 Lectures)

Evolution of molecular networks, Network-guided GWAS studies, FBA and epistasis detection, protein function prediction

VI. Practicals (16 Lectures)

Biological networks, Graph theoretic modelling and analysis of biological networks, Discrete Dynamic modeling; Continuous dynamic modeling; Probabilistic modeling; Genome-scale modelling and network integration; Evolution of molecular networks, Network-guided GWAS studies, FBA and epistasis detection, protein function prediction.

VII. Suggested Reading

- Junker BH. 2008. *Analysis of Biological Networks*.
- Koch I Reisig, W. Schreiber F. 2010. *Modeling in Systems Biology: The Petri Net Approach*.
- Ramadan EY. 2008. *Biological Networks: Modeling and Structural Analysis*.
- Laubenbacher R. 2007. *Modeling and Simulation of Biological Networks*.

I. Course Title : Computer Programming in Bioinformatics

II. Course Code : BI 508

III. Credit Hours : 2+1

IV. Aim of the course

To learn programming skills for parsing biological data, parallel computing, database connectivity and web-interface.

V. Theory

Unit I (7 Lectures)

BioJava- Packages, Data Import, Manipulation; Python- Basic Syntax, Loops, Functions; BioPython.

Unit II (7 Lectures)

Bioperl: Introduction, Modules: SeqIO, SearchIO, Seq Feature, Finding introns, Alignments, LiveSeq and Tree.

Unit III (12 Lectures)

OpenMP: Clauses, Worksharing constructs, Synchronization constructs, Environment variables, Global Data, Runtime functions, Message Passing Interface (MPI): Introduction and programming, Point to point communications, Collective communications, Advanced MPI1 concepts, MPI2 introduction, Hybrid (openMP + MPI) programming.

Unit IV (6 Lectures)

Compute Unified Device Architecture (CUDA): Introduction and Programming, GPU computing.

VI. Practicals (16 Lectures)

BioPerl programing using bioperl modules such as SeqIO, SearchIO, LiveSeq and Tree; OpenMP programming on Work sharing and Synchronization constructs, Environment variables and global data; MPI programming on Point to point communications and Collective communications; Compilation of OpenMP and MPI programs; Execution of OpenMP and MPI programs; Use of high performance computing, computing resources and job scheduling.

VII. Suggested Reading

- Tisdall J. 2001. *Beginning Perl for Bioinformatics*. O-Reilly.
- Schwartz RL, Phoenix T, Foy BD. 2008. Learning Perl. O-Reilly.
- Orfali R and Harkey H. 1999. *Client/Server Programming with JAVA and CORBA*. John Wiley.
- Sriram Srinivasan. 1997. *Advanced Perl Programming*. O-Reilly.
- Bunce T and Descartes A. 2000. *Programming the Perl DBI*. O-Reilly.
- Mitchell L Model. 2010. *Bioinformatics Programming Using Python*, O'Reilly media, Cambridge, Bal HP 2003. *Perl Programming for Bioinformatics*, Tata McGraw Hill.

I. Course Title : Machine Learning Techniques in Bioinformatics

II. Course Code : BI 509

III. Credit Hours : 2+1

IV. Aim of the course

The purpose of the course is to explain various machine learning techniques and its applications on biological data.

V. Theory

Unit I (10 Lectures)

Introduction to statistical learning theory, Empirical Risk Minimization, Structural Risk Minimization; Classification: Decision tree, Bayesian, Rule based classification, ANN, SVM, KNN; Case based reasoning and Applications in Bioinformatics.

Unit II (12 Lectures)

Clustering: Partition Methods, Heirarchical methods, Density based methods, Grid based clustering, Model based clustering, clustering of high dimensional data, constraints based clustering, Analysis of MD trajectories, Protein Array data Analysis.

Unit III (10 Lectures)

Dimensional Reduction Techniques, Methods of Feature Selection, Resampling Techniques, Elements of Text Mining and Web Mining, Soft Computing and Fuzzy logic system and application in bioinformatics.

VI. Practicals (16 Lectures)

Decision tree, classification techniques: ANN, SVM, KNN, Case based reasoning and its applications on biological data. Clustering techniques; Clustering of high dimensional data; Dimensional reduction techniques; Resampling techniques; Text mining and Web mining. Soft Computing and Fuzzy logic system & application in bioinformatics.

VII. Suggested Reading

- Witten, H.I., Frank, E. and Hall, M.A. 2011. *Data Mining: Practical Machine Learning Tools and Techniques*.
- Hastie, T., Tibshirani, R., Friedman, J.H. 2009. *The Elements of Statistical Learning: Data Mining Interface and Prediction*.
- Clarke, S.B., Fokoue, E. and Zhang, H.H. 2009. *Principles and Theory for Data Mining and Machine Learning*.

Course Title with Credit Load
Ph.D. in Bioinformatics

Course Code	Course Title	Credits (L+P)
	Major: 12 credits	
	(5 credits of core plus 7 credits of optional)	
BI 601	Genome wide association study*	2+1
BI 602	#Computational analysis of Non-coding RNAs	1+1
BI 603	#Big data analytics	1+1
BI 604	#Systems Biology	3+0
BI 605	#Comparative and functional genomics*	1+1
BI 606	Phylogenetics	2+1
BI 607	#R and high dimensional genome data	1+1
BI 608	Pharmacogenomics & IPR	3+1
BI 609	Biological data integration and quality control	1+1
BI 610	Quantum theory and applications in bioinformatics	1+1
	Any other from 500 series	
	Minor (6 credits) – Any one/two of the following disciplines	
	Molecular Biology and Biotechnology	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Supporting (5 credits) Any from the following disciplines	
	Statistics	
	Mathematics	
	Computer Science	
	Common Courses	
BI	Seminar I	0+1
BI	Seminar II	0+1
BI 600	Research	0+75
	Total	**100**

Course Contents
Ph.D. in Bioinformatics

I. Course Title : Genome Wide Association Study
II. Course Code : BI 601
III. Credit Hours : 2+1
IV. Aim of the course

To introduce the concepts, principles, various designs and techniques of genome wide association study.

V. Theory

Unit I (12 Lectures)

Definition, Allelic spectra of common diseases, Allele frequencies for susceptibility loci, Risks associated with disease-susceptibility variants, Applications of linkage-disequilibrium metrics, SNP map, Genome resequencing for full coverage in genome-wide association studies, Transmission Disequilibrium Test, common variant hypothesis, rare allele hypothesis, Genome-wide graph theory algorithms

Unit II (12 Lectures)

Case-Control design, Trio design, Cohort design, Cross-sectional designs for GWAS Selection of Study Participants, Environmental confounders in GWAS, Confounding by population stratification, Genotyping and Quality Control in GWA Studies, Analysis of association between SNP and traits.

Unit III (8 Lectures)

Uses of GWAS: gene-gene interaction, detection of candidate haplotypes, association between SNPs and gene expression.

VI. Practicals (16 Lectures)

Allelic spectra of common diseases, Allele frequencies for susceptibility loci, linkage-disequilibrium metrics, SNP map, Genome resequencing for full coverage in GWAS; Case-Control design, Trio design, Cohort design, Cross-sectional designs for GWAS Selection; Genotyping and Quality Control in GWA Studies; Analysis of association between SNP and traits.

VII. Suggested Reading

- Qin H. 2008. *Statistical Approaches for Genome-wide Association Study and Microarray Analysis*.
- Yang C. 2011. *SNP Data Analysis in Genome-wide Association Studies*.
- Kraft JS. 2010. *Genome-wide Association Study of Persistent Developmental Stuttering*.

I. Course Title : Computational analysis of Non-coding RNAs
II. Course Code : BI 602
III. Credit Hours : 1+1
IV. Aim of the course

To introduce non-coding RNAs, its role and regulation in model organisms and tools and methods for *in silico* analyses

V. Theory

Unit I (8 Lectures)

Course overview; RNA molecules: biogenesis, types, structure and functions. Introduction to ncRNAs: types of ncRNAs, small ncRNAs, long ncRNAs, function of ncRNAs, Role of ncRNAs in plants and animals

Unit II (6 Lectures)

Small ncRNA**:** Introduction, miRNAs, siRNAs, hiRNAs, piRNAs, shRNAs; Post-transcriptional processing of microRNA; microRNA: target pairing and RISC function; miRNA target genomics; Functions and roles of miRNAs in growth & development of plants and animals. Stress responsive miRNAs, oncomiRs & tumour suppresser miRNAs.

Unit III (6 Lectures)

lncRNAs: biogenesis, classifications, structure and function of lncRNAs. Endogenous target mimic lncRNAs, triplet associated lncRNAs (miRNA, mRNA, lncRNAs); Circular RNAs: structure and functions. Role of circular RNA in cancer, growth and development.

Unit IV (6 Lectures)

Splicing and splice variants; Alternative splicing; Alternative splicing regulation; Nonsense mediated RNA decay; RNA editing.

Unit-V (6 Lectures)

Coding and non-coding sequences; TEs; lincRNAs and lncRNAs; Bacterial RNAs; riboswitches; Introduction to CRISPRs.

VI. Practicals (16 Lectures)

Exploration of databases and tools for identification and characterization of ncRNAs (miRNA, lncRNAs, circular RNAs); Prediction and characterization of ncRNAs from RNA-seq profiles; Structure prediction and validation of ncRNAs; Generation of new ncRNA resources and submission to genomic databases.

VII. Suggested Reading

- Ernesto Picardi Eds. 2015. *RNA bioinformatics*. Springer
- Ruzyo, G. J., and Walter, L., (Eds.) 2014. *RNA sequence, structure and function: computational and bioinformatic methods* –Springer
- Krebs, J. E., Lewin, B., Goldstein, E. S., Kilpatrick, S. T., 2014. *Lewin's Genes XI*- Jones & Bartlett Publishers
- MRS Rao. (ed.). 2017. *Long non-coding RNA biology*, springer
- Darnell J. 2011. *RNA: Life's indispensable molecule* – CSH press
- Krishnarao A. 2008. *MicroRNA-from basic science to disease biology*-Cambridge univ press

I. Course Title : Big Data Analytics

II. Course Code : BI 603

III. Credit Hours : 1+1

IV. Aim of the course

To introduce concepts of Big Data, Handling of unstructured genomic data using Big data analytics based tools.

V. Theory

Unit I (5 Lectures)

Big Data- Concepts, characteristics and relevance; MapReduce – Algorithm and application. Programming Models for Big Data.

Unit II (3 Lectures)

Hadoop framework, Hadoop Distributed File System (HDFS), YARN.

Unit III (5 Lectures)

Big Data SQL: – Hive Data Definition Language, Hive Data Manipulation Language, Hive Analytics: RegexSerDe, Views.

Unit IV (3 Lectures)

Apache Spark: Spark SQL, Spark DataFrame; PIG

VI. Practicals (16 Lectures)

Hadoop environment setup, HDFS, Spark SQL, Hadoop MapReduce, YARN, Hive, PIG.

VII. Suggested Reading

- Zikopoulos, P. C., Eaton, C., DeRoos, D., Deutsch, T., and Lapis, G. 2012. *Understanding big data: Analytics for enterprise class hadoop and streaming data* (p. 176). New York: Mcgraw-hill.
- Gandomi, A., and Haider, M. 2015. *Beyond the hype: Big data concepts, methods, and analytics*. *International Journal of Information Management*, *35*(2), 137-144.
- Akerkar R. (Ed.). 2013. *Big data computing*. CRC Press.
- Prajapati, V. 2013. *Big data analytics with R and Hadoop*. Packt Publishing Ltd.

I. Course Title : Systems Biology

II. Course Code : BI 604

III. Credit Hours : 3+0

IV. Aim of the course

This course provides emphasis on synthetic biology, modeling of genetic networks, cell-cell interactions, and evolutionary dynamics.

V. Theory

Unit I (16 Lectures)

Basic concepts in networks and chemical reactions; Input function of a gene, Michaelis-Menten kinetics, and cooperativity; Autoregulation, feedback and bistability; Introduction to synthetic biology and stability analysis in the toggle switch; Oscillatory genetic networks, Graph properties of transcription networks, Feed-forward loop network motif.

Unit-II (8 Lectures)

Introduction to stochastic gene expression, Causes and consequences of stochastic gene expression, Stochastic modeling—The master equation, Fokker-Planck Equation, and the Gillespie algorithm

Unit III (12 Lectures)

Introduction to microbial evolution experiments, and optimal gene circuit design, Evolution in finite populations, genetic drift, and the theory of neutral molecular evolution; Clonal interference and the distribution of beneficial mutations, Fitness landscapes and sequence spaces.

Unit IV (12 Lectures)

Evolutionary games; Survival in fluctuating environments, Parasites, the evolution of virulence and sex; Interspecies interactions, the Lotka-Volterra model, and predator-prey oscillations; Ecosystem stability, critical transitions, and the maintenance of biodiversity; Dynamics of populations in space, The neutral theory of ecology.

VI. Suggested Reading

- Alon, Uri. 2006. *An Introduction to Systems Biology: Design Principles of Biological Circuits*. Chapman & Hall / CRC. ISBN: 9781584886426.
- Nowak, M. A. 2006. *Evolutionary Dynamics: Exploring the Equations of Life*. Belknap Press, ISBN: 9780674023383.
- Bruce A. 2009. *Essential Cell Biology*. Garland Science, ISBN: 9780815341291.
- Strogatz, Steven H. 2014. *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*. Westview Press, ISBN: 9780813349107.
- L. AlberghinaH.V.westerhoff, 2005. *Systems Biology: Definitions and perspectives* Springer.
- A.Kriete, R.Eils,. 2014. *Computational systems biology* Second edition, Academic Press
- E.KlippR.Herwig, A.Kowlad, C.Wierling and H.Lehrach 2005. *Systems Biology in practice: Concepts, Implementation and applications*, WileyInterScience.
- Pengcheng Fu, Panke S. 2009. *Systems Biology and Synthetic Biology* Wiley InterScience.
- Rigoutsos I. and G. Stephanopoulos G. 2007. *Systems Biology* Vol.1: Genomics Oxford University Press Inc., USA.
- Choi S. 2007. *Introduction to Systems Biology*. Humana press Inc, New Jercy, USA.
- A.Kriete, R. Eils 2014. *Computational Systems Biology* (Second edition) Academic Press.

I. Course Title : Comparative and Functional Genomics

II. Course Code : BI 605

III. Credit Hours : 1+1

IV. Theory

Unit 1 (8 Lectures)

Functional elements, Chromosomes and transposons, Organellar Genomes, Symbiosis, Horizontal gene transfer, Gene duplication, Ploidy, Gene fates, Pan and core genomes, Recombination, Transposons, Gene clustering, SNPs and HapMaps, GWAS. Comparative methods for detection of species / organism relationships, Domain evolution, Study of co-evolution: Plant-insect interactions. Host-parasite interactions, viral evolution.

Unit II (8 Lectures)

Pre-and post-genomic era; major advancements in genomic approaches; epigenetics and metagenomics; forward versus reverse genetics, Genome editing approaches and their applications; gene expression analyses and applications. RNAi. DNA chips and their use in transcriptome analysis, qPCR, SAGE, MPSS. Connecting Traits to Genes, and Genes to Functions; protein-protein interaction, and protein networks.

V. Practicals (16 Lectures)

Getting started on the HPC, Regular expressions, Unix and basic sequence statistics Databases, Genome browsers, Blast & HMMER, Short sequence alignments, Distance trees, Maximum likelihood trees, Whole Genome Alignments, DotPlots, CoGeWebTool, AntiSMASHWebTool

VI. Suggested Reading

- Brown TA. 2006. *Genomes. 3rd edition. Garland Science*, New York.
- Sankoff D and Nadeau JH. 2000. *Comparative Genomics: Empirical and Analytical Approaches to Gene Order Dynamics, Map Alignment and the Evolution of Gene Families*. Netherlands, Kluwer Academic Publisher
- Jonathan Pevsner. 2009. *Bioinformatics and Functional Genomics*. Wiley Blackwell
- Wilkins MR, Williams KL, Appel RD, Hochstrasser DF. (Eds) 1997. *Proteome Research: New Frontiers in Functional Genomics*. Springer Verlag Berlin Heidelberg
- Gupta PK and Varshney RK. 2009. *Cereal genomics*.
- Grotewold E. 2006. *Plant Functional Genomics. Methods in Molecular Biology* Vol 236.
- Azuaje F and Dopazo J. 2005. *Data Analysis and Visualization in Genomics and Proteomics*. John Wiley & Sons, US
- Primrose S.B and Twyman R. 2003. *Principles of Genome Analysis and Genomics*. Third Edition.
- Baxevanis. A. D. and Ouellette. B. F. F. (Eds). 2001. *Bioinformatics: A Practical guide to the analysis of genes and proteins*. Wiley Interscience. New York. 470p.
- Hunt and Livesey. 2000. *Functional Genomics: A Practical Approach*. Oxford University Press.
- Jollès P and Jörnvall H. 2000. *Proteomics in Functional Genomics: Protein Structure Analysis*. Birkhäuser.
- Branden. C and J. Troze. 1999. *Introduction to Protein Structure*. Second Edition.
- Brown TA. 2002. *Genomes* IInd Edition. Oxford Wiley Press (ISBN-10: 0-471-25046-5)
- Yun Bi Xu. 2009. *Molecular Plant Breeding*. CABI (ISBN: 978 1 84593 392)

I. Course Title : Phylogenetics

II. Course Code : BI 606

III. Credit Hours : 2+1

IV. Aim of the course

To find out the evolutionary relationship among various species by using different phylogenetic techniques and algorithms.

V. Theory

Unit I (14 Lectures)

Phylogenetic trees and their comparison: Definition and description, various types of trees; Consensus (strict, semi-strict, Adams, majority rule, Nelson); Data partitioning and combination Tree to tree distances, similarity; Phylogenetic analysis algorithms: Maximum Parsimony, Distance based: UPGMA, Transformed Distance, Neighbors-Relation, Neighbor-Joining.

Unit II (18 Lectures)

Probabilistic models of evolution, Maximum likelihood algorithm; Approaches for tree reconstruction: Character optimization; delayed and accelerated transformation, Reliability of trees, Bootstrap, jackknife, decay, randomization tests; Applications of phylogeny analyses: Comparison of Phylogenetic Trees obtained using DNA seq. vs. protein seq. vs. Full genomes. Need for addition of other properties towards total phylogenetic analysis, Comparative methods for detection of species/ organism relationships, Gene duplication, Horizontal transfer, Domain evolution, Study of co-evolution: Plant-insect interactions. Host-parasite interactions, viral evolution.

VI. Practicals (16 Lectures)

Different software for phylogenetic tree construction and evolution of tree such as EMBOSS, MrBayes, PAUP, PHYLIP, PAML, TREE puzzle, Dandogram, cladogram analysis.

VII. Suggested Reading

- Hall, B. G. 2001. *Phylogenetic Tress Made Easy: A How to Manual for Molecular Biologists*. SinauerAss.,USA.
- Nei, M. and Kumar, S. 2000. *Molecular Evolution and Phylogenetics*. Oxford University Press.
- Sankoff, D. & Nadeau JH. 2000. *Comparative Genomics: Empirical and Analytical Approaches to Gene Order Dynamics, Map Alignment and the Evolution of Gene Families*. Netherlands, Kluwer Academic Publisher
- Gustavo Caetano. 2010. *Evolutionary Genomics and Systems Biology*. Wiley-blackwell.
- Mount.D.W.2001. *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor Laboratory Press. New York. 564 pp.
- Nei M and Kumar S. 2000. *Molecular Evolution and Phylogenetics* Oxford University Press.
- Engels J.M.M, RamanathaRao.V, Brown.A.H.D and Jackson.M.T, 2002. *Managing Plant Genetic Diversity*, CABI Publishers, CAB International UK 489pp.

I. Course Title : R and High Dimensional Genome Data

II. Course Code : BI 607

III. Credit Hours : 1+1

IV. Aim of the course

This course mainly aims at teaching R and its packages, programming to the students and make them acquainted with the use of R for data analysis, in general, and genomic data analysis, in particular.

V. Theory

Unit I (8 Lectures)

R programming language: Introduction and basics, R data types- Arithmetic and Logical Operators. R Matrix- Create, Print, add Column, Slice; R Data Frame- Create, Append, Select, Subset, Sort; List in R- Create, Select; R Functions; If, Else, Else If statements in R; For loop and While Loop in R; Data Importing and Exporting; Correlation, Anova, T test , Simple and Linear Regression, Scatter Plot, Bar Chart and Histogram in R; Memory management;

Unit II (8 Lectures)

Applications of R: Univariate and Multivariate phenotypic data analysis; Linear Models – fixed effects model, random effects model, mixed effects model for genetic parameter estimation; GGE Biplot and AMMI for Stability analysis; Gene Expression analysis – Microarray and RNA-Seq data; Genome Wide Association Study (GWAS), Genomic Selection (GS), Sequence analysis; Genome Assembly and Annotation; Machine Learning – ANN, SVM, Random Forest, Deep Learning.

VI. Practicals (16 Lectures)

Matrix Operations In R; R Data Frame, Functions in R, Correlation in R, Simple and Linear Regression in R. ANOVA in R, Other applications of R for crop and animal improvement.

VII. Suggested Reading

- Ihaka R and Gentleman R. 1996. *R: a language for data analysis and graphics*. *Journal of computational and graphical statistics*, *5*(3), 299-314.
- Gentleman R. 2008. *R programming for bioinformatics*. Chapman and Hall/CRC.

I. Course Title : Pharmacogenomics and IPR

II. Course Code : BI 608

III. Credit Hours : 3+1

IV. Theory

Unit I (8 Lectures)

Introduction to Drugs: Sources of drug- plant, animal, microbes, minerals. Drug name – chemical name, brand name or trade name, general name or common name. Drug classification – Chemotherapeutic agents, Pharmacodynamic agents, Miscellaneous agents. Routes of administration – Oral route and Parental route. Drug Absorption, Distribution, Metabolism and Excretion (ADME).

Unit II (8 Lectures)

Drug Response to Genetic Variations: SNP as markers in Pharmacogenomics- Turning SNPs into Useful Markers of Drug Response. Mechanism of drug action – receptor, agonist, ion channel. Inheritance and drug response - Pharmacogenetics of drug metabolism – Phase I metabolism, Phase II metabolism. Pharmacogenomics of Drug Transporters- Organic Anion and Cation Transporter Family, Peptide Transporter Family, Multidrug Resistance-Associated Proteins.

Unit III (6 Lectures)

Case Studies in Pharmacogenomics: Pharmacogenomics of Chemotherapeutic Agents in Cancer Treatment, Pharmacogenomics of Neurodegenerative Diseases: Examples and Perspectives, Pharmacogenomics of Alcoholism, Ethnicity and Pharmacogenomics. Ayugenomics. Pharmacogenomics and pharmaceutical Industries.

Unit IV (8 Lectures)

Basics of Toxicogenomics: Definition, genetic polymorphisms, Comparative toxicogenomics database (CTD) – Chemical gene interaction, chemical – disease association, gene – disease association. Specific applications of toxicogenomics – xenobiotics – insecticide - exposure assessment, hazard screening, variability of susceptibility, mechanistic information, cross-species extrapolation, dose-response relationship, development exposures, mixture.

Unit V (6 Lectures)

Databases for Toxicogenomics: Sample collection and data uniformity. Sharing and distributing data. Building toxicogenomic databases. ToxicogenomicDataRepositories – Standardization, availability, transparency. Data repositories - Stanford Microarray Database, CaBIG, DrugMatrix database, Tox-Express.

Unit VI (12 Lectures)

WTO and TRIPS Agreement: World Trade Organization (WTO)-Globalization-Trade Related Intellectual Property Rights (TRIPs) -General Obligations–substantive requirement of the TRIPS agreement in the WTO –International Union for the Protection of New Varieties of Plants (UPOV)- Multilateral treaties on patent

Forms of IPR and Role of Institutions: Different forms of IPR-Patents, Copyrights, GIs, Trademarks, Industrial Designs and Layouts, Trade secrets – Types of IPR forms-Utility, Design and plant patents, Generic and descriptive trademarks Role of Indian Patent Office (IPO), National Association of Creators, Owners and Users of Intellectual Property (NIPO), Geographical Indications (GI) registry-Multilateral organizations- World Intellectual Property Organization (WIPO), European Patent Office (EPO), US Patent and Trademark Office (USPTO),

Biotechnology and IP Rights: Biotech market in India- Biotech: SWOT – Bioinformatics in India – patent claims in biotechnology – patentable and non-patentable biotech inventions- patenting microorganisms and GMOs - Utility patents for genetic materials-patenting of biotech research tools - Types of bioinformatics patents -Infringement laws at National and International level- Acquisition / licensing of bio-tech patents and trade secrets.

IP Issues in Biotech Research and Development: Research and Development in Biotechnology - Biotechnology and seed policy- Role of Multi-national and Domestic Seed Firms- Moral issues in Patenting Biotechnological inventions- Bio-safety and Bioethics- International bio-safety protocols-cartegena protocols.

IP in Indian Agriculture: Sui-generis system and Status of plant varieties protection in India- Protection of plant genetic resources- protection of Bio-diversity in India- Protection of GIs.

V. Practicals (16 Lectures)

Literature resources: selection and study on a disease, Identification of receptor and ligand involved, search on the drugs at practice, mechanism of their action, toxicity issues-using search engines, Databases on Toxicogenomics- KEGG, chemical databases- Chemfinder, ADME databases, Identification of pharmacophores using databases- retrieving their properties, structure in Smiles notation using Pubchem/ drug bank. Conversion of SMILES, SYBYL, MOL files to PDB format- CORINA, conversion of coordinate file to topology formats- prodrg server, Small molecule generation, evaluation and optimization using Chemsketch, Comparative gene expression analysis on normal and diseased condition, A study on ADME properties- ADME database, calculation of ADME properties- Lipinski rule – Molinspiration tool, High throughput assay to determine a drug toxic effect- ADMEtox, Structural analysis of Protein and Pharmacophores; structural alignment, structural properties- Rasmol/SPDBV, Study of instruments used in experimental Pharmacology, smoking and fixing a kymograph - Handling of laboratory animals - Techniques of drug administrations in animals - Influence of route of administration of drugs on drug response.

VI. Suggested Reading

- Qing Yan. 2006. *Pharmacogenomics in Drug Discovery and Development*. Humana press.
- Licinio, J., and Wong, M.L. 2002. *Pharmacogenomics: The Search for Individualized Therapies*. Wiley-VCH,Verlag GmbH.
- Burcznski, M. E. 2003. *An Introduction to Toxicogenomics*. CRC press.
- Catania MG. 2005. *An A-Z Guide to Pharmacogenomics*, AACC Press.
- Kille P. 2008. *Comparative Toxicogenomics*. Christer Hogstrand. Elsevier Science
- Erbisch FH and Maredia K. 1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
- Anonymous. 2004. *State of Indian Farmer*. Vol. V. Technology, Ministry of Agriculture, Government of India.

- Rothschild M and Scott N. (Ed.). 2003. *Generation and IPR Issues*. Academic Foundation.
- B.L.Wadera. 1996. *Patents, Trade Marks, Copy Right Designs & Geographical Indications*. Universal Law Publishing Co.Pvt.Ltd.
- Narayana PS. 2004. *Intellectual Property Law in India*. K.C.Gogia ,M/S Gogia Law Publication.
- Ganguli P. 2008. *Intellectual Property Rights: Unleashing Knowledge Economy*, McGraw Hill, New Delhi
- Santaniello V, Evenson RE, Zilberman D, Carlson GA. 2000. *Agriculture and Intellectual Property Rights: Economic, Institutional and Implementation Issues in Biotechnology*, CABI Publishing, Wallingford, UK

I. Course Title : Biological Data Integration and Quality Control

II. Course Code : BI 609

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the techniques of data sources, data curation and integration of data sources

Unit I (5 Lectures)

Curation of genomics, genetic, proteomics, High-throughput screening, array, qPCR data sets; Quality management of data: tools and techniques.

Unit II (6 Lectures)

Biological data sources, Data granularity, Schema modelling, architecture, query design, extraction, transformation and loading, Long term data management, storage and security.

Unit III (5 Lectures)

Bio-chip information system, visualization and reporting, Risk factors for data quality management.

V. Practicals (16 Lectures)

Understanding the data sources, Data granularity, Data modeling and architecture, development of database, Storage, Security, Visualization and reporting.

VI. Suggested Reading

- Kozak, K. 2010. Large Scale Data Handling in Biology. 2010. Ventus Publishing ApS. ISBN 978-87-7681-555-4.
- Harold, E. and Means W.S. 2004. *XML in a Nutshell*, Third Ed. O'Reilly, Sebastopol, CA
- Witten, I.H. and Frank E. 2005. *Data Mining: Practical Machine Learning Tools and Techniques* WEKA, 2nd Ed. San Francisco, Morgan Kaufmann
- Lodish, H. *et al*. 2000. *Molecular Cell Biology*. New York: Freeman & Co.
- Kaneko K. 2006. *Life: An Introduction to Complex Systems Biology*. Springer.

I. Course Title : Quantum Theory and Applications in Biology

II. Course Code : BI 610

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces the concepts of quantum theory with application in molecular biology

V. Theory

Unit I (5 Lectures)

Classical mechanics, Newton, Lagrange and Hamilton's equations, Schrodinger's equation and its complete solution for S.H.O, central force and angular momentum

Unit II (6 Lectures)

Atomic orbital models, the wave equation, molecular orbitals, the LCAO method, the overlap method, coulomb and resonance integrals, the hydrogen molecule, charge distributions, approximate methods

Unit III (5 Lectures)

Absorbance of frequency-specific radiation (photosynthesis), Conversion of chemical energy into motion, Magneto reception in animals, DNA mutation and Brownian motors in many cellular processes

VI. Practicals (16 Lectures)

Classical mechanics, Central force and angular momentum; Atomic orbital model, Wave equation, Resonance integers. DNA mutation and Brownian motors in many cellular processes.

VII. Suggested Reading

- Heisenberg W. 1949. *The Physical Principles of the Quantum T1heory*.
- Bohm D. 1951. *Quantum Theory*.
- Ghatakm AK and Lokanathan S. 2004. *Quantum Mechanics: Theory and Applications*.
- Bittner ER. 2009. *Quantum Dynamics: Applications in Biological and Materials Systems*.
- Blinder SM. 2004. *Introduction to Quantum Mechanics: In Chemistry, Materials Science, and Biology*.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Biotechnology and Bioinformatics
– Molecular Biology and Biotechnology

Executive Summary
(Molecular Biology and Biotechnology)

There has been a surge of knowledge during the past decades in various streams of science and technology applicable to agriculture, attributed largely to growth in the frontier areas of basic sciences. Plant molecular biology is one such area that has evolved rapidly from conventional genetics, cell biology and tissue culture-based knowledge to the present level of precision genomic selection and genome editing technologies. This has been made possible by a deeper understanding of the basic molecular processes, genome organization, evolution and gene expression at molecular, cellular, organ and finally trait level. Explosion of plant genome and transcriptome data over the past two decades has enrichedour understanding of the vast amounts of genetic information present in the plant species and its role in plant growth and development. This is particularly important for agriculture where breaking the yield barrier has become a real challenge with limited availability of genetic resources for biotic and abiotic stress toleranceto face the global climate change. In such a scenario, plant Molecular Biology and Biotechnology assumes great significance as it has shown the potential for development of products and disruptive technologies with far reaching impact on the Indian agriculture.With this background, the present M.Sc. and Ph.D. syllabi for Molecular Biology and Biotechnology (MBB) is designed to acquaint the students with the basic and applied aspects of Plant Biotechnology. The course contents are structured to provide a complete insight in the subject and ignite the young minds with knowledge and wisdom to take up the challenge of research and teaching of modern Plant Biotechnology. The syllabus has now separate course contents for M.Sc.(500 series courses) and Ph.D.(600 series courses) programme, however a Ph.D. student may take some the M.Sc. courses if required to build the basic understanding in an area not studied during his/ her Master's programme. Following are the key features of the revised MBB course curriculum.

- A set of four courses (total 12 credits) including(i) Fundamentals of Molecular Biology, (ii) Molecular Cell Biology, (iii) Omics and Systems Biology and (iv) Techniques in Molecular Biology I now constitute the major 'Core' for the Masters programme. Additional 8 credits from the major subject will be taken as optional courses which will lead to specialization of the student towards functional genomics, molecular breeding or genetic engineering.
- The technique courses are designed to provide hands on exposure in the experimental procedures. This will prime the students with the basic laboratory skills for moving to diverse advance courses that cater to newer and frontier areas of Plant Biotechnology.
- Genomics is now a full-fledged domain consisting of various components. It combines the power of Bioinformatics to provide the necessary thrust for undertaking advance molecular breeding. A course on Omics and Systems Biology has been developed to address diverse areas including ionomics, metabolomics and proteomics.
- GM technology has now captured the public attention with huge societal impact and students need to prepare to understand its potential. The courses have been deigned to include contents on the latest techniques like genome editing for

developing precisiongenetic engineering.

- Climate change has been ravaging the rainfed agriculture for some time now and particularly abiotic stresses like heat, drought, flooding and salinity have assumed greater importance. Hence, a new course on “Stress Biology and Genomics” has been included to provide the students an insight into various approaches for tackling such crisis.
- Another new course on”Gene Regulation” is now part of the syllabus, its content includes various pathways involved in growth and development.
- Biotechnology is skill oriented with great market potential in the agrarian economy. A new course on “Bio-entrepreneurship” has been included to empower the students with basics of business creation, so that the idea of a “Startup” can be taken up at an early stage.
- Lately, RNAs have attracted immense attention as they assume greater significance in gene regulation. Hence, a new course on “RNA Biology” has been added as an advanced course to provide insights into potential role of non-coding RNAs in various regulatory pathways.
- Keeping in view the importance of plant hormones a new course on “Plant Hormones and Signaling” has been proposed.
- A course on “Plant Microbe Interaction” has been reintroduced as it is now more relevant under the changing soil and climatic conditions and provide a wealth of information through Metagenomics approaches.
- Genomics is incomplete without Bioinformatics and a new advanced course on “Computational and Statistical tools in Biotechnology” has been introduced in the doctorate program.
- Courses on Animal biotechnology have been dropped for providing a focused content exclusive to Plant Biotechnology.

Preamble

Development of cutting-edge technologies and skilled human resource is the need of the hourto put the country's agricultural growth on fast track. Biotechnology one such area which is essentially interdisciplinary in nature incorporating genetics, biochemistry, molecular biology, microbiology, immunology and most recently bioinformatics. It is based on techniques dealing with genes, genomes, nucleic acids and other related macro and micro biomolecules. Agricultural Biotechnology is a rapidly evolving branch of science that is expanding exponentially as an advanced interdisciplinary technology with immense application potential for Agriculture. To cite a few successful examples- banana, orchids and date palm cultivations in parts of India has become possible only because of tissue culture generated planting material. Similarly, Bt-cotton has been a commercial success, with new generation of Bt-cotton coming up to tackle emerging problems, genetically modified crops including brinjal, mustard, potato, tomato and maize have also been developed, awaiting regulatory approval for commercialization. Several varieties developed through of marker-assisted breeding have been already released and notified for commercial cultivation, *e.g.* rice varieties Swarna-Sub-1, Improved Samba Mahsuri, Pusa Basmati 1637, Pusa Basmati 1718, DRR Dhan 50, Ranjit-Sub-1, wheat variety Unnat PBW343, super chickpea variety BGM 10216 and so on. With the availability of high-quality reference genomes of many crop plants it is now possible to dissect the genetics of complex agronomic traits in a precise manner and utilize the information for marker-assisted breeding. With advancing gene editing tools,directed genome modification has now become a reality ushering in a new era of precision plant breeding. Thus, rice plants immune to bacterial leaf blight (BLB) disease have been developed by knocking down three sweet genes which are essential susceptibility factors for BLB infection. Other biotechnological applications include disease diagnostics, DNA bar coding for varietal protection, bio-pesticides, bio-fertilizers, crop residue management, bio-ethanol production, cryopreservation, artificial seed production, exploiting apomixis, male sterility and so on. Biotechnology is an emerging discipline with scope for constant innovations made possible by a deeper understanding of the basic molecular and cellular processes including their genetic basis. It is particularly important forthe agriculture sector where breaking the yield barrier is a challenge, and newsources for biotic and abiotic stress tolerance for adaptation to theglobal climate change are limited. In such a scenario, plant molecular biology and biotechnology assumes enormous significance as it has shown the potential for product development with far reaching impact on the Indian agriculture.

The tremendous impetus received for biotechnological research and education has been due to its direct impact on human and animal health, agricultural productivity and environment issues. Due to increasing acceptance of genetically modified foods and agricultural produce, big pharmaceutical and agribusiness companies are investing huge funds in the biotechnology R&D sector. At present in India the number of companies involved in R&D or product development or production related to biotechnology and life sciences products has grown close to 350. The demand for trained workforce in Biotechnology is ever growing in Research and Industry Sectors. Academic and research sectors require interdisciplinary trained human resource to furtherharness the power of biotechnological revolution. The need of the hour is to design appropriate syllabi that keeps pace with changing times and technology with emphasizes on utilization with in depth elucidation of the technology.With this background, the present syllabus for the Molecular Biology and Biotechnology (MBB) discipline was designed to acquaint the students with a basic and modern outlook of plant biotechnology. The course contents hve been structured to provide a complete insight and ignite the young minds with knowledge and wisdom to take up the dual challenge of research and teaching in modern agriculture.

A set of four courses namely Fundamentals of Molecular Biology, Molecular Cell Biology, Omics and Systems Biologyand Techniques in Molecular Biology I with a total of 12 credit hours constitutes the major core. The student will have to take 8 more credits of optional major courses according to their interest in functional genomics, molecular breeding or genetic engineering to complete the required 20 credit hours of major courses. A minor with total 6 credits needs to be taken from any of the related disciplines such as Genetics & Plant Breeding, Biochemistry, Plant Physiology, Microbiology, Plant Pathology, Plant Genetic Resources, Bioinformatics and others. Total 5 credit hours of courses must be taken from of the basic supporting disciplines including Genetics, Biochemistry, Microbiology, Bioinformatics, Computer Applications and Statistics. One credit of seminar and 30 credits of thesis research make up the total 70 credit hours required for the M.Sc. degree programme. Similarly, the credit hour distribution for Ph.D. courses have been revised to give added emphasis on research component as compared to theoretical courses. The overall requirement for Ph.D. programme is 12 credits for major courses (6 credits of core plus 6 credits of optional courses), 6 credits of minor courses from one of the related disciplines, 5 credits for basic supporting courses, 2 credits of seminar and 75 credits of thesis research, making a total of 100 credit hours.

All courses have been revised and new courses have been introduced keeping in view the recent developments in the MBB discipline. The new courses include: (i) **Omics and System biology** to address all the high throughput areas including genomics, transcriptomics, proteomics, metabolomics and ionomics; (ii) **Stress Biology and Genomics** to provide insights into various approaches for tackling climate change induced stresses; (iii) **Gene Regulation** focusing on various pathways of plant growth and development; (iv) **Bio-entrepreneurship** to empower the students with the basic knowledge of the business of Biotechnology; (v) **RNA Biology**to provide deeper insights into the potential role of non-coding RNAs in various regulatory pathways; (vi) **Plant Hormones and Signaling** to get deeper insights into the role of plant hormones; (vii) **Plant Microbe Interactions**to provide a wealth of information through microbial genomics and metagenomics approaches; and (viii) '**Computational and Statistical Tools in Biotechnology**' to cater for the growing need of the knowledge of Bioinformatics in MBB discipline. Animal biotechnology courses have been deleted to provide a focused content exclusive to Plant Biotechnology.

Thus, the present syllabus provides a proper balance of the advance molecular biology and their biotechnological applications.The restructuring of syllabus and courses has been done anticipating the future needs of Biotechnology Sector with more emphasis on imparting practical knowledge and skills. The main thrust was to makeit compatible with the recent developments in new education policy, research and industrial sectors and imparting an skill-set that will contribute to nation building through dissemination of specialized knowledge and skills in Agricultural Biotechnology.

Course Title with Credit Load
M.Sc. in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
	Major: 20 credits	
	(12 credits of core + 8 credits of optional)	
MBB 501	Principles of Biotechnology	3+0
MBB 502	Fundamentals of Molecular Biology*	3+0
MBB 503	Molecular Cell Biology*	3+0
MBB 504	Techniques in Molecular Biology I*	0+3
MBB 505	Omics and Systems Biology*	2+1
MBB 506	Plant Genetic Engineering	3+0
MBB 507	Techniques in Molecular Biology II	0+3
MBB 508	Introduction to Bioinformatics	2+1
MBB 509	Plant Tissue culture	2+1
MBB 510	Microbial and Industrial Biotechnology	2+1
MBB 511	Molecular Plant Breeding	2+1
MBB 512	IPR, Bio-safety and Bioethics	2+0
MBB 513	Immunologyand Molecular Diagnostics	3+0
MBB 514	Nano Biotechnology	2+1
MBB 515	Environmental Biotechnology	3+0
MBB 516	Bio-entrepreneurship#	1+0
MBB 517	Stress Biology and Genomics#	2+0
MBB 518	Gene Regulation#	2+0
	Minor (8 credits) – from one of the related disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Plant Physiology	
	Plant Pathology	
	Entomology	
	Bioinformatics	
	Plant Genetic Resources	
	Any other related discipline	

Course Code	Course Title	Credits (L+P)
	Basic Supporting (6 credits) from the following disciplines	
	Biochemistry	
	Microbiology	
	Genetics and Plant Breeding	
	Statistics	
	Bioinformatics	
	Computer Applications	
	Common courses	5
MBB	Seminar	0+1
MBB500	Research	0+30
	Total	**70**

*Core Courses; # New Courses

Course Contents
M.Sc. in Molecular Biology and Biotechnology

I. Course Title : Principles of Biotechnology
II. Course Code : MBB 501
III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics of Molecular biology, plant and microbial Biotechnology
- Importance and applications in agriculture, case studies and success stories
- Public education, perception, IPR and related issues

V. Theory

Unit I (12 Lectures)

History, scope and importance of Biotechnology; Specializations in Agricultural Biotechnology: Genomics, Genetic engineering, Tissue Culture, Bio-fuel, Microbial Biotechnology, Food Biotechnology etc. Basics of Biotechnology, Primary metabolic pathways, Enzymes and its activities.

Unit II (16 Lectures)

Structure of DNA, RNA and protein, their physical and chemical properties. DNA function: Expression, exchange of genetic material, mutation. DNA modifying enzymes and vectors; Methods of recombinant DNA technology; Nucleic acid hybridization; DNA/RNA libraries; Applications of gene cloning in basic and applied research, Plant transformation: Gene transfer methods and applications of GM crops.

Unit III (8 Lectures)

Molecular analysis of nucleic acids -PCR and its application in agriculture and industry, Introduction to Molecular markers: RFLP, RAPD, SSR, SNP etc, and their applications; DNA sequencing, different methods; Plant cell and tissue culture techniques and their applications.Introduction to genomics, transcriptomics, ionomics, metabolomics and proteomics. Plant cell and tissue culture techniques and their applications.

Unit IV (12 Lectures)

Introduction to Emerging topics: Genome editing, gene silencing, Plant microbial interactions,Success stories in Biotechnology, Careers and employment in biotechnology. Public perception of biotechnology; Bio-safety and bioethics issues; Intellectual property rights in biotechnology.

VI. Suggested Reading

- Watson JD, Baker TA, Bell SP, Gann A, Levine M and Losick R. 2014. *Molecular Biology of the Gene*, 7th edition, Cold Spring Harbor Laboratory Press, New York
- Brown T A. 2010. *Gene Cloning and DNA analysis an Introduction* 6th edition, Wiley Blackwell
- Primrose SB and Twyman R. 2006. *Principles of gene Manipulation* 7th edition, Wiley Blackwell

- Singh BD. 2012. *Biotechnology: Expanding Horizons* 4th edition, Kalyani publisher, New Delhi, India

I. Course Title : Fundamentals of Molecular Biology

II. Course Code : MBB 502

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics of DNA, RNA, structure, types and chromatin assembly.
- To get insights into the Central Dogma, basic cellular processes, role of mutation and recombination.
- To understand different levels of gene regulation and the pathways involved.

V. Theory

Unit I (8 Lectures)

Historical developments of molecular biology, Nucleic acids as genetic material, Chemistry and Nomenclature of nucleic acids; Structure of DNA: primary structure; secondary structure, Forms of DNA: A,B, Z and their function; Structure andTypes of RNA Genome organization in prokaryotes and eukaryotes; DNA Topology; DNA re-association kinetics, Types of repeat sequences.

Unit II (10 Lectures)

Central dogma of Molecular Biology; DNA replication- Classical experiments, Models of DNA replication; DNA replication, Origin and Steps in DNA replication - initiation, elongation and termination; Enzymes and accessory proteins and its mechanisms; Eukaryotic DNA replication in brief. Types of DNA damages and mutations; DNA repair mechanisms, Recombination: Homologous and non-homologous, Genetic consequences.

Unit III (8 Lectures)

Prokaryotic transcription, initiation, elongation and termination, promoters, Structure and function of eukaryotic RNAs and ribosomal proteins. Eukaryotic transcription – RNA polymerase I, II and III, Elongation and Termination, Eukaryotic promoters and enhancers, Transcription factors,Post transcriptional processing, Splicing: Catalytic RNAs, RNA stability and transport, RNA editing.

Unit IV (10 Lectures)

Genetic code and its characteristics,Universal and modified genetic code and its characteristics,Wobble hypothesis; Translational machinery; Ribosomes in prokaryotes and Eukaryotes. Initiation complex formation, Cap dependent and Cap independent initiation in eukaryotes,Elongation: translocation,transpeptidation and termination of translation; Co- and Post-translational modifications of proteins; Translational control; Protein stability -Protein turnover and degradation.

Unit V (12 Lectures)

Gene regulation in prokaryotes, Constitutive and Inducible expression, small molecule regulators; Operon concept: *lac* and *trp* operons, attenuation, anti-termination, stringent control.Gene regulation in eukaryotes– regulatory RNA and RNA interference mechanisms,Silencers, insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix etc. Epigenetic regulations

VI. Suggested Reading

- Nelson DL and Cox M.M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York.
- Krebs, J.E., Goldstein, E.S., Kilpatrick, S.T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc.
- Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M and Losick R. 2014. *Molecular Biology of the Gene*, 7th edition, Cold Spring Harbor Laboratory Press, New York.
- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Allison, L.A. 2011. *Fundamentals of Molecular Biology*. 2nd Edition, John Wiley and Sons.

I. Course Title : Molecular Cell Biology

II. Course Code : MBB 503

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics structure and function of plant and animal cell
- To get insights into the basic cellular processes, transport, signalling, cell movement, cell division and general regulation mechanisms.

V. Theory

Unit I (8 Lectures)

Origin of life, History of cell biology, Evolution of the cell: endo-symbiotic theory, treeof life, General structure and differences between prokaryotic and eukaryotic cell; Similarities and distinction between plant and animal cells; different kinds of cells inplant and animal tissues.

Unit II (8 Lectures)

Cell wall, cell membrane, structure and composition of bio-membranes, Structure and function of major organelles: Endoplasmic reticulum Ribosomes, Golgi apparatus, Mitochondria, Chloroplasts, Lysosomes, Peroxisomes, Micro-bodies, Vacuoles, Nucleus, Cyto-skeletal elements.

Unit III (12 Lectures)

Membrane transport; Diffusion, osmosis, ion channels, active transport, mechanism of protein sorting and regulation of intracellular transport, transmembrane and vesicular transport - endocytosis and exocytosis; General principles of cell communication: hormones and their receptors,signaling through G-protein coupled receptors, enzyme linked receptors; signal transduction mechanisms and regulation, Cell junctions, Cell adhesion, Cell movement; Extracellular matrix.

Unit IV (10 Lectures)

Chromatin structure, Cell division and regulation of cell cycle; Mechanisms of cell division, Molecular eventsat M phase, mitosis and cytokinesis, Ribosomes in relation to cell growth and division, Extracellular and intracellular Control of Cell Division; abnormal cell division: cancer- hall marks of cancer and role of oncogenes and tumor suppressor genes in cancer development - Programmed cell death (Apoptosis).

Unit V (10 Lectures)

Morphogenetic movements and the shaping of the body plan, Cell diversification, cellmemory, cell determination, and the concept of positional values; Differentiated cells and the maintenance of tissues and organ development; Stem cells: types and applications; Basics of Animal development in model organisms (*C. elegans*; *Drosophila*); Plant development.

VI. Suggested Reading

- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin, K.C., 2016. *Molecular Cell Biology* 8th Edition. W.H. Freeman & Co. New York.
- Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K., Hopkin, K., Johnson, A., Walter, P., 2013 *Essential of Cell Biology*, WW Norton & Co, Inc.
- Cooper, G.M. and Hausman, R.E. 2013. *The cell: A Molecular Approach* 6th edition, Sinauer Associates, Inc.

I. Course Title : Techniques in Molecular Biology I

II. Course Code : MBB 504

III. Credit Hours : 0+3

IV. Aim of the course

- To get a basic overview of molecular biology techniques, good lab practices and recombinant DNA technology
- To get a hands on training in chromatography, protein analysis, nucleic acid analysis, bacterial and phage genetics

V. Practicals

- Good lab practices, preparation of buffers and reagents.
- Principle of centrifugation and spectrophotometry.
- Growth of bacterial culture and preparation of growth curve, Isolation of Genomic DNA from bacteria.
- Isolation of plasmid DNA from bacteria.
- Growth of lambda phage and isolation of phage DNA.
- Isolation and restriction of plant DNA (e.g. Rice / Moong / Mango / Merigold).
- Quantification of DNA by (a) Agarose Gel electrophoresis and (b) Spectrophotometry
- PCR using isolated DNA.
- PAGEGel electrophoresis.
- Restriction digestion of plasmid and phage DNA, ligation, Recombinant DNA construction.
- Transformation of *E. coli* and selection of transformants
- Chromatographic techniques
  a. TLC
  b. Gel Filtration Chromatography,
  c. Ion exchange Chromatography,
  d. Affinity Chromatography
- Dot blot analysis, Southern hybridization,Northern hybridization.
- Western blotting and ELISA.
- Radiation safety and non-radio isotopic procedure.

VI. Suggested Reading

- Sambrook, J., and Russell, R.W. 2001. *Molecular Cloning: A Laboratory Manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J., 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th edition, Cambridge University Press.
- Ausubel FM, Brent R, Kingston RE, Moore DD, Seidman JG, Smith JA and Struhl K. 2002. *Short Protocols in Molecular Biology* 5th edition, Current Protocols publication.

I. Course Title : Omics and Systems Biology

II. Course Code : MBB 505

III. Credit Hours : 2+1

IV. Aim of the course

- To get a basic overview of genomics, proteomics, ionomics and metabolomics
- To get a primary information on the application of omics science across the industry

V. Theory

Unit I (8 Lectures)

Different methods of genome sequencing, principles of various sequencing chemistries, physical and genetic maps, Comparative and evolutionary genomics, Organelle genomics, applications in phylogenetics, case studies of completed genomes, preliminary genome data analysis, basics of ionomics analysis, different methods

Unit II (6 Lectures)

Protein-basics: primary-, secondary- and tertiary structure, Basics of X-ray crystallography and NMR, Principal and Applications of mass spectrometry, Proteomics: Gel based and gel free, Basics of software used in proteomics, MASCOT, PD-Quest, etc., Study of protein interactions, Prokaryotic and yeast-based expression system and purification

Unit III (6 Lectures)

Metabolomics and its applications, Use of 1D/2D NMR and MS in metabolome analysis, Multivariate analysis and identification of metabolite as biomarkers, Study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), X-Ray Fluorescence (XRF), Neutron activation analysis (NAA), Data integration using genome, transcriptome, proteome, metabolome and ionome with phenome.

Unit IV (6 Lectures)

Introductory systems Biology - The biochemical models, genetic models and systems model, Molecules to Pathway, Equilibrium binding and cooperatively – Michaelis-Menten Kinetics, Biological oscillators, Genetic oscillators,Quorum Sensing, Cell-cell communication, *Drosophila* Development, Pathways to Network, Gene regulation at a single cell level, transcription network, REGULATORY CIRCUITS, Negative and positive auto-regulation, Alternative Stable States, Bimodal Switches, Network building and analysis

VI. Practical (12)

- Isolation of HMW DNA and brief overview of sequencing, Primary information on genome data analysis.
- BSA Standard curve preparation, Extraction of protein and estimation methods.
- Quantification of proteins from different plant tissues using spectrophotometry.
- 2-D Gel Electrophoresis, 2-D Image analysis.
- Experiments on protein-protein interaction (Yeast 2-hybrid, Split Ubiquitin system).
- Demonstration on MALDI-TOF.
- Demonstration on ICP-MS, AAS, Nitrogen estimation using various methods.

VII. Suggested Reading

- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. Course Title : Plant Genetic Engineering

II. Course Code : MBB 506

III. Credit Hours : 3+0

IV. Aim of the course

- To get a basic overview of molecular cloning, vectors and genomic library construction.
- To get anoverview of PCR and its applications, sequencing, gene knockouts, transgenics etc.

V. Theory

Unit I (10 Lectures)

Historical background, Restriction Enzymes; DNA Modifying enzymes, ligase, T4 DNA polymerase, Polynucleotide kinaseetc, Cohesive and blunt end ligation; Labeling of DNA: Nick translation, Random priming, Radioactive and non-radioactive probes, Hybridization techniques: Northern, Southern and Colony hybridization, Fluorescence in situ hybridization; Chromatin Immunoprecipitation; DNA-Protein Interactions: Electromobility shift assay.

Unit II (14 Lectures)

Plasmids; Bacteriophages; M13, Phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Animal Virus derived vectors-SV-40; Expression vectors; pMal,pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag, etc.; Baculovirus vectors system, Plant based vectors, Ti and Ri plasmids as vectors, Yeast vectors, Shuttle vectors. Transformation; Construction of libraries; Isolation of mRNA and total RNA; cDNA and genomic libraries; cDNA and genomic cloning, Jumping and hopping libraries, Protein-protein interactive cloning and Yeast two hybrid system; Phage display; Principles in maximizing gene expression; Codon optimization for heterologous expression. Introduction of DNA into mammalian cells; Transfection techniques

Unit III (12 Lectures)

Principles of PCR, Primer design,DNApolymerases, Types of PCR – multiplex, nested, reverse transcriptase, real time PCR, touchdown PCR, hot start PCR, colony PCR, cloning of PCR products; T- vectors; Applications of PCR in gene recombination, Site specific mutagenesis, in molecular diagnostics; Viral and bacterial detection; Mutation detection: SSCP, DGGE, RFLP, Oligo Ligation Assay.

Unit IV (12 Lectures)

Genetic transformation of plants: DNA delivery – *Agrobacterium* mediated method. Direct DNA delivery – chemical mediated electroporation and particle bombardment. Vectors and transgene design - Promoters and Marker genes. Chloroplast transformation. Development of marker-free plants. Analysis of transgenic plants – molecular and Biochemical assays, genetic analysis - Identification of gene integration site - Advance methods – *cis* genesis, intragenesis and targeted genome modification – ZFN, TALENS and CRISPR. Application of transgenic technology.

VI. Suggested Reading

- Brown, T.A. 2010. *Gene Cloning and DNA Analysis an Introduction.* 6th edition, Wiley Blackwel.
- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell.
- Sambrook, J., and Russell, R.W. 2001. *Molecular cloning: A laboratory manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. Course Title : Techniques in Molecular Biology II

II. Course Code : MBB 507

III. Credit Hours : 0+3

IV. Aim of the course

- To get a basic overview of molecular biology techniques, good lab practices and molecular markers.
- To get a hands on training in RNAi, microarrays, yeast2 hybrid and immunological techniques.

V. Practicals

Construction of gene libraries (cDNA and Genomics).

- Synthesis and cloning of cDNA.
- Real time PCR and interpretation of data.
- Molecular markers
  - i. RAPD.
  - ii. SSR.
  - iii. AFLP / ISSR and their analysis.
- Case study of SSR markers - construction of linkage map.
- QTL analysis using genotypic data based on SSR.
- SNP identification and analysis.
- Microarray studies and use of relevant software.
- Proteomics
  - i. 2D gels,
  - ii. Mass spectrometry
- RNAi - designing of construct, phenotyping of the plant.
- Yeast 1 and 2-hybrid interaction.
- Generation and screening of mutants.
- Transposon mediated mutagenesis.
- Immunology and molecular diagnostics: Ouchterlony double diffusion, Immunoprecipitation, Radiation Immunodiffusion, Immunoelectrophoretic, Rocket Immunoelectrophoretic, Counter Current Immunoelectrophoretic,ELISA, Latex Agglutination, Immunohistochemistry.

VI. Suggested Reading

- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press
- Bonifacino, J. S., Dasso, M., Harford, J. B., Liipincott-Schwartz, J., and Yamada, K. M. 2004. *ShortProtocols in Cell Biology*. John Wiley & Sons, New Jersey

- Hawes, C., and Satiat-Jeunemaitre, B. 2001. *Plant Cell Biology: Practical Approach*. Oxford University Press, Oxford
- Sawhney, S.K., Singh, R. 2014. *Introductory Practical Biochemistry*, Alpha science international limited

I. Course Title : Introduction to Bioinformatics

II. Course Code : MBB 508

III. Credit Hours : 2+1

IV. Aim of the course

- To get a basic overview of computational techniques related to DNA, RNA and protein analysis.
- To get a hands on training in software's and programs used to analyse, assemble or annotate genomes, phylogenetics, proteomics etc.

V. Theory

Unit I (8 Lectures)

Bioinformatics basics, scope and importance of bioinformatics; Biological databases for DNA and Protein sequences -PIR, SWISSPROT, GenBank, DDBJ, secondary database, structural databases –PDB,SCOP and CATH, Specialized genomic resources, Microarray database.

Unit II (10 Lectures)

Bioinformatics Tools Facilitate the Genome-Wide Identification of Protein-Coding Genes, Sequence analysis, Sequence submission and retrieval system-SEQUIN, BANKit, SAKURA, Webin, Sequence alignment, pair wise alignment techniques, multiple sequence alignment; Tools for Sequence alignment- BLAST and its variants; Phylogenetic analysis- CLUSTAL X, CLUSTAL W, Phylip, Tcoffee

Unit III (10 Lectures)

Sequencing of protein; Protein secondary structure prediction- Chousfasman, GOR Method, Protein 3DStructure Prediction: Evaluation of models- Structure validation and refinement - Ramachandran plot, Force field calculations, SAVES. Protein function prediction- sequence and domain based, Primer designing- principles and methods.Drug discovery**,** Structure Based Drug Design- Rationale for computer aided drug designing, basic principles, docking, QSAR.

VI. Practical (12 Lectures)

- Usage of NCBI resources
- Retrieval of sequence/structure from databases and submission
- Different Databases, BLAST exercises.
- Assembly of DNA and RNA Seq data
- Annotation of assembled sequences,Phylogenetics and alignment
- Visualization of structures, Docking of ligand receptors
- Protein structure analysis and modeling

VII. Suggested Reading

- Attwood, T.K., and Parry-Smith, D. J. 2004. *Introduction to Bioinformatics*, Pearson Education (Singapore) Pvt. Ltd.
- David Edwards (Ed.) 2007. *Plant Bioinformatics: Methods and Protocols*. Humana Press, New Jersey, USA.

- Mount, D.W. 2004. *Bioinformatics: Sequence and Genome Analysis*. 2nd Revised edition Cold Spring Harbor Laboratory Press, U.S.
- Pevsner J. 2009. *Bioinformatics and Functional Genomics*, 2nd edition, Wiley-Blackwell.

I. Course Title : Plant Tissue Culture

II. Course Code : MBB 509

III. Credit Hours : 2+1

IV. Aim of the course

- To provide insight into principles of plant cell culture and genetic transformation.
- To get a hands on training in basic plant tissue culture techniques, callusing, micropropagation and analysis.

V. Theory

Unit I (12 Lectures)

History of plant tissue culture, principle of Totipotency; Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Applications of planttissueculture; National certification and Quality management of TC plants; Genetic Fidelity testing and Virus indexing methods – PCR, ELISA

Unit II (12 Lectures)

Micropropagation of field and ornamental crops; Virus elimination by meristem culture, meristemtip culture and micrografting; Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization; Protoplast culture - isolation and purification; Protoplast culture; Protoplast fusion; Somatic hybridization - Production of Somatic hybrids and Cybrids;, Wide hybridization - embryo culture and embryo rescuetechniques; Ovule, ovary culture and endosperm culture.

Unit III (12 Lectures)

Large-scalecell suspension culture - Production of alkaloids and other secondary metabolites- techniques to enhance secondary metabolite production, Somaclonal and gametoclonal variations – causes and applications; Callus culture and *in vitro* screening for stress tolerance; Artificial seeds, *In vitro* germplasm storage and cryo-preservation. Commercial Tissue Culture: Case studies and success stories, Market assessment; project planning and preparation, economics, government policies

VI. Practical (12)

- Preparation of stocks - macronutrients, micronutrients, vitamins and hormones, filter sterilization of hormones and antibiotics. Preparation of Murashige and Skoog medium.
- Micro-propagation of plants by nodal and shoot tip culture.
- Embryo culture to overcome incompatibility, Anther culture for haploid production.
- Callus induction in tobacco leaf discs, regeneration of shoots, root induction, role of hormones in morphogenesis.
- Acclimatization of tissue culture plants and establishment in greenhouse.
- Virus indexing in tissue culture plants. (Using PCR and ELISA).
- Plan of a commercial tissue culture unit.

VII. Suggested Reading

- Razdan, M.K. 2003. *Introduction to plant tissue culture*, 2nd edition, Oxford publications group
- Butenko, R.G. 2000. *Plant Cell Culture* University Press of Pacific
- Herman, E.B. 2008. *Media and Techniques for Growth, Regeneration and Storage*, Agritech Publications, New York, USA.
- Bhojwani, S.S and Dantu P. 2013. *Plant Tissue Culture – An Introductory Text*. Springer Publications.
- Gamborg, O.L and G.C. Philips (eds.). 2013. *Plant Cell, Tissue and Organ culture-Lab Manual*. Springer Science & Business media.

I. Course Title : Microbial/ Industrial Biotechnology

II. Course Code : MBB 510

III. Credit Hours : 2-+1

IV. Aim of the course

To familiarize about the various microbialprocesses/systems/activities, which have been used for the development of industrially important products/processes.

V. Theory

Unit (8 Lectures)

Introduction, scope and historical developments; Isolation, screening and genetic improvement (involving classical approaches) of industrially important organisms.

Unit II (8 Lectures)

Primary metabolites, production of industrial ethanol as a case study; Secondary metabolites, bacterial antibiotics and non-ribosomal peptide antibiotics as case study; Recombinant DNA technologies for microbial processes; Strategies for development of industrial microbial strains with scale up production capacities; Metabolic pathway engineering of microbes for production of novel product for industry.

Unit III (8 Lectures)

Microbial enzymes, role in various industrial processes, production of fine chemicals for pharmaceutical industries; Bio-transformations, Bio- augmentation with production of vitamin C as a case study; Bioreactors, their design and types; Immobilized enzymes-based bioreactors; Microencapsulation technologies for immobilization of microbial enzymes.

Unit IV (8 Lectures)

Environmental Biotechnology, biotreatment for pollution control, treatment of industrial and other wastes, biomass production involving single cell protein; Bio-remediation of soil; Production of eco-friendly agricultural chemicals, bio- pesticides, bio-herbicides, bio-fertilizers, bio-fuels, etc.

VI. Practical

- Isolation of industrially important microorganisms, their maintenance and improvement.
- Lab scale production of industrial compounds such as alcohol, beer, citric acid, lactic acid and their recovery.
- Study of bio-reactors and their operations.
- Production of bio-fertilizers.
- Experiments on microbial fermentation processofantibiotics, bio-pigments, dairy products,

harvesting purification and recovery of end products.
- Immobilization of cells and enzymes, studies on its kinetic behavior, growth analysis and biomassestimation.
- Determination of mass transfer coefficient.

VII. Suggested Reading

- Waites, M.J., Morgan, N.L., Rockey, J.S., Higton, G. 2001. *Industrial Microbiology: An Introduction*, Wiley-Blackwell.
- Slater, A., Scott, N.W., & Fowler, M.R. 2003. *The Genetic Manipulation of Plants. Plant Biotechnology Oxford, England: Oxford University Press*.
- Kun, L.Y. (Ed.). 2003. *Microbial biotechnology: principles and applications*. World Scientific Publishing Company.

I. Course Title : Molecular Plant Breeding
II. Course Code : MBB 511
III. Credit Hours : 2-+1

IV. Aim of the course
- To familiarize the students about the use of molecular biology tools in plant breeding.
- To provide a hands on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (8 Lectures)

Inheritance of qualitative and quantitative traits. Heritability – its estimation, Population structure of self- and cross-pollinated species, Factors affecting selection efficiency. Development of different kinds of segregating populations – F_2, F_3, BC_1F_1, BC_1F_2, BC_4F_2, RIL (Recombinant Inbred Lines), AIL (Advanced Intercrossed Lines), DH (Di-haploid population), NIL (Near Isogenic lines), NAM (Nested Association Mapping), MAGIC (Multi-parent Advanced Generation Intercross population).

Unit II (8 Lectures)

Causes of sequence variation and its types, Types of molecular markers and development of sequence based molecular markers – RFLP, AFLP, SCARs, CAPS, SSRs, STMS, SNPsInDel and DARTseq; Inheritance of markers, Linkage analysis using test cross, F_2, F_3, BC_1F_1, RIL. Construction of genetic map, Mapping genes for qualitative traits; Genotyping by sequencing and high-density chip arrays.

Unit III (8 Lectures)

QTL mapping using structured populations; Association mapping using unstructured populations; Genome Wide Association Studies (GWAS),Principle of Association mapping– GWAS-SNP genotyping methods, DART array sequencing, Illumina's Golden Gate Technology, Genotyping by sequencing methods- Fluidigm; GBS, Illumina Hi seq- Nano pore sequencing, Principles and methods of Genomic Selection, Fine mapping of genes/QTL; Development of gene based markers; Allele mining by TILLING and Eco-TILLING.

Unit IV (8 Lectures)

Tagging and mapping of genes. Bulk segregant and co-segregation analysis, Marker assisted selection (MAS); Linked, unlinked, recombinant, flanking, peak markers. Foreground and background selection; MAS for gene introgression and pyramiding: MAS for specific traits with examples. Haplotype concept and Haplotype-based breeding; Genetic variability and DNA fingerprinting. Molecular markers in Plant variety protection, IPR issues, hybrid purity testing, clonal fidelity testing and transgenic testing.

VI. Practical

- Construction of linkage map.
- QTL analysis using the QTL cartographer and other software.
- SNP data analysis using TASEEL.
- Detection of haplotype block using SNP data - pLinksoftware.
- Genotyping by sequencing methods –Illumina genotyping platform.
- Marker assisted breeding – MABB case studies quality traits in rice/maize.
- Genome Assisted Breeding in model crops, Genomic Selection models usingthe morphological and SNP data

VII. Suggested Reading

- Acquaah, G. 2007. *Principles of Plant Genetics and Breeding*, Blackwell Publishing Ltd. USA.
- Weising, K., Nybom, H., Wolff, K., and Kahl, G. 2005. *DNA Fingerprinting in Plants: Principles, Methods and Applications*, 2nd ed. Taylor and Francis Group, Boca Raton, FL.
- Halford, N. 2006. *Plant Biotechnology-Current and future applications of genetically modified crops*, John Wiley and Sons, England.
- Singh, B. D. and Singh, A. K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.

5. Boopathi, NM. 2013. *Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits*. Springer India. p293.

I. Course Title : IPR, Bio-safety & Bioethics

II. Course Code : MBB 512

III. Credit Hours : 2+0

IV. Aim of the course

- To familiarize the students about ethical and biosafety issues in plant biotechnology.
- To provide a hands-on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (10 Lectures)

IPR: historical background in India; trade secret; patent, trademark, design& licensing; procedure for patent application in India; Patent Cooperation Treaty (PCT); Examples of patents in biotechnology-Case studies in India and abroad; copyright and PVP; Implications of IPR on the commercialization of biotechnology products, ecological implications; Trade agreements- The WTO and other international agreements, and Cross border movement of germplasms.

Unit II (8 Lectures)

Biosafety and bio-hazards; General principles for the laboratory and environmental bio-safety; Biosafety and risk assessment issues; handling and disposal of bio-hazards; Approved regulatory laboratory practice and principles,The Cartagena

Protocol on biosafety; Biosafety regulations in India; national Biosafety Policy and Law; Regulations and Guidelines related to Biosafety in other countries

Unit III (8 Lectures)

Potential concerns of transgenic plants – Environmental safety and food and feed safety. Principles of safety assessment of Transgenic plants – sequential steps in risk assessment. Concepts of familiarity and substantial equivalence. Risk - Environmental risk assessment – invasiveness, weediness, gene flow, horizontal gene transfer, impact on non-target organisms; food and feed safety assessment – toxicity and allergenicity.Monitoring strategies and methods for detecting transgenics.

Unit IV (6 Lectures)

Field trails – Biosafety research trials – standard operating procedures, labeling of GM food and crop,Bio-ethics- Mankind and religion, social, spiritual & environmental ethics; Ethics in Biotechnology, labeling of GM food and crop; Biopiracy

VI. Suggested Reading

- Goel, D. and Parashar, S. 2013. *IPR, biosafety, and bioethics*.
- Joshi, R. 2006. *Biosafety and Bioethics*.
- Nambisan, P. 2017. *An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology*.

I. Course Title : Immunology and Molecular Diagnostics

II. Course Code : MBB 513

III. Credit Hours : 3+0

IV. Theory

Unit I (6 Lectures)

Immunity and its classification; Components of innate and acquired immunity; Lymphatic system; Hematopoiesis; Organs and cells of the immune system- primary, secondary and tertiary lymphoid organs Descriptions of Antigens - immunogens, hapten and adjuvants.

Unit II (12 Lectures)

Immunoglobulins-basic structure, classes & subclasses of immunoglobulins, antigenic determinants; Multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; Principles of cell signaling; Basis of self and non-selfdiscrimination; Kinetics of immune response, memory; B cell maturation, activation and differentiation; Generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; Functional T Cell Subsets; Cell-mediated immune responses, ADCC; Cluster of Differentiations (CDs), Cytokines-properties, receptors and therapeutic uses.

Unit III (8 Lectures)

Phagocytosis; Complement and Inflammatory responses; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility, HLA typing; Antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; Cell-cell co-operation, Hapten-carrier system

Unit IV (10 Lectures)

Precipitation, agglutination and complement mediated immune reactions; Advanced immunological techniques – RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; Surface plasmon resonance, Biosenor assays for assessing ligand –receptor interaction, CMI techniques- lymphoproliferation assay, Mixed lymphocyte reaction, Cell Cytotoxicity assays, Apoptosis, Transgenic mice, Gene knock outs

Unit V (12 Lectures)

Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies, Immunity to Infection,Bacteria, viral, fungal and parasitic infections, Hypersensitivity – Type I-IV; Autoimmunity; Types of autoimmune diseases, MHC and TCR in autoimmunity; Transplantation, Immunological basis of graft rejection, immunosuppressive therapy; Tumor immunology – Tumor antigens.

V. Suggested Reading

- Owen J.A., Punt, J., & Stranford, S. A. 2013. *Kuby immunology* (p. 692). New York: WH Freeman.
- Kenneth, M., and Weaver, C. 2017. *Janeways Immunobiology*, 9th Edition, New York, USA: Garland Science, Taylor & Francis publisher.
- William, P. 2013. *Fundamental of Immunology*, 7th edition, Lippencott, William and Wilkins publisher.

I. Course Title : Nano Biotechnology

II. Course Code : MBB 514

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the molecular techniques involved in structure and functions of nano-biomolecules in cells such as DNA, RNA and proteins.

V. Theory

Unit I (8 Lectures)

Introduction to Nanotechnology - Nanomaterials - Self-assembly to artificial assembly for creation of useful nanostructures – Bottoms up and Top down approach (Nano rods, nano cages, nanotubes, quantum dots, nanowires, metal/ polymer-based nanostructures) – Preparation and Characterization of nanoparticles (particle size analyzer, microscopy, viz. electron microscopy, atomic force microscopy, etc).

Unit (8 Lectures)

Cell structure – Bio macromolecules: Types, Structure, Dynamics and interaction with water – Cellular nano machines – cellular transducers, membrane channels, membrane transporters, Membrane motors – Creation of bio-nanostructures (Nano liposomes, Nano micelles, Nanomotors, etc).

Unit III (8 Lectures)

Chemical, physical and biological properties of biomaterials and bio response: biomineralization, biosynthesis, and properties of natural materials (proteins, DNA, and polysaccharides), structure-property relationships in polymeric materials (synthetic polymers and structural proteins); Aerosol properties, application and dynamics; Statistical Mechanics in Biological Systems,

Unit (8 Lectures)

Nanoparticular carrier systems; Micro- and Nano-fluidics; Drug and gene delivery system; Microfabrication, Biosensors, Chip technologies, Nano- imaging, Metabolic engineering and Gene therapy.

VI. Practical

- Isolation of enzymes and nucleic acids involved in biosynthesis of nanomaterials
- Synthesis of Gold/silver Nanoparticles by biogenic methods, Synthesis of micelles and inverse micelles
- Synthesis of Carbon Nano-materials by Chemical Vapor Deposition and Sputtering technique
- Preparation ofthiolate silver nanoparticles, Purification and measurement of carbon nano materials
- Zinc selenide quantum dot preparation, Synthesis of Iron Oxide Nanoparticle
- Thin film preparation by spin coating technique, Synthesis of Nickel metal nanoparticle by urea decomposition method
- Synthesis of Zinc Oxide nanoparticle

VII. Suggested Reading

- Nalwa, H.S. 2005. *Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology*. American Scientific Publications.
- Niemeyer C.M. and Mirkin C.A. (Eds) 2005. *Nanobiotechnology: Concepts Applications and Perspectives,* Wiley Inter-science publications.
- Cao, G., and Wang, Y. 2004. *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, Imperial College Press.

I. Course Title : Environmental Biotechnology

II. Course Code : MBB 515

III. Credit Hours : 3+0

IV. Aim of the course

To apprise the students about the role of biotechnology in environment management for sustainable eco-system and human welfare.

V. Theory

Unit I (8 Lectures)

Basic concepts and environmental issues; types of environmental pollution; problems arising from high-input agriculture; methodology of environmental management; air and water pollution and its control; waste water treatment - physical, chemical and biological processes; need for water and natural resource management.

Unit II (8 Lectures)

Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of Xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides and toxic chemicals,detergentsetc; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc); anaerobic processes: digestion, filtration, etc.

Unit III (8 Lectures)

Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; microbial hydrogen production; conversion of sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture etc.

Unit IV (8 Lectures)

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by microorganisms; global environmental problems: ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; biotechnological approaches for the management environmental problems.

VI. Suggested Reading

- Evans, G. M. and Furlong, J. C. 2010. *Environmental Biotechnology: Theory and Application*. 2nd edition, Wiley-Blackwell.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

I. Course Title : Bio-entrepreneurship

II. Course Code : MBB 516

III. Credit Hours : 1+0

IV. Aim of the course

The objective of this course is to teach students about fundamentals of entrepreneurship, launching a venture or a start up in biotechnology-based theme.

V. Theory

Unit I (4 Lectures)

Scope in biotechnology; types of bio-industries – bio-pharma, bio-agri, bio-services and bio-industrial; Importance of entrepreneurship; introduction to bioentrepreneurship – biotechnology in a global scale; –skills for successful entrepreneur–creativity, leadership, managerial, team building, decision making; opportunities for bio-entrepreneurship- entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Startup & Make in India)

Unit II (4 Lectures)

Business plan preparation; business feasibility analysis by SWOT, socio-economic costs benefit analysis; funds/ support from various agencies; statutory and legal requirements for starting a company/ venture.

Unit III (4 Lectures)

Entry and exit strategy; identifying needs of customers; Market linkages, branding issues; developing distribution channels - franchising; policies, promotion, advertising; branding and market linkages for 'virtual startup company'. Pricing strategy.

Unit IV (4 Lectures)

Knowledge centers e.g., in universities, innovation centres, research institutions (public & private) and business incubators; R&D for technology development and upgradation; assessment of technology development; managing technology transfer;

VI. Suggested Reading

- Adams, D.J. and Sparrow, J.C. 2008. *Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences*. Bloxham: Scion.
- Shimasaki, C.D. 2014. *Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies*. Amsterdam: Elsevier. Academic Press is an imprint of Elsevier.
- Onetti, A., and Zucchella, A. 2014. *Business Modeling for Life Science and Biotech Companies: Creating Value and Competitive Advantage with the Milestone Bridge*. Routledge.
- Jordan, J. F. 2014. *Innovation, Commercialization, and Start-Ups in Life Sciences*. London: CRC Press.
- Desai, V. 2009. *The Dynamics of Entrepreneurial Development and Management*. New Delhi: Himalaya Pub. House.

I. Course Title : Stress Biology and Genomics

II. Course Code : MBB 517

III. Credit Hours : 2+0

IV. Aim of the course

To provide advanced knowledge on genomics with reference to abiotic stress tolerance and biotic stress resistance in plants tolerance.

V. Theory

Unit I (10 Lectures)

Different kinds of stresses (biotic and abiotic) and adaptation strategies: Plant cell as a sensor of environmental changes; role of cell membranes in signal perception; Ways of signal transduction in cells and whole plants as a response to external factors.Abiotic stresses affecting plant productivity – Drought, salinity, water logging, temperature stresses, light stress and nutrient stress; Drought stress – Effects on plant growth and development; Components of drought resistance; Physiological, biochemical and molecular basis of tolerance mechanisms; Biotic stress (insect and pathogen) resistance mechanism.

Unit II (12 Lectures)

Strategies to manipulate drought tolerance – Osmotic adjustment and Osmoprotectants - synthesis of proline, glycine betaine, poly amines and sugars; ROS and antioxidants; hormonal metabolism - ABA signaling; signaling components – transcription factors. Water logging stress – effects on plant growth and metabolism; adaptation to water logging,tolerance mechanisms -hormones and flooding tolerance. Strategies for improving submergence tolerance. Salinity stress – effects on physiology and metabolism of plants, SOS pathways and ion homeostasis,Strategies to improve salinity tolerance in plants. Water logging stress – effects on plant growth and metabolism; tolerance mechanisms. Physiological and biochemical changes – High & Low temperature tolerance mechanisms - molecular basis of thermo tolerance. Morphological and physiological changes in plants due to high and low light stresses - photo oxidation -plastid development. Characters of heliophytes and sciophytes – solar tracking – sieve effect and light channeling. Heavy metal stress – Al and Cd stress - effects on plant growth and development, biotech Strategies to overcome heavy metal stress Nutrient stress-effects on plant growth and development. Genetic manipulation strategies to overcome the stress effects.

Unit III (10 Lectures)

Genomics; transcriptomes, small RNAs and epigenomes; functional genomics; transfer of tolerance/resistant genes to model plants and validation of gene function. Different techniques for the functional validation of genes.

Signaling pathway related to defense gene expression, R proteins, RNAi approach and genes from pathogens and other sources, coat protein genes, detoxification genes, transgenic and disease management. Bt proteins, resistance management strategies in transgenic crops, ecological impact of field release of transgenic crops. Bioinformatics approaches to determine gene function and network in model plants under stress.

VI. Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Sarwat, M., Ahmad, A., Abdin, M.Z. 2013. *Stress Signaling in Plants: Genomics and Proteomics Perspective*, Volume 1, Springer.
- Heribert Hirt. 2010. *Plant Stress Biology: From Genomics to Systems Biology*, John Wiley.
- Pandey, G.K. 2015. *Elucidation of Abiotic Stress Signaling in Plants*, Stringer.

I. Course Title : Gene Regulation

II. Course Code : MBB 518

III. Credit Hours : 2+0

IV. Aim of the course

To understand the basics of gene regulation including a wide range of mechanisms that are used by organisms to increase or decrease the production of specific gene products in terms of time, space, conditions or their combinations.

V. Theory

Unit I (8 Lectures)

Transcriptional regulation – Regulatory proteins, Activators and Repressors, Binding of RNA polymerase, Allosteric regulation, DNA looping, Cooperative binding, Anti-termination, Combinatorial control – Regulation of *lac, trp* and *ara* Operons. Gene regulation in Lambda phage – lytic or lysogenic establishment.

Unit II (10 Lectures)

Regulatory sequences – Promoters, Enhancers, Silencers, Insulators, Locus Control Region. Activator proteins and their binding sites, DNA binding domain – Homeodomain, Zinc containing proteins, Leucine Zipper Motif, Helix-Loop-Helix, HMG proteins. Recruitment of RNA polymerase to promoter region, Nucleosomes and their modifiers. Signal integration. Signal transduction and transcriptional regulation. Gene Silencing. Epigenetic gene regulation.

Unit III (10 Lectures)

Regulation by RNA in prokaryotes and eukaryotes, RNA as defense agents. Riboswitches. Gene Silencing by RNA - siRNA & miRNA – synthesis and function. Non-coding RNAs their impact, categories and role in gene regulation, chromatin assembly etc.

Unit IV (4 Lectures)

Negative auto-regulation, Positive auto-regulation, Bistable and Bimodal switch, Oscillating pattern of gene expression.

VI. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York
- Krebs, J. E., Goldstein, E. S., Kilpatrick, S. T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc
- Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine,M., & Lonick, R. 2014. *Molecular Biology of the Gene*, 7th Edition, Cold Spring Harbor Laboratory Press, New York.
- Gardner, E. J., Simmons MJ and Snustad, D.P. 2006. *Principles of Genetics* (2006) eighth Edition. Wiley

Course Title with Credit Load
Ph.D in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
	Major: 12 credits (6 credits of core + 6 credits of optional)	
MBB 601	Plant Molecular Biology*	3+0
MBB 602	Plant GenomeEngineering*	3+0
MBB 603	Plant Omics and Molecular Breeding	3+0
MBB 604	Commercial Plant Tissue Culture	2+0
MBB 605	Plant Microbe interaction#	2+0
MBB 606	RNA Biology#	1+0
MBB 607	Plant Hormones and Signaling#	2+0
MBB 608	Computational and Statistical tools in Biotechnology#	2+1
	Any other appropriate 500 series courses	
	Minor (6 credits) from anyof the following disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Plant Physiology	
	Plant Pathology	
	Entomology	
	Bioinformatics	
	Plant Genetic Resources	
	Any other related discipline	
	Supporting (5 credits) from the following disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Bioinformatics	
	Computer Applications	
	Statistics	
	Common Courses	-
MBB	Seminar I	0+1
MBB	Seminar II	0+1
MBB 600	Research	0+75
	Total	**100**

*Core Courses; # New Courses

Course Contents
Ph.D. in Molecular Biology and Biotechnology

I. Course Title : Plant Molecular Biology
II. Course Code : MBB 601
III. Credit Hours : 3+0

IV. Aim of the course

- To provide in depth knowledge of recent developments of plant molecular biology and applications
- To discuss case studies and success stories in agriculture and industry

V. Theory

Unit I (10 Lectures)

Model Systems in Plant Biology (Arabidopsis, Rice, etc.) Forward and Reverse Genetic Approaches. Organization expression and interaction of nuclear, Mitochondrial and Chloroplast Genomes. Cytoplasmic male sterility.

Unit II (12 Lectures)

Transcriptional and Post-transcriptional Regulation of Gene Expression, Isolation of promoters and other regulatory elements, RNA interference, Transcriptional Gene Silencing, Transcript and Protein Analysis.

Unit III (12 Lectures)

Plant Developmental Processes, ABC Model of Floral Development, Role of hormones (Ethylene, Cytokinin, Auxin and ABA, SA and JA) in plant development. Regulation of Flowering, Plant photoreceptors and light signal transduction, vernalization, Circadian Rhythms.

Unit IV (14 Lectures)

Abiotic Stress Responses: Salt, Cold, Heat and Drought.Biotic Stress Responses. Molecular Biology of Plant-pathogen Interactions, Molecular Biology of *Rhizobium* and *Agrobacterium*- Plant interaction. Role of programmed Cell Death in Development and Defense.

VI. Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Slater, A., Scott, N.W., and Fowler, M.R. 2003. *The Genetic Manipulation of Plants. Plant Biotechnology Oxford, England: Oxford University Press*.
- Walker, J.M., Rapley, R. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.

I. Course Title : Plant Genome Engineering

II. Course Code : MBB 602

III. Credit Hours : 3+0

IV. Aim of the course

To discuss the specialized topics and advances in field of genetic engineering and application of molecular tools in breeding of specific crops.

V. Theory

Unit I (14 Lectures)

Conventional versus non-conventional methods for crop improvement; Present status and recent developments on available molecular marker, transformation and genomic tools for crop improvement.Genetic engineering for resistance against abiotic (drought, salinity, flooding, temperature, etc) and biotic (insect pests, fungal, viral and bacterial diseases, weeds, etc) stresses; Genetic Engineering for increasing crop productivity by manipulation of photosynthesis, nitrogen fixation and nutrient uptake efficiency; Genetic engineering for quality improvement (protein, essential amino acids, vitamins, mineral nutrients, etc.); edible vaccines, etc.

Unit II (12 Lectures)

Recent developments in plant transformation strategies; Role of antisense and RNAi-based gene silencing in crop improvement; Regulated and tissue-specific expression of transgenes for crop improvement;

Unit III (12 Lectures)

Gene stacking; Pathway engineering; Marker-free transgenic development strategies; Genome editing: principles and methods, Development of genome edited plants; High throughput phenotyping of transgenic plants.

Unit IV (10 Lectures)

Field studies with transgenic crops; Environmental issues associated with transgenic crops; Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops.

VI. Suggested Reading

- Christou P and Klee H. 2004. *Handbook of Plant Biotechnology*. John Wiley & Sons.
- Stewart Jr, C.N. 2016. *Plant Biotechnology and Genetics: Principles, Techniques, and Applications*. John Wiley & Sons.
- Kirakosyan A and Kaufman PB. 2009. *Recent Advances in Plant Biotechnology* p. 409. Dordrecht: Springer.

I. Course Code : MBB603

II. Course Title : Plant Omics and Molecular Breeding

III. Credit Hours : 3+0

IV. Aim of the course

To discuss the specialized topics and advances in field of genomics and genomics assisted molecular breeding.

V. Theory

Unit I (12 Lectures)

Complex traits and genetic architecture, Mapping genes and QTLs, statistical concepts in QTL mapping, high-throughput genotyping using automated platforms, genetic and physical mapping of genomes, study of population structure and kinship, association genetic analysis of QTL, case studies on QTL mapping using different approaches, map-based of cloning genes and QTLs – case studies.

Unit II (12 Lectures)

Marker Assisted Breeding (MAB): Principles and methods, marker assisted foreground and background selection, marker assisted recurrent selection, whole genome selection, case studies in MAS, requirement for successful marker assisted breeding, cost of MAB.

Unit III (12 Lectures)

Concepts and methods of next generation sequencing (NGS), assembly and annotation of NGS data, genome resequencing, DNA sequence comparison, annotation and gene prediction. Genome-wide insertion mutagenesis and its use in functional genomics, transcriptome profiling using microarrays and deep sequencing, study of methylome and its significance, proteome analysis using mass spectrometry, crystallography and NMR, analysis of proteome data, study of protein- protein interactions.

Unit IV (12 Lectures)

Study of themetabolome, use of 1D/2D NMR and MS in metabolome analysis, multivariate analysis and identification of metabolite as biomarkers, study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome.

VI. Suggested Reading

- Speicher, D.W. (Ed.). 2004. *Proteome analysis: interpreting the genome*. Elsevier.
- Tomita, M. and Nishioka, T. (Eds.). 2006. *Metabolomics: the frontier of systems biology*. Springer Science and Business Media
- Horst, L. and Wenzel, G. (Eds.). 2007. *Molecular marker systems in plant breeding and crop improvement* (Vol. 55). Springer Science and Business Media.
- Stewart C.N. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.
- Singh, B.D. and Singh, A.K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.

I. Course Title : Commercial Plant Tissue Culture

II. Course Code : MBB 604

III. Credit Hours : 2+0

IV. Aim of the course

- To provide awareness into development of commercial scale plant tissue culture units.
- To provide an insight into the commercial applications of plant tissue culture in agriculture, medicine and industry.
- To educate about biosafety, regulatory as well as entrepreneurship opportunities.

V. Theory

Unit I (8 Lectures)

Micro-propagation of commercially important plant species; plant multiplication, hardening, and transplantation; genetic fidelity; scaling up and cost reduction; bioreactors; synthetic seeds; management and marketing.

Unit II (8 Lectures)

Production of useful compounds via, biotransformation and secondary metabolite production: suspension cultures, immobilization, examples of chemicals being produced for use in pharmacy, medicine and industry.

Unit III (9 Lectures)

Value-addition by transformation; development, production and release of transgenic plants; patent, bio-safety, regulatory, environmental and ethical issues; management and commercialization.

Unit IV (7 Lectures)

Project planning and preparation, economics (entrepreneurship, cost profit ratio), government policies (incubators, different facilitation projects, loan opportunities). Some case studies on success stories on commercial applications of plant tissue culture. Visits to some tissue culture based commercial units/industries.

VI. Suggested Reading

- Honda, H., Liu, C., Kobayashi, T. 2001. *Large-Scale Plant Micropropagation*. In: Zhong J.J. *et al*. (eds) *Plant Cells. Advances in Biochemical Engineering / Biotechnology*, vol 72. Springer, Berlin, Heidelberg.
- Bhojwani SS and Razdan MK. 1986. *Plant tissue culture: theory and practice* (Vol. 5). Elsevier.

I. Course Title : Plant Microbe Interaction

II. Course Code : MBB 605

III. Credit Hours : 2+0

IV. Aim of the course

To discuss the specialized topics and advances in field of plantmicrobe interaction for understanding their potential in enhancing crop growth and development.

V. Theory

Unit I (8 Lectures)

Microbial communities in the soil and atmosphere, Community dynamics and population interactions with particular reference to plant–microbe and microbe-microbe interactions leading to symbiotic, associative, endophytic and pathogenic interactions, effects of microorganisms on plants, effects of plants on microorganisms. Recognition processes and signal exchange, Molecular aspects of Plant Growth Promoting Rhizobacteria (PGPR), Symbiotic diazotrophs: Rhizobia and association with legumes. Mycorrhizal associations: Ectomycorrhizae, Endomycorrhizae with particular emphasis to AM fungi, Ectendomycorrhizae. Biocontrol agents and their action, endophytes associations

Unit II (8 Lectures)

Enzymes, toxins, pili, siderophores, secretion systems of microbes and plants determining soil health, nutrient availability and uptake defense responses in plants: pamp-triggered immunity,effector-triggered susceptibility,qualitative resistance, r genes, structure and function, effector-triggered immunity, regulation of plant cell death, plant hormones in immunity, Plant parasite interactions and its molecular basis and impact on plant functions including photosynthesis, respiration, nitrogen metabolism and translocation

Unit III (8 Lectures)

Quorum sensing in bacteria, understanding microbiome,phytobiomes,dynamics, Applied and ecological aspects of symbioses and pathogen defense, techniques to study plant microbe interaction including microbe tagging, metagenomics and use of organismal databases to identify genes involved in interactions. Industrial application of agriculturally important microbes.

Unit III (8 Lectures)

Resistance mechanisms against attack by plant pathogens, gene-for-gene interactions; induced resistance; non-host resistance. Systemic Acquired Resistance (SAR) and Induced Systemic Resistance (ISR), Plant and microbial gene expression and signal exchange, specific regulators for different interactions including transgenic plants. Recognition mechanism and signal transduction during plant - pathogen interaction

VI. Suggested Reading

- Rangaswamy, G. Bhagyaraj. 1993. *Agricultural Microbiology*, Prentice Hall India.
- Stacey, G., and Keen, N.T. (Eds.). 1996. *Plant-microbe interactions*. Springer Science & Business Media.
- Dickinson M. 2005. *Molecular Plant Pathology*. Bios Scientific Press, Taylor and Francis group.
- Kosuge T and Nester EW. 1989. *Plant-Microbe Interactions: Molecular and Genetic Perspectives.*Vols I-IV. McGraw Hill.
- González MBR and Gonzalez-López J. (Eds.). 2013. *Beneficial plant-microbial interactions: ecology and applications*. CRC press.

I. Course Title : RNA Biology

II. Course Code : MBB 606

III. Credit Hours : 1+0

IV. Aim of the course

To discuss the specialized topics and advances in the field of Plant RNAs, their structure and role in cellular regulation and scope for crop improvement.

V. Theory

Unit I (4 Lectures)

RNA structure, functional evolution: RNA structure, types of RNA and function; Genome evolution- RNA as genetic material to regulatory molecule, Non-Coding RNAs, structure, function and regulation

Unit II (4 Lectures)

RNA synthesis, processing and regulation: transcription and its regulation in prokaryotes and eukaryotes; RNA splicing and editing; Translation and its regulation in prokaryotes and eukaryotes

Unit III (4 Lectures)

Genome regulation: Prokaryotic- attenuation, ribozymes, aptamers, riboswitches, CRISPER-Cas; eukaryotic-Exon skipping, nonsense-mediated decay, RNAi, Long non-coding RNA.

Unit IV (4 Lectures)

Epigenetic regulation. RNA-based gene silencing technologies and their applications for crop improvement

VI. Suggested Reading

- Elliott, D., and Ladomery, M. 2017. *Molecular biology of RNA*. Oxford University Press.
- Rao, M.R.S. (Ed.) 2017. *Long Non-Coding RNA Biology*, Springer,
- Donald, C.R., Hannon, G., Ares, M. and Nilsen, T.W. 2011. *RNA: A Laboratory Manual,* CSHL Press.
- Maas, S. (Ed.). 2013. *RNA Editing: Current Research and Future Trends*. Horizon Scientific Press.

I. Course Title : Plant Hormones and Signaling

II. Course Code : MBB 607

III. Credit Hours : 2+0

IV. Aim of the course

To provide in-depth knowledge of plant hormone and their role in plant growth and development.

V. Theory

Unit I (12 Lectures)

Hormone Biosynthesis, Metabolism and its Regulation: Auxin biosynthesis and metabolism, Gibberellin biosynthesis and Inactivation, Cytokinin biosynthesis and metabolism, Ethylene biosynthesis, Abscisic acid biosynthesis and metabolism, Brassinosteroid biosynthesis and metabolism. Salicylic acid and jasmonate biosynthesis and metabolism.

Unit II (12 Lectures)

Functioning of hormones in plant growth and development: Transport of Auxins, Induction of vascular tissues by Auxin, Hormones and the regulation of water balance, seed development and germination, Hormonal control of day length and senescence.

Unit III (12 Lectures)

Action of Hormones: Hormones in defense against insects and disease; Role of jasmonates, salicylic acids and peptide hormones for defense, growth, development and reproduction; Methods of plant hormone analysis. NPR 1 dependent Salicylic acid signaling, PAMP and effector triggered immunity, systemic acquired resistance and SA signaling.

Unit IV (12 Lectures)

Hormone Signal Transduction: Auxin metabolism, transport and signal transduction, Cytokinin types, synthesis, metabolism, transport and signal transduction, Gibberellin biosynthesis, transport, signal transduction in stem elongation & Leaf Growth, Ethylene metabolism, perception and signaling in seedling growth and development, Ethylene signal transduction in fruits and flowers, Abscisic acid metabolism, transport and signal transduction in nuclear gene expression and stomatal responses. Brassinosteroid biosynthesis, catabolism and signal transduction. Strigalactone biosynthesis, transport and signaling in plant parasitism and symbiosis. Methods of Plant Hormone Analysis**:** Quantitative analysis of plant hormones based on LC/MS.

VI. Suggested Reading

- Davies Jr. F. *et al*. 2017. Hart Mann and KRster's. *Plant Propagation: Principles and Practices.* Pearson.

I. Course Title : Computational and Statistical tools in Biotechnology

II. Course Code : MBB 608

III. Credit Hours : 2+1

IV. Aim of the course

To provide information on basic principles of computational biology and statistical tools used for data analysis

V. Theory

Unit I (8 Lectures)

Basic molecular biology; introduction to the basic principles of structure/function analysis of biological molecules; genome analysis; different types and classification of genome databases (e.g. HTGS, DNA, Protein, EST, STS, SNPs, Unigenes, etc.)

Unit II (8 Lectures)

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack- knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling

Unit III (8 Lectures)

DNA sequence retrieval system, various DNA and protein sequence file formats, Basic concepts of similarity searching and sequence alignments, pair wise and multiple sequence alignments, DNA sequence analysis, different gene prediction models and gene annotation tools,

Unit IV (8 Lectures)

Protein sequence analysis and structure prediction, comparative genome analysis, phylogenetic analysis, gene expression analysis tools, programming languages and their applications in bioinformatics

VI. Practical (16)

- Different Types of Databases and Database Search and Retrieval,
- DNA and Protein Sequence Analysis,
- Similarity Searching and Multiple Alignments,
- Gene Annotation,
- Phylogenetic Analysis,
- Sequence Analysis,
- Protein Structure Prediction,

- Analysis of Microarray Data,
- Programming Languages in Bioinformatics.

VII. Suggested Reading

- Xiong J. 2012. *Essential Bioinformatics*, Cambridge University Press.
- Andreas, D.B., and Ouellette B.F.F., (Eds) 2004. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* 3rd Edition, Wiley Interscience.
- Mount D. 2004. *Bioinformatics: Sequence and Genome Analysis*, 2nd Edition. By, CSHL Press.
- Augen J. 2004. *Bioinformatics in the Post-Genomic Era: Genome, Transcriptome, Proteome, and Information-Based Medicine*.
- Galperin M.Y. and Koonin E.V. (Eds) 2003. *Frontiers in Computational Genomics*.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Statistical Sciences

- Agricultural Statistics
- Computer Application

Contents

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On behalf of the Broad Subject Matter Area (BSMA) Committee on Statistical Sciences and on our own personal behalf we wish to place on record our deepest sense of gratitude to Dr Arvind Kumar, Chairman, National Core Group and Vice Chancellor, RLBCAU, Jhansi for entrusting us with the responsibility to undertake this challenging but noble cause of revising the course curricula of all the disciplines in Statistical Sciences. This was a herculean task but the leadership of Dr Arvind Kumar, his fresh and fragrant ideas, and his knowledge and wisdom made the job easy for the committee. We would also like to articulate our feelings of indebtedness towards Dr G. Venkateshwarlu, ADG (EQR), Education Division, ICAR in particular, and for the Education Division, ICAR, in general, for providing necessary guidance from time to time and for also extending fullest support in successfully completing this exercise.

We gratefully acknowledge the full support received from Dr SD Sharma, Former Chairman, BSMA Committee (Statistical Sciences) New Delhi, during course of preparation of this report. The logistic support provided by Director and his dedicated team at ICAR-IASRI for holding the meetings of the BSMA committee and the workshop is duly acknowledged.

We have no word to express our most sincere and heartfelt gratefulness to Dr B.V.S. Sisodia, Dr S.P. Singh, Dr S.D. Samantray, and Dr A. Dhandapani members of the BSMA Committee (Statistical Sciences), whose unflinching efforts have culminated in the preparation of this report. The help received from Dr Sukanta Dash, Co-opted members of the BSMA Committee is praise worthy and we would like to express our highest appreciation of his efforts in this formidable work. The help received from Dr H.K. Jain, Head, Department of Agricultural Statistics and Computer application, Rajasthan Agriculture College, and his team members in organizing the meeting at Rajasthan Agriculture University, is held in high esteem. We would also like to express our sincere thanks to all the faculty of the meeting whose valuable suggestions have helped in shaping the course curricula.

The whole exercise started with a rough draft of course curricula prepared by the previous BSMA Committee during 2008 for which the BSMA Committee would like to convey its thankfulness to the entire members of the committee. Their help is also duly acknowledged. Another very important base material for revising the course curricula was the syllabi of the PG Courses of IARI, provided by ICAR-IASRI. The draft on the syllabi was also prepared by various members of the Committee. We very sincerely appreciate the help received from one and all which helped lay the foundation of the success of this phenomenal task.

Lastly, but most importantly, we would articulate our feelings for one and alland would like to reiterate the fact that it has been indeed a great pleasure working with everyone in the committee as well as outside the committee.

L.M. Bhar
Anil Kumar

Preamble

The origin of the discipline of Agricultural Statistics can be traced back to 1930 when the then Imperial Council of Agricultural Research decided setting up a Statistical Section to assist the State Departments of Agriculture and Animal Husbandry in planning their experiments and analysis of data. The activities of this section increased rapidly and acquired International recognition as a centre for research and training in the field of Agricultural Statistics. Training programmes were started in this discipline in 1945. This activity resulted in the conversion of this section to a full-fledged Institute named as Institute of Agricultural Research Statistics (IARS) where subsequently the M.Sc. and Ph.D. degree courses in Agricultural Statistics were started in 1964 in collaboration with Indian Agricultural Research Institute (IARI). With the strengthening of NARS through more SAUs and ICAR Institutes, the demand for trained and qualified manpower in Agricultural Statistics increased rapidly which resulted in starting of M.Sc. and Ph. D. degree courses in Agricultural Statistics in many other State Agricultural Universities (SAUs) and Deemed-to-be Universities (DUs). Throughout the growth of this discipline, the main emphasis was to develop trained manpower in the country in the field of Agricultural Statistics and later on in the field of Computer Application so as to meet the challenges of agricultural research in the newer emerging areas. These disciplines have now become an integrated component of agricultural research and help in making agricultural research globally acceptable.

Use of computers in agricultural research began more than three decades ago. Initially the electronic data processing requirements of agricultural research workers and students in the NARS were catered by ICAR-Indian Agricultural Statistics Research Institute (ICAR-IASRI). Late sixties and seventies saw statisticians - programmers at IASRI shouldering the onerous responsibility of training agricultural research workers in the use of computers. Around the same time a course on Computer Programming was introduced and offered in the curriculum of M.Sc. and Ph.D. students of PG School of IARI and subsequently at many other SAUs. Seventies witnessed an increase in the computing facilities in NARS; there was a great demand for qualified and trained manpower to manage these facilities. During mid-eighties, M.Sc. Course in Computer Application in Agriculture was introduced in the PG programme of IARI. During this time the computing environment started witnessing changes and Mainframe computers were getting replaced by PCs. Concepts like LAN, WAN, Information Technology (IT), Databases, Information Systems, etc., all became bywords among agricultural research workers. PG Programme in Computer Science/Application was also introduced in other SAUs. Computer Application became an important discipline in agricultural research and as such this discipline was introduced in the Agricultural Research Service of the ICAR in 1985. In the present day world, the role of Information Technology has become very important. Together with the discipline of Statistics, it does wonders in agricultural research. The newer areas of research like genomics, geo-informatics, market intelligence, quality management depend very heavily on Statistics and Information Technology. For outreaching the research in the labs to the farmers, information technology plays a vital role. Advisory and consultancy, distance learning, etc. have become possible through IT only. Data warehouses and data mining are the orders of the day.

In view of the importance of Statistical Sciences, it is important that the course curricula framed to initiate the students to conduct research in these areas and to expose them to their applications to agricultural sciences.Courses Syllabi content should have modified as practical oriented and job oriented. All modifications in syllabus are must be focused to Govt. sector and Corporate sector/ Industrial Benefits. Accordingly, a national level core group was constituted to revise the syllabi of agricultural sciences so as to cater to the requirements of the present day world. A Broad Subject Matter Area (BSMA) Committee for statistical sciences was constituted to look into the revision of the course curricula of the disciplines of Agricultural Statistics and ComputerApplication.

A meeting of the BSMA committee was held on 10th August, 2018 at IASRI, New Delhi to initiate the process of course curricula revision. The need for revision of the curricula was discussed and highlighted the importance and scope of statistical sciences due to its high practical applications in basic and applied research in agriculture. It wasalso emphasized about the need to broaden the scope, explore possibilities of collaboration and cooperation in all courses and to introduce technology oriented courses in statistical sciences. It was felt that the revised curricula should include all the necessary courses required to be studied by M.Sc. and Ph.D. students so as to prepare them to initiate the students to conduct research in these areas and to expose them to their applications to agricultural sciences. It was decided to ensure that the curricula mustbe modified as practical oriented and job oriented to handle competitive exam at both National and International level. Further, the course curricula should be such that it is focused to Govt. sector and Corporate sector/ Industrial Benefits. It was also felt that the curricula should be so framed that it includes the courses on newer areas of research. The committee members were then assigned the responsibility of restructuring the course curricula.

Thereafter another meeting of the BSMA committee was held during 24-25 November, 2018 at Rajasthan Agriculture College, MPUAT, Udaipur in which the revised course curricula was discussed. The committee was enlarged by inviting some experienced faculty members so as to take advantage of their experience. Several new courses were introduced. Since there are no Master's degrees of Computer applications in any SAUs except IARI, hence, it was decided to prepare the syllabus of computer applications in a view of IARI course content. Two courses for Ph.D. prgoramme in agricultural statistics have been restructuredand renamed as per modifications such as 'Advanced Statistical Computing' modified as 'Advanced Data Analytics' and 'Statistical Modeling' modified as 'Modeling Techniques for Forecasting'. Also the course 'Advanced Statistical Methods' was partitioned to two different courses as (i) 'Advanced Statistical Methods' and (ii) Linear Models.

A major recommendation from the meeting was to introduce many new course on computer application based on emerging issues in education like (i) IT Informatics-IT in Agriculture, (ii) Internet Technologies, (iii) Introduction to Big Data, (iv) Introduction to IoT, (v) Management Information. Also several courses have been restructuredand renamed as per modifications in computer application for both M.Sc. and Ph.D. programme.

Organization of Course Contents and Credit Requirements

- The current nomenclature of M.Sc. and Ph.D. programme has been finalized as M.Sc. (Ag.) Statistics/ Computer application and Ph.D. (Agricultural Statistics/ Computer Application).
- All courses are divided into two series: 500-series courses pertain to Master's level, and 600-series to Doctoral level. A Ph.D. student must take 500-series courses if not studied during Master's programme.
- Master's programme have a minimum 70 Credit Hours (consisting of 20 from core course, 8 from minorcourse, 6 from supporting course, 5 from common course, 1 credit seminar and 30 research credit hours).
- Similarly, for Ph.D. programme,the members suggested a total of 100 credit hours (including 12 from core course, 6 from minorcourse, 5 from supporting course, 2 credit seminars and 75 credit for research work).
- Maximum of credit load of 20 credit hours and 18 credit hours per semester for M.Sc. and Ph.D. programmes respectively.
- Credit seminar for Master's level is designated by Code no. 591, and the two seminars for Doctoral level are coded as 691 and 692, respectively.
- Similarly, 599 and 699 codes have been given for Master's research and Doctoral research, respectively.

Course Contents

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not unequivocally exclude other such reference material that may be recommended according to the advancements and local requirements.
- A list of journals pertaining to the discipline is provided at the end which may be useful as study material for 600-series courses as well as research topics.
- E-Resources - for quick update on specific topics/events pertaining to the subject.
- Broad research topics provided at the end would facilitate the advisors for appropriate research directions to the Students.

Minimum Credit Requirements

		Masters' Programme	Doctoral Programme
i.	Course work		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
ii.	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken given *mark.

Minor courses: From the subjects closely related to a student's major subject.

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/her overall competence.

Common Courses: The following courses(one credit each) will be offered to all students undergoing Master's degree programme.

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approvalof the HoD/ BoS.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Statistical Sciences
– Agricultural Statistics

Course Title with Credit Load
M.Sc. in Agricultural Statistics

Course Code	Course Title	Credit Hours	Semester
*STAT 552	Probability Theory	2+0	I
*STAT 553	Statistical Methods	2+1	I
*STAT 562	Statistical Inference	2+1	II
*STAT 563	Design of Experiments	2+1	II
*STAT 564	Sampling Techniques	2+1	II
*STAT 565	Statistical Genetics	2+1	II
*STAT 571	Multivariate Analysis	2+1	III
*STAT 572	Regression Analysis	1+1	III
*STAT 573	Statistical Computing	1+1	III
STAT 591	Seminar	0+1	III
STAT 599	Research	0+30	II-IV
STAT 551	Mathematics-I	3+0	I
STAT 554	Actuarial Statistics	2+0	I
STAT 555	Bioinformatics	2+0	I
STAT 556	Econometrics	2+0	I
STAT 561	Mathematics-II	2+0	II
STAT 566	Statistical Quality Control	2+0	II
STAT 567	Optimization Techniques	1+1	II
STAT 574	Time Series Analysis	1+1	III
STAT 575	Demography	2+0	III
STAT 576	Statistical Methods for Life Sciences	2+0	III
STAT 577	Statistical Ecology	2+0	III
	Supporting Courses		
STAT 501	Mathematics for Applied Sciences	2+0	I
STAT 502	Statistical Methods for Applied Sciences	3+1	I
STAT 511	Experimental Designs	2+1	II
STAT 512	Basic Sampling Techniques	2+1	II
STAT 521	Applied Regression Analysis	2+1	III
STAT 522	Data Analysis Using Statistical Packages	2+1	III

*Core Courses

Course Contents
M.Sc. in Agricultural Statistics

I. Course Title : Mathematics for Applied Sciences

II. Course Code : STAT 501

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

V. Theory

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

VI. Suggested Reading

- Hohn FE. 2013. *Elementary Matrix Algebra*, 3rd Ed., Kindle Edition
- Harville D.A. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Hohn F.E. 1973. *Elementary Matrix Algebra*. Macmillan.
- Searle S.R. 1982. *Matrix Algebra Useful for Statistics*. John Wiley. Stewart J. 2007. *Calculus*. Thompson.
- Thomas G.B. Jr. and Finney R.L. 1996. *Calculus*. 9th Ed. Pearson Edu.

I. Course Title : Statistical Methods for Applied Sciences

II. Course Code : STAT 502

III. Credit Hours : 3+1

IV. Aim of the course

This course is meant for students who do not have sufficient background of Statistical

Methods. The students would be exposed to concepts of statistical methods and statistical inference that would help them in understanding the importance of statistics. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation. The students would get an exposure to presentation of data, probability distributions, parameter estimation, tests of significance, regression and multivariate analytical techniques.

V. Theory

Unit I

Box-plot, Descriptive statistics, Exploratory data analysis, Theory of probability, Random variable and mathematical expectation.

Unit II

Discrete and continuous probability distributions, Binomial, Poisson, Negative Binomial, Normal distribution, Beta and Gamma distributions and their applications. Concept of sampling distribution: chi-square, t and F distributions. Tests of significance based on Normal, chi-square, t and F distributions.

Unit III

Introduction to theory of estimation and confidence-intervals, Simple and multiple correlation coefficient, partial correlation, rank correlation, Simple and multiple linear regression model, test of significance of correlation coefficient and regression coefficients, Coefficient of determination, Fitting of quadratic models.

Unit IV

Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test.

Unit V

Introduction to ANOVA: One way and Two Way, Introduction to Sampling Techniques, Introduction to Multivariate Analysis, Transformation of Data.

VI. Practical

- Exploratory data analysis, fitting of distributions ~ Binomial, Poisson, Negative Binomial, Normal.
- Large sample tests, testing of hypothesis based on exact sampling distributions ~ chi square, t and F.
- Confidence interval estimation and Correlation and regression analysis, fitting of Linear and Quadratic Model.
- Non-parametric tests. ANOVA: One way, Two Way, SRS.

VII. Suggested Reading

- Goon A.M, Gupta M.K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A.M, Gupta M.K. and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P.G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R.V and Craig T.T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Morrison D.F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Hogg RV, McKean JW, Craig AT. 2012. *Introduction to Mathematical Statistics* 7th Edition.
- Siegel S, Johan N & Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.
- Anderson TW. 2009. *An Introduction to Multivariate Statistical Analysis*, 3rd Ed . John Wiley

- http://freestatistics.altervista.org/en/learning.php.
- http://www.statsoft.com/textbook/stathome.html.

I. Course Title : Experimental Designs
II. Course Code : STAT 511
III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Agricultural Statistics. Designing an experiment is an integrated component of research in almost all sciences. The students would be exposed to concepts of Design of Experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental data.

V. Theory

Unit I

Need for designing of experiments, characteristics of a good design. Basic principles of designs- randomization, replication and local control.

Unit II

Uniformity trials, size and shape of plots and blocks, Analysis of variance, Completely randomized design, randomized block design and Latin square design.

Unit III

Factorial experiments, (symmetrical as well as asymmetrical). orthogonality and partitioning of degrees of freedom. Concept of confounding.

Unit IV

Split plot and strip plot designs, analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, Balanced Incomplete Block Design, resolvable designs and their applications, Lattice design, alpha design - concepts, randomization procedure, analysis and interpretation of results. Response surfaces. Combined analysis.

VI. Practical

- Uniformity trial data analysis, formation of plots and blocks, Fairfield Smith Law, Analysis of data obtained from CRD, RBD, LSD, Analysis of factorial experiments,
- Analysis with missing data,
- Split plot and strip plot designs.

VII. Suggested Reading

- Cochran WG and Cox GM. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean AM and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Montgomery DC. 2012. *Design and Analysis of Experiments*, 8th Ed. John Wiley.
- Federer WT. 1985. *Experimental Designs*. MacMillan.
- Fisher RA. 1953. *Design and Analysis of Experiments*. Oliver & Boyd.
- Nigam AK and Gupta VK. 1979. *Handbook on Analysis of Agricultural Experiments*. IASRI Publ.
- Pearce SC. 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice*. John Wiley.
- www.drs.icar.gov.in.

I. Course Title : Basic Sampling Techniques

II. Course Code : STAT 512

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Statistics. The students would be exposed to elementary sampling techniques. It would help them in understanding the concepts involved in planning and designing their surveys, presentation of survey data analysis of survey data and presentation of results. This course would be especially important to the students of social sciences.

V. Theory

Unit I

Concept of sampling, sample survey vs complete enumeration, planning of sample survey, sampling from a finite population.

Unit II

Simple random sampling with and without replacement, sampling for proportion, determination of sample size, inverse sampling, Stratified sampling.

Unit III

Cluster sampling, Multi-stage sampling, systematic sampling; Introduction to PPS sampling,

Unit IV

Use of auxiliary information at estimation, Ratio product and regression estimators. Double Sampling, sampling and non-sampling errors.

VI. Practical

- Random sampling ~ use of random number tables, concepts of unbiasedness, variance, etc.;
- Simple random sampling, determination of sample size, inverse sampling, stratified sampling, cluster sampling and systematic sampling;
- Estimation using ratio and regression estimators;
- Estimation using multistage design, double sampling.

VII. Suggested Reading

- Cochran WG. 1977. *Sampling Techniques*. John Wiley.
- Murthy MN. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Soc., Calcutta.
- Singh D, Singh P and Kumar P. 1982. *Handbook on Sampling Methods*. IASRI Publ.
- Sukhatme PV, Sukhatme BV, Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Cochran WG. 2007. *Sampling Techniques*, 3rd Edition. John Wiley & Sons Publication

I. Course Title : Applied Regression Analysis

II. Course Code : STAT 521

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of all disciplines including agricultural and animal sciences. The students would be exposed to the concepts of correlation and regression. Emphasis will be laid on diagnostic measures such as autocorrelation, multi collinearity and heteroscedasticity. This course would prepare students to handle their data for analysis and interpretation.

V. Theory

Unit I

Introduction to correlation analysis and its measures, Correlation from grouped data, correlation, Rank correlation, Testing of population correlation coefficients; Multiple and partial correlation coefficients and their testing.

Unit II

Problem of correlated errors; Auto correlation; Heteroscedastic models, Durbin Watson Statistics; Removal of auto correlation by transformation; Analysis of collinear data; Detection and correction of multi collinearity, Regression analysis; Method of least squares for curve fitting; Testing of regression coefficients; Multiple and partial regressions.

Unit III

Diagnostic of multiple regression equation; Concept of weighted least squares; regression equation on grouped data; Various methods of selecting the best regression equation.

Unit IV

Concept of nonlinear regression and fitting of quadratic, exponential and power curves; Economic and optimal dose, Orthogonal polynomial.

VI. Practical

- Correlation coefficient, various types of correlation coefficients, partial and multiple, testing of hypotheses;
- Multiple linear regression analysis, partial regression coefficients, testing of hypotheses, residuals and their applications in outlier detection;
- Handling of correlated errors, multi collinearity;
- Fitting of quadratic, exponential and power curves, fitting oforthogonal polynomials.

VII. Suggested Reading

- Kleinbaum DG, Kupper LL, Nizam A. 2007. *Applied Regression Analysis and Other Multivariable Methods* (Duxbury Applied) 4th Ed.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Ezekiel M. 1963. *Methods of Correlation and Regression Analysis*. John Wiley.
- Koutsoyiannis A. 1978. *Theory of Econometrics*. MacMillan.
- Kutner MH, Nachtsheim CJ and Neter J. 2004. *Applied Linear Regression Models*. 4th Ed. With Student CD. McGraw Hill.

I. Course Title : Data Analysis Using Statistical Packages

II. Course Code : STAT 522

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for exposing the students in the usage of various statistical packages for analysis of data. It would provide the students a hands on experience in the analysis of their research data. This course is useful to all disciplines.

V. Theory

Unit I

Introduction to various statistical packages: Excel, R, SAS, SPSS. Data Preparation; Descriptive statistics; Graphical representation of data, Exploratory data analysis.

Unit II

Test for normality; Testing of hypothesis using chi-square, t and F statistics and Z-test.

Unit III

Data preparation for ANOVA and ANCOVA, Factorial Experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.

Unit IV

Analysis of mixed models; Estimation of variance components; Correlation and regression analysis, Probit, Logit and Tobit Models.

Unit V

Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data, Fitting of non-linear models; Neural networks.

VI. Practical

- Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;
- Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;
- Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;
- Linear regression, Multiple regression, Regression plots;
- Discriminant analysis - fitting of discriminant functions, identification of important variables;
- Factor analysis. Principal component analysis - obtaining principal component.

VII. Suggested Reading

- Anderson C.W. and Loynes R.M. 1987. *The Teaching of Practical Statistics*. John Wiley.
- Atkinson A.C. 1985. *Plots Transformations and Regression*. Oxford University Press.
- Chambers J.M., Cleveland W.S., Kleiner B and Tukey P.A. 1983. *Graphical Methods for Data Analysis*. Wadsworth, Belmount, California.
- Chatfield C. 1983. *Statistics for Technology*. 3rd Ed. Chapman & Hall. Chatfield C. 1995. *Problem Solving: A Statistician's Guide*. Chapman & Hall.
- Cleveland W.S. 1985. *The Elements of Graphing Data*. Wadsworth, Belmont, California.
- Ehrenberg ASC. 1982. *A Primer in Data Reduction*. John Wiley.
- Erickson B.H. and Nosanchuk T.A. 1992. *Understanding Data*. 2nd Ed. Open University Press, Milton Keynes.
- Snell E.J. and Simpson HR. 1991. *Applied Statistics: A Handbook of GENSTAT Analyses*. Chapman and Hall.
- Sprent P. 1993. *Applied Non-parametric Statistical Methods*. 2nd Ed. Chapman & Hall.
- Tufte ER. 1983. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, Conn.
- Velleman PF and Hoaglin DC. 1981. *Application, Basics and Computing of Exploratory Data Analysis*. Duxbury Press.
- Weisberg S. 1985. *Applied Linear Regression*. John Wiley.
- Wetherill GB. 1982. *Elementary Statistical Methods*. Chapman & Hall.

- Wetherill GB.1986. *Regression Analysis with Applications*. Chapman & Hall.
- Cleveland WS. 1994. *The Elements of Graphing Data*, 2nd Ed., Chapman & Hall
- http://freestatistics.altervista.org/en/learning.php.
  http://freestatistics.altervista.org/en/stat.php.
  http://www.cas.lancs.ac.uk/glossary_v1.1/main.html.
  http://www.stat.sc.edu/~grego/courses/stat706/.
- www.drs.icar.gov.in.

I. Course Title : Mathematics-I

II. Course Code : STAT 551

III. Credit Hours : 3+0

IV. Aim of the course

This course lays the foundation of all other courses of Agricultural Statistics discipline by preparing them to understand the importance of mathematical methods in research. The students would be exposed to the basic mathematical tools of real analysis, calculus, differential equations and numerical analysis. This would prepare them to study their main courses that involve knowledge of Mathematics.

V. Theory

Unit I

Calculus: Limit and continuity, differentiation of functions, successive differentiation, partial differentiation, mean value theorems, Taylor and Maclaurin's series. Application of derivatives, L'hospital's rule.

Unit II

Real Analysis: Convergence and divergence of infinite series, use of comparison tests -D'Alembert's Ratio - test, Cauchy's nth root test, Raabe's test, Kummer's test, Gauss test. Absolute and conditional convergence. Riemann integration, concept of Lebesgue integration, power series, Fourier, Laplace and Laplace -Steiltjes' transformation, multiple integrals.Integration of rational, irrational and trigonometric functions. Application of integration.

Unit III

Differential equation: Differential equations of first order, linear differential equations of higher order with constant coefficient.

Unit IV

Numerical Analysis: Simple interpolation, Divided differences, Numerical differentiation and integration.

VI. Suggested Reading

- Bartle RG. 1976. *Elements of Real Analysis*. John Wiley. Chatterjee SK. 1970. *Mathematical Analysis*. Oxford & IBH.
- Gibson GA. 1954. *Advanced Calculus*. Macmillan.
- Henrice P. 1964. *Elements of Numerical Analysis*. John Wiley.
- Hildebrand FB. 1956. *Introduction to Numerical Analysis*. Tata McGraw Hill.
- Priestley HA. 1985. *Complex Analysis*. Clarenton Press.
- Rudin W. 1985. *Principles of Mathematical Analysis*. McGraw Hill. Sauer T. 2006. *Numerical Analysis With CD-Rom*. Addison Wesley. Scarborough JB. 1976. *Numerical Mathematical Analysis*. Oxford & IBH. Stewart J. 2007. *Calculus*.Thompson.
- Thomas GB Jr. and Finney RL. 1996. *Calculus*. 9th Ed. Pearson Edu.

I. Course Title : Probability Theory

II. Course Code : STAT 552

III. Credit Hours : 2+0

IV. Aim of the course

This is a fundamental course in Statistics. This course lays the foundation of probability theory, random variable, probability distribution, mathematical expectation, etc. which forms the basis of basic statistics. The students are also exposed to law of large numbers and central limit theorem. The students also get introduced to stochastic processes.

V. Theory

Unit I

Basic concepts of probability. Elements of measure theory: class of sets, field, sigma field, minimal sigma field, Borel sigma field in R, measure- probability measure. Axiomatic approach to probability. Properties of probability based on axiomatic definition. Addition and multiplication theorems. Conditional probability and independence of events. Bayes theorem.

Unit II

Random variables: definition of random variable, discrete and continuous, functions of random variables. Probability mass function and Probability density function, Distribution function and its properties. Notion of bivariate random variables, bivariate distribution function and its properties. Joint, marginal and conditional distributions. Independence of random variables. Transformation of random variables (two dimensional caseonly). Mathematical expectation: Mathematical expectation of functions of a random variable. Raw and central moments and their relation, covariance, skewness and kurtosis. Addition and multiplication theorems of expectation. Definition of moment generating function, cumulating generating function, probability generating function and statements of their properties.

Unit III

Conditional expectation and conditional variance. Characteristic function and its properties. Inversion and uniqueness theorems. Chebyshev, Markov, Cauchy-Schwartz, Sequence of random variables and modes of convergence (convergence in distribution in probability, almost surely, and quadratic mean) and their interrelations.

Unit IV

Laws of large numbers: WLLN, Bernoulli and Kintchin's WLLN. Kolmogorov inequality, Kolmogorov's SLLNs.Central Limit theorems: Demoviere- Laplace CLT, Lindberg – Levy CLT and simple applications.

VI. Suggested Reading

- Ash RB. 2000. *Probability and Measure Theory*. 2nd Ed. Academic Press. Billingsley P. 1986. *Probability and Measure*. 2nd Ed. John Wiley.
- Capinski M and Zastawniah. 2001. *Probability Through Problems*. Springer. Dudewicz EJ & Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Feller W. 1972. *An Introduction to Probability Theory and its Applications*. Vols. I., II. John Wiley.
- Loeve M. 1978. *Probability Theory*. 4th Ed. Springer.

- Marek C, Tomasz JZ. 2003. *Probability* Through Problems (Problem Books in Mathematics) Corrected Ed.
- Marek F. 1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rohatgi VK & Saleh AK Md. E. 2005. *An Introduction to Probability and* Statistics. 2nd Ed. John Wiley.

I. Course Title : Statistical Methods

II. Course Code : STAT 553

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of probability distributions and sampling distributions and their application which forms the basis of Statistical Inference. Together with probability theory, this course is fundamental to the discipline of Statistics. The students are also exposed to correlation and regression, and order statistics and their distributions. Categorical data analysis is also covered in this course.

V. Theory

Unit I

Descriptive statistics: probability distributions: Discrete probability distributions ~ Bernoulli, Binomial, Poisson, Negative-binomial, Geometric and Hyper Geometric, uniform, multinomial ~ Properties of these distributions and real life examples. Continuous probability distributions ~ rectangular, exponential, Cauchy, normal, gamma, beta of two kinds, Weibull, lognormal, logistic, Pareto. Properties of these distributions. Probability distributions of functions of random variables.

Unit II

Concepts of compound, truncated and mixture distributions (definitions and examples). Sampling distributions of sample mean and sample variance from Normal population, central and non–central chi-Square, t and F distributions, their properties and inter relationships.

Unit III

Concepts of random vectors, moments and their distributions. Bivariate Normal distribution - marginal and conditional distributions. Distribution of quadratic forms. Cochran theorem. Correlation, rank correlation, correlation ratio and intra-class correlation. Regression analysis, partial and multiple correlation andregression.

Unit IV

Sampling distribution of correlation coefficient, regression coefficient. Categorical data analysis, Association between attributes. Variance StabilizingTransformations.

Unit V

Order statistics, distribution of r-th order statistics, joint distribution of several order statistics and their functions, marginal distributions of order statistics.

VI. Practical

- Fitting of discrete distributions and test for goodness of fit;
- Fitting of continuous distributions and test for goodness of fit; Fitting of truncated distribution;

- Computation of simple, multiple and partial correlation coefficient, correlation ratio and intra-class correlation;
- Regression coefficients and regression equations;
- Fitting of Pearsonian curves;
- Analysis of association between attributes, categorical data and log-linear models.

VII. Suggested Reading

- Agresti, A. 2012. *Categorical Data Analysis* 3rd Ed. John Wiley.
- Arnold BC, Balakrishnan N and Nagaraja HN. 1992. *A First Course in Order Statistics*. JohnWiley.
- David HA and Nagaraja HN. 2003. *Order Statistics*. 3rd Ed. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Huber PJ. 1981. *Robust Statistics*. John Wiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Continuous Univariate Distributions*. JohnWiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Discrete Univariate Distributions*. JohnWiley.
- Marek F.1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. John Wiley.
- Rohatgi VK and Saleh AK Md. E. 2005. *An Introduction to Probability and Statistics*. 2nd Ed. John Wiley.
- Gupta. S.P 2008. *Statistical Methods*. Sultan Chand & sons Educational Publisher

I. Course Title : Actuarial Statistics

II. Course Code : STAT 554

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant to expose to the students to the statistical techniques such as probability models, life tables, insurance and annuities. The students would also be exposed top practical applications of these techniques in computation of premiums that include expenses, general expenses, types of expenses and per policy expenses.

V. Theory

Unit I

Insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality.

Unit II

Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

Unit III

Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws. Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement, net single premiums and their numerical evaluations.

Unit IV

Distribution of aggregate claims, compound Poisson distribution and its applications.

Unit V

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

Unit VI

Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions.

Unit VII

Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due.

Unit VIII

Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi-continuous basis, reserves based on true monthly premiums, reserves on an apportionable or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.

Unit IX

Some practical considerations: Premiums that include expenses-general expenses types of expenses, per policy expenses. Claim amount distributions, approximating the individual model, stop-loss insurance.

VI. Suggested Reading

- Atkinson ME and Dickson DCM. 2000. *An Introduction to Actuarial Studies*. Elgar Publ.
- Bedford T and Cooke R. 2001. *Probabilistic Risk Analysis*. Cambridge.
- Booth PM, Chadburn RG, Cooper DR, Haberman, S and James DE.1999. Modern *Actuarial Theory and Practice*. Chapman & Hall.
- Borowiak Dale S. 2003. *Financial and Actuarial Statistics: An Introduction*. Marcel Dekker.
- Bowers NL, Gerber HU, Hickman JC, Jones DA and Nesbitt CJ.1997. *Actuarial Mathematics*. 2nd Ed. Society of Actuaries, Ithaca, Illinois.
- Dale SB, Arnold FS. 2013. *Financial and Actuarial Statistics: An Introduction*, 2nd Ed. (Statistics: A Series of Textbooks and Monogrphs)
- Daykin CD, Pentikainen T and Pesonen M. 1994. *Practical Risk Theory for Actuaries*. Chapman & Hall.
- Klugman SA, Panjer HH, Willmotand GE and Venter GG. 1998. *Loss Models: From data to Decisions*. John Wiley.
- Medina PK and Merino S. 2003. *Mathematical Finance and Probability: A Discrete Introduction*. Basel, Birkhauser.
- Melnikov, A. 2011. *Risk Analysis in Finance and Insurance* (Chapman & Hall/Crc Financial Mathematics Series) 2nd Ed.
- Neill A. 1977. *Life Contingencies*. Butterworth-Heinemann.
- Rolski T, Schmidli H, Schmidt V and Teugels J. 1998. *Stochastic Processes for Insurance and Finance*. John Wiley.
- Rotar VI. 2006. *Actuarial Models. The Mathematics of Insurance. Chapman*& Hall/CRC.
- Spurgeon ET. 1972. *Life Contingencies*. Cambridge Univ. Press.

I. Course Title : Bioinformatics

II. Course Code : STAT 555

III. Credit Hours : 2+0

IV. Aim of the course

Bioinformatics is a new emerging area. It is an integration of Statistics, Computer applications and Biology. The trained manpower in the area of Bioinformatics is required for meeting the new challenges in teaching and research in the discipline of Agricultural Sciences. This course is meant to train the students on concepts of basic biology, statistical techniques and computational techniques for understanding bioinformatics principals.

V. Theory

Unit I

Basic Biology: Cell, genes, gene structures, gene expression and regulation, Molecular tools, nucleotides, nucleic acids, markers, proteins and enzymes, bioenergetics, single nucleotide polymorphism, expressed sequence tag. Structural and functional genomics: Organization and structure of genomes, genome mapping, assembling of physical maps, strategies and techniques for genome sequencing and analysis.

Unit II

Computing techniques: OS and Programming Languages – *Linux, perl, bioperl*,*python, biopython*,*cgi*, *MySQL*, *phpMyAdmin*; Coding for browsing biological databases on web, parsing & annotation of genomic sequences; Database designing; Computer networks – Internet, World wide web, Web browsers– EMBnet, NCBI; Databases on public domain pertaining to Nucleic acid sequences, protein sequences, SNPs, etc.; Searching sequence databases, Structural databases.

Unit III

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack-knifing; Hidden Markov Models; Bayesian estimation and Gibbs sampling;

Unit IV

Tools for Bioinformatics: DNA Sequence Analysis – Features of DNA sequence analysis, Approaches to EST analysis; Pairwise alignment techniques: Comparing two sequences, PAM and BLOSUM, Global alignment (The Needleman and Wunsch algorithm), Local Alignment (The Smith-Waterman algorithm), Dynamic programming, Pairwise database searching; Sequence analysis– BLAST and other related tools, Multiple alignment and database search using motif models, ClustalW, Phylogeny; Databases on SNPs; EM algorithm and other methods to discover common motifs in biosequences; Gene prediction based on Neural Networks, Genetic algorithms, Computational analysis of protein sequence, structure and function; Design and Analysis of microarray/ RNAseqexperiments.

VI. Suggested Reading

- Baldi P. and Brunak S. 2001. *Bioinformatics: The Machine Learning Approach.* 2nd Ed. (Adaptive Computation and Machine Learning). MIT Press.
- Baxevanis A.D. and Francis B.F. (Eds.). 2004. *Bioinformatics: A Practical Guide to the*

Analysis of Genes and Proteins. John Wiley.
- Bergeron B.P. 2002. *Bioinformatics Computing*. Prentice Hall.
- Duda R.O, Hart P.E and Stork D.G. 1999. *Pattern Classification*. John Wiley.
- Ewens W.J and Grant G.R. 2001. *Statistical Methods in Bioinformatics: An Introduction* (*Statistics for Biology and Health*). Springer.
- Graham B. Zweig, J. Buffett, WE. 2006.*The Intelligent Investor: The Definitive Book on Value Investing*. A Book of Practical Counsel, Revised Edition
- Hunt S and Livesy F. (Eds.). 2000. *Functional Genomics: A Practical Approach* (*The Practical Approach Series, 235*). Oxford Univ. Press.
- Jones N.C. and Pevzner P.A. 2004. *An Introduction to Bioinformatics Algorithims*. MIT Press.
- Koski T and Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.
- Krane D.E. and Raymer M.L. 2002. *Fundamental Concepts of Bio-informatics*. Benjamin / Cummings.
- Krawetz S.A and Womble D.D. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk A.M. 2002. *Introduction to Bio-informatics*. Oxford Univ. Press.
- Percus J.K. 2001. *Mathematics of Genome Analysis*. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics*. Springer.
- Tisdall J.D. 2001. *Mastering Perl for Bioinformatics*. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.
- Wu C.H. and McLarty J.W. 2000. *Neural Networks and Genome Informatics*. Elsevier.
- Wunschiers R. 2004. *Computational Biology Unix/Linux, Data Processing and Programming*. Springer.

I. Course Title : Econometrics

II. Course Code : STAT 556

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for training the students in econometric methods and their applications in agriculture. This course would enable the students in understanding the economic phenomena through statistical tools and economics principles.

V. Theory

Unit I

Representation of Economic phenomenon, relationship among economic variables, linear and non-linear economic models, single equation general linear regression model, basic assumptions, Ordinary least squares method of estimation for simple and multiple regression models; summary statistics correlation matrix, co-efficient of multiple determination, standard errors of estimated parameters, tests of significance and confidence interval estimation. BLUE properties of Least Squares estimates. Chow test, test of improvement of fit through additional regressors. Maximum likelihood estimation.

Unit II

Heteroscedasticity, Auto-correlation, Durbin Watson test, Multi-collinearity. Stochastic regressors, Errors in variables, Use of instrumental variables in regression analysis. Dummy Variables. Distributed Lag models: Koyck's Geometric Lag scheme, Adaptive Expectation and Partial Adjustment Mode, Rational Expectation Models and test for rationality.

Unit III

Simultaneous equation model: Basic rationale, Consequences of simultaneous relations, Identification problem, Conditions of Identification, Indirect Least Squares, Two-stage least squares, K-class estimators, Limited Information and Full Information Maximum Likelihood Methods, three stage least squares, Generalized least squares, Recursive models, SURE Models. Mixed Estimation Methods, use of instrumental variables, pooling of cross-section and time series data, Principal Component Methods.

Unit IV

Problem and Construction of index numbers and their tests; fixed and chain based index numbers; Construction of cost of living index number.

Unit V

Demand analysis – Demand and Supply Curves; Determination of demand curves from market data. Engel's Law and the Engel's Curves, Income distribution and method of its estimation, Pareto's Curve, Income inequality measures.

VI. Suggested Reading

- Croxton F.E. and Cowden D.J. 1979. *Applied General Statistics*. Prentice Hall of India.
- James H.S. and Mark W.W. 2017. Introduction to Econometrics, 3rd Ed. John Wiley
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge G.C., Hill R.C., Griffiths W.E., Lutkepohl H and Lee T.C. 1988. *Introduction to the Theory and Practice of Econometrics*. 2nd Ed. John Wiley.
- Kmenta J. 1986. *Elements of Econometrics*. 2nd Ed. University of Michigan Press.
- Koop G. 2007. *Introduction to Econometrics*. John Wiley.
- Maddala G.S. 2001. *Introduction to Econometrics*. 3rd Ed. John Wiley.
- Pindyck R.S. and Rubinfeld D.L. 1998. *Econometric Models and Economic Forecasts*. 4th Ed. McGraw Hill.
- Verbeek M. 2008. *A Guide to Modern Econometrics*. 3rd Ed. John Wiley.

I. Course Title : Mathematics-II

II. Course Code : STAT 561

III. Credit Hours : 2+0

IV. Aim of the course

This is another course that supports all other courses in Agricultural Statistics. The students would be exposed to the advances in Linear Algebra and Matrix theory. This would prepare them to study their main courses that involve knowledge of Linear Algebra and Matrix Algebra.

V. Theory

Unit I

Linear Algebra: Group, ring, field and vector spaces, Sub-spaces, basis, Gram Schmidt's orthogonalization, Galois field - Fermat's theorem and primitive elements. Linear transformations. Graph theory: Concepts and applications.

Unit II

Matrix Algebra: Basic terminology, linear independence and dependence of vectors.

Row and column spaces, Echelon form. Determinants, Trace of matrices rank and inverse of matrices. Special matrices – idempotent, symmetric, orthogonal. Eigen values and eigen vectors, Spectral decomposition of matrices.

Unit III

Unitary, Similar, Hadamard, Circulant, Helmert's matrices. Kronecker and Hadamard product of matrices, Kronecker sum of matrices. Sub-matrices and partitioned matrices, Permutation matrices, full rank factorization, Grammian root of a symmetric matrix. Solutions of linear equations, Equations having many solutions.

Unit IV

Generalized inverses, Moore-Penrose inverse, Applications of g-inverse. Inverse and Generalized inverse of partitioned matrices, Differentiation and integration of vectors and matrices, Quadratic forms.

VI. Suggested Reading

- Aschbacher M. 2000. *Finite Group Theory*. Cambridge University Press.
- Deo N. 1984. *Graph Theory with Application to Engineering and Computer Science*. Prentice Hall of India.
- Gentle JE. 2007. *Matrix Algebra: Theory, Computations and Applications in Statistics*. Springer.
- Graybill FE.1961. *Introduction to Matrices with Applications in Statistics*. Wadsworth Publ.
- Hadley G. 1969. *Linear Algebra*. Addison Wesley.
- Harville DA. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Robinson DJS. 1991. *A Course in Linear Algebra with Applications*. World Scientific.
- Searle SR. 2006. *Matrix Algebra Useful for Statistics* John Wiley, 2nd Ed.
- Seber GAF. 2008. *A Matrix Handbook for Statisticians*. John Wiley.

I. Course Title : Statistical Inference

II. Course Code : STAT 562

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of Statistical Inference. The students would be taught the problems related to point and confidence interval estimation and testing of hypothesis. They would also be given the concepts of nonparametric and sequential test procedures and elements of decision theory.

V. Theory

Unit I

Concepts of point estimation: unbiasedness, consistency, efficiency and sufficiency. Statement of Neyman's Factorization theorem with applications. MVUE, Rao-Blackwell theorem, completeness, Lehmann- Scheffe theorem. Fisher information, Cramer-Rao lower bound and its applications.

Unit II

Moments, minimum chi-square, least square and maximum likelihood methods of estimation and theirproperties.Interval estimation-Confidence level, shortest length CI. CI for the parameters of Normal, Exponential, Binomial and Poisson distributions.

Unit III

Fundamentals of hypothesis testing-statistical hypothesis, statistical test, critical region, types of errors, test function, randomized and non- randomized tests, level of significance, power function, most powerful tests: Neyman-Pearson fundamental lemma, MLR families and UMP tests for one parameter exponential families. Concepts of consistency, unbiasedness and invariance of tests. Likelihood Ratio tests, asymptotic properties of LR tests with applications (including homogeneity of means and variances).Relation between confidence interval estimation and testing of hypothesis.

Unit IV

Sequential Probability ratio test, Properties of SPRT.Termination property of SPRT, SPRT for Binomial, Poisson, Normal and Exponential distributions. Concepts of loss, risk and decision functions, admissible and optimal decision functions, estimation and testing viewed as decision problems, conjugate families, Bayes and Minimax decision functions with applications to estimation with quadratic loss.

Unit V

Non-parametric tests: Sign test, Wilcoxon signed rank test, Runs test for randomness, Kolmogorov – Smirnov test for goodness of fit, Median test and Wilcoxon-Mann-Whitney U-test. Chi-square test for goodness of fit and test for independence of attributes. Spearman's rank correlation and Kendall's Tau tests for independence.

VI. Practical

- Methods of estimation - Maximum Likelihood, Minimum c^2 and Moments;
- Confidence Interval Estimation;
- MP and UMP tests;
- Large Sample tests;
- Non-parametric tests, Sequential Probability Ratio Test;
- Decision functions.

VII. Suggested Reading

- Box G.E.P. and Tiao G.C. 1992. *Bayesian Inference in Statistical Analysis*.John Wiley.
- Casela G and Berger R.L. 2001. *Statistical Inference*. Duxbury Thompson Learning.
- Christensen R. 1990. *Log Linear Models*. Springer.
- Conover W.J. 1980. *Practical Nonparametric Statistics*. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. JohnWiley.
- Gibbons J.D. 1985. *Non Parametric Statistical Inference*. 2nd Ed. Marcel Dekker.
- Kiefer J.C. 1987. *Introduction to Statistical Inference*. Springer.
- Lehmann EL. 1986. *Testing Statistical Hypotheses*. John Wiley.
- Lehmann EL. 1986. *Theory of Point Estimation*. John Wiley.
- Randles R.H and Wolfe D.S. 1979. *Introduction to the Theory of Nonparametric Statistics*. John Wiley.
- Rao C.R. 2009. *Linear Statistical Inference and Its Applications*, 3rdEd. John Wiley.
- Rohatgi V.K. and Saleh A.K. Md. E. 2005. *An Introduction to Probability and Statistics*. 2nd Ed. John Wiley.
- Rohtagi V.K. 1984. *Statistical Inference*. John Wiley
- Sidney S and Castellan N.J. Jr. 1988. *Non Parametric Statistical Methods for Behavioral Sciences*. McGraw Hill.
- Wald A. 2004. *Sequential Analysis*. Dover Publ.
- Michael J.Panik. 2012. *Statistical Inference*. A John Wiley & Sons, INC, publication

I. Course Title : Design of Experiments

II. Course Code : STAT 563

III. Credit Hours : 2+1

IV. Aim of the course

Design of Experiments provides the statistical tools to get maximum information from least amount of resources. This course is meant to expose the students to the basic principles of design of experiments. The students would also be provided with mathematical background of various basic designs involving one-way and two-way elimination of heterogeneity and their characterization properties. This course would also prepare the students in deriving the expressions for analysis of experimental data.

V. Theory

Unit I

Elements of linear estimation, Gauss Markoff Theorem, relationship between BLUEs and linear zero-functions. Aitken's transformation, test of hypothesis, Analysis of Variance, Partitioning of degrees of freedom.

Unit II

Orthogonality, contrasts, mutually orthogonal contrasts, analysis of covariance; Basic principles of design of experiments, uniformity trials, size and shape of plots andblocks, Randomization procedure.

Unit III

Basic designs - completely randomized design, randomized complete block design and Latin square design; Construction of orthogonal Latin squares, mutually orthogonal Latin squares (MOLS), Youden square designs, Graeco Latin squares.

Unit IV

Balanced Incomplete Block (BIB) designs – general properties and analysis without and with recovery of intra block information, construction of BIB designs. Partially balanced incomplete block designs with two associate classes - properties, analysis and construction, Lattice designs, alpha designs, cyclic designs, augmented designs.

Unit V

Factorial experiments, confounding in symmetrical factorial experiments ($2^n$and 3^nseries), partial and total confounding, asymmetrical factorials.

Unit VI

Cross-over designs. Missing plot technique; Split plot and Strip plot design; Groups of experiments.Sampling in field experiments.

VI. Practical

- Determination of size and shape of plots and blocks from uniformity trials data;
- Analysis of data generated from completely randomized design, randomized complete block design;
- Latin square design, Youden square design; Analysis of data generated from a BIB design, lattice design, PBIB designs;
- 2^n, 3^n factorial experiments without and with confounding;
- Split and strip plot designs, repeated measurement design;
- Missing plot techniques,

- Analysis of covariance;
- Analysis of Groups of experiments,
- Analysis of clinical trial experiments.

VII. Suggested Reading

- Chakrabarti M.C. 1962. *Mathematics of Design and Analysis of Experiments*. Asia Publ.House.
- Cochran W.G. and Cox D.R. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean A.M. and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Dey A and Mukerjee R. 1999. *Fractional Factorial Plans*. John Wiley.
- Dey A 1986. *Theory of Block Designs*. Wiley Eastern. Hall M Jr. 1986. *Combinatorial Theory*. John Wiley.
- John J.A. and Quenouille M.H. 1977. *Experiments: Design and Analysis*. Charles & Griffin.
- Kempthorne, O. 1976. Design and Analysis of Experiments. John Wiley. Khuri AI & Cornell JA. 1996. *Response Surface Designs and Analysis*. 2nd Ed. Marcel Dekker.
- Kshirsagar A.M. 1983. *A Course in Linear Models*. Marcel Dekker.
- Montgomery D.C. 2013. *Design and Analysis of Experiments*. John Wiley & Sons
- Raghavarao D. 1971. *Construction and Combinatorial Problems in Design of Experiments*. John Wiley.
- Searle S.R. 2006. *Linear Models*. John Wiley.
- Street A.P. and Street D.J. 1987. *Combinatorics of Experimental Designs*. Oxford Science Publ.
- Design Resources Server. *Indian Agricultural Statistics Research Institute (ICAR), New Delhi-110 012, India*. Hyperlink "http: //www.iasri.res.in/design" www.drs.icar.gov.in.

I. Course Title : Sampling Techniques

II. Course Code : STAT 564

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant to expose the students to the techniques of drawing representative samples from various populations and then preparing them on the mathematical formulations of estimating the population parameters based on the sample data. The students would also be exposed to the real life applications of sampling techniques and estimation of parameters.

V. Theory

Unit I

Sample survey vs complete enumeration, probability sampling, sample space, sampling design, sampling strategy; Determination of sample size; Confidence-interval; Simple random sampling, Estimation of population proportion, Stratified random sampling, Proportional allocation and optimal allocation, Inverse sampling.

Unit II

Ratio, Product and regression methods of estimation, Cluster sampling, Systematic sampling, Multistage sampling with equal probability, Separate and combined ratio estimator, Double sampling, Successive sampling –two occasions. Unbiased ratio type estimators

Unit III

Non-sampling errors – sources and classification, Non-response in surveys, Randomized response techniques, Response errors/ Measurement error – interpenetrating sub-sampling.

Unit IV

PPS Sampling with and without replacement, Cumulative method and Lahiri's method of selection, Horvitz-Thompson estimator, Ordered and unordered estimators, Sampling strategies due to Midzuno-Sen and Rao-Hartley-Cochran. Inclusion probability proportional to size sampling.

VI. Practical

- Determination of sample size and selection of sample;
- Simple random sampling, Inverse sampling, Stratified random sampling, Cluster sampling, systematic sampling;
- Ratio and regression methods of estimation;
- Double sampling, multi-stage sampling, Imputation methods;
- Randomized response techniques;
- Sampling with varying probabilities.

VII. Suggested Reading

- Cassel C.M., Sarndal C.E. and Wretman J.H. 1977. *Foundations of Inference in Survey Sampling*. John Wiley.
- Chaudhari A and Stenger H. 2005. *Survey Sampling Theory and Methods*. 2nd Ed. Chapman & Hall.
- Chaudhari A and Voss J.W.E. 1988. *Unified Theory and Strategies of Survey Sampling*. North Holland.
- Cochran W.G. 1977. *Sampling Techniques*. John Wiley.
- Hedayat A.S. and Sinha B.K. 1991. *Design and Inference in Finite Population Sampling*. John Wiley.
- Kish L. 1965. *Survey Sampling*. John Wiley.
- Mukhopadhyay, P. 2008.
- *Theory and Methods of Survey Sampling*, John Wiley & Sons
- Murthy M.N. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Society, Calcutta.
- Sukhatme P.V., Sukhatme B.V., Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Thompson SK. 2000. *Sampling*. John Wiley.
- Kochran WG. 2007. *Sampling Techniques*. A John Wiley & Sons *Publication*

I. Course Title : Statistical Genetics

II. Course Code : STAT 565

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant to prepare the students in applications of statistics in quantitative genetics and breeding. The students would be exposed to the physical basis of inheritance, detection and estimation of linkage, estimation of genetic parameters and development of selection indices.

V. Theory

Unit I

Physical basis of inheritance. Analysis of segregation, detection and estimation of linkage for qualitative characters. Amount of information about linkage, combined estimation, disturbed segregation.

Unit II

Gene and genotypic frequencies, Random mating and Hardy -Weinberg law, Application and extension of the equilibrium law, Fisher's fundamental theorem of natural selection. Disequilibrium due to linkage for two pairs of genes, sex-linked genes, Theory of path coefficients.

Unit III

Concepts of inbreeding, Regular system of inbreeding. Forces affecting gene frequency - selection, mutation and migration, equilibrium between forces in large populations, Random genetic drift, Effect of finite populationsize.

Unit IV

Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning, Effect of inbreeding on quantitative characters, Multipleallelism in continuous variation, Sex-linked genes, Maternal effects - estimation of their contribution.

Unit V

Correlations between relatives, Heritability, Repeatability and Genetic correlation. Response due to selection, Selection index and its applications in plants and animals' improvement programmes, Correlated response to selection.

Unit VI

Restricted selection index. Variance component approach and linear regression approach for the analysis of GE interactions. Measurement of stability and adaptability for genotypes. Concepts of general and specific combining ability. Diallel and partial diallel crosses - construction and analysis.

VI. Practical

- Test for the single factor segregation ratios, homogeneity of the families with regard to single factor segregation;
- Detection and estimation of linkage parameter by different procedures;
- Estimation of genotypic and gene frequency from a given data.
- Hardy-Weinberg law;
- Estimation of changes in gene frequency due to systematic forces, inbreeding coefficient, genetic components of variation, heritability and repeatability coefficient, genetic correlation coefficient;
- Examination of effect of linkage, epistasis and inbreeding on mean and variance of metric traits;
- Mating designs;
- Construction of selection index including phenotypic index, restricted selection index. Correlated response to selection.

VII. Suggested Reading

- Agarwal BL and Agarwal SP. 2007. *Statistical Analysis of Quantitative Genetics*. New Age International Publisher.
- Bailey NTJ. 1961. *The Mathematical Theory of Genetic Linkage*.Clarendon Press.
- Balding DJ, Bishop M and Cannings C. 2001. *Hand Book of Statistical Genetics*. John Wiley.
- Crow JF and Kimura M. 1970. *An Introduction of Population Genetics Theory*. Harper and Row.
- Dahlberg G. 1948. *Mathematical Methods for Population Genetics*. Inter Science Publ.
- East EM and Jones DF. 1919. *Inbreeding and Outbreeding*.
- Lippincott JB & Co. Ewens WJ. 1979. *Mathematics of Population Genetics*. Springer.

- Falconer DS. 1985. *Introduction to Quantitative Genetics*. ELBL.
- Fisher RA. 1949. *The Theory of Inbreeding*. Oliver & Boyd.
- Fisher RA. 1950. *Statistical Methods for Research Workers*. *Oliver*& Boyd.
- Fisher RA. 1958. *The Genetical Theory of Natural Selection*. *Dover* Publ.
- Kempthorne O. 1957. *An Introduction to Genetic Statistics*. The Iowa State Univ. Press.
- Lerner IM. 1950. *Population Genetics and Animal Improvement*.Cambridge Univ. Press.
- Lerner IM. 1954. *Genetic Homeostasis*. Oliver & Boyd.
- Lerner IM. 1958. *The Genetic Theory of Selection*. John Wiley.
- Li CC. 1982. *Population Genetics*. The University of Chicago Press.
- K & Jinks JL. 1977. *Introduction to Biometrical Genetics*.Chapman & Hall.
- Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.
- Mather K. 1949. *Biometrical Genetics*. Methuen.
- Mather K. 1951. *The Measurement of Linkage in Heredity*.
- Methuen. N. P. 1990. *Statistical Genetics*. Wiley Eastern.

I. Course Title : Statistical Quality Control

II. Course Code : STAT 566

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the concepts of Statistical Quality Control and their applications in agribusiness and agro- processing industries. This course would enable the students to have an idea about the statistical techniques used in quality control. Students who do not have sufficient background of Statistical Methods.

V. Theory

Unit I

Introduction to Statistical Quality Control; Control Charts for Variables – Mean, Standard deviation and Range charts; Statistical basis; Rational subgroups.

Unit II

Control charts for attributes- 'np', 'p' and 'c' charts.

Unit III

Fundamental concepts of acceptance, sampling plans, single, double and sequential sampling plans for attributes inspection.

Unit IV

Sampling inspection tables for selection of single and double sampling plans.

VI. Suggested Reading

- Cowden D.J. 1957. *Statistical Methods in Quality Control*. Prentice Hall of India.
- Dodge H.F. and Romig H.G. 1959. *Sampling Inspection Tables*. John Wiley.
- Duncan A.J. 1986. *Quality Control and Industrial Statistics*. 5th Ed. Irwin Book Co.
- Grant E.L. and Leavenworth R.S. 1996. *Statistical Quality Control*. 7th Ed. McGraw Hill.
- Montgomery D.C. 2008. *Introduction to Statistical Quality Control*. 6th Ed. John Wiley.
- Wetherhil G.B. 1977. *Sampling Inspection and Quality Control*. Halsted Press.

I. Course Title : Optimization Techniques

II. Course Code : STAT 567

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students to the mathematical details of the techniques optimization techniques. They will be taught numerical methods of optimization, linear programming techniques, nonlinear programming and multiple objective programming. Students will also be exposed to practical applications of these techniques.

V. Theory

Unit I

Classification of optimization problems, Classical optimization techniques: single variable optimization, multivariable optimization techniques with no constraints, multivariable optimization techniques with equality constraints, multivariable optimization techniques with inequality constraints.

Unit II

Linear programming: simplex method, duality, sensitivity analysis, Karmarkar's method, transportation problem.

Unit III

Nonlinear programming Unconstrained optimization techniques: direct search methods such as random search, grid search, Hooke and Jeeves' method, Powel's method. Descent methods such as gradient method, steepest descent method, conjugate gradient method, Newton's method, Marquardt method.

Unit IV

Quadratic programming, integer linear programming, integer nonlinear programming, geometric programming, dynamic programming, stochastic programming, multiobjective optimization, optimal control theory, genetic algorithms, simulated annealing, neural network based optimization,

VI. Practical

- Problems based on classical optimization techniques, optimization techniques with constraints, minimization problems using numerical methods.
- Linear programming (LP) problems through graphical method, simplex method, simplex two-phase method, primal and dual method.
- Sensitivity analysis for LP problem, LP problem using Karmarkar's method.
- Problems based on Quadratic programming, integer programming, dynamic programming, stochastic programming.
- Problems based on Pontryagin's maximum principle.
- Problems based on multiobjective optimization.

VII. Suggested Reading

- Antunes C.H., Alves, M.J., Climaco J. 2016. *Multi objective Linear and Integer Programming* (EURO Advanced Tutorials on Operational Research)
- Nocedal, J. and Wright, S.J. 1999. *Numerical Optimization*. Springer.
- Rao, S.S. 2007. *Engineering Optimization: Theory and Practice*. New Age International Publishers.
- Rustagi, J.S. 1994. *Optimization Techniques in Statistics*. Academic Press.

- Taha, H.A. 2007. *Operations Research: Introduction with CD*. Pearson Education.
- Xu, H, Teo, K.L. Zhang Y. 2016. *Optimization and Control Techniques and Applications* (Springer Proceedings in Mathematics & Statistics)
- Zeleny, M. 1974. *Linear Multi objective Programming*. Springer.

I. Course Title : Multivariate Analysis

II. Course Code : STAT 571

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of Multivariate data analysis. Most of the data sets in agricultural sciences are multivariate in nature. The exposure provided to multivariate data structure, multinomial and multivariate normal distribution, estimation and testing of parameters, various data reduction methods would help the students in having a better understanding of agricultural research data, its presentation and analysis.

V. Theory

Unit I

Concept of random vector, its expectation and Variance-Covariance matrix. Marginal and joint distributions. Conditional distributions and Independence of random vectors. Multinomial distribution. Multivariate Normal distribution, marginal and conditional distributions. Sample mean vector and its distribution. Maximum likelihood estimates of mean vector and dispersion matrix. Tests of hypothesis about mean vector.

Unit II

Wishart distribution and its simple properties. Hotelling's T^2 and Mahalanobis D^2 statistics. Null distribution of Hotelling's T^2. Rao's U statistics and its distribution. Wilks' λ criterion and its properties. Concepts of discriminant analysis, computation of linear discriminant function, classification between k (≥ 2) multivariate normal populations based on LDF and Mahalanobis D^2.

Unit III

Principal Component Analysis, factor analysis. Canonical variables and canonical correlations. Cluster analysis: similarities and dissimilarities of qualitative and quantitative characteristics, Hierarchical clustering. Single, Complete and Average linkage methods. K-means cluster analysis.

Unit IV

Path analysis and computation of path coefficients, introduction to multidimensional scaling, some theoretical results, similarities, metric and non-metric scaling methods.

VI. Practical

- Maximum likelihood estimates of mean-vector and dispersion matrix;
- Testing of hypothesis on mean vectors of multivariate normal populations;
- Cluster analysis, Discriminant function, Canonical correlation, Principal component analysis, Factor analysis;
- Multivariate analysis of variance and covariance, multidimensional scaling.

VII. Suggested Reading

- Abdelmonem A, Virginia AC and Susanne M. 2004. *Computer Aided Multivariate Analysis*. Chapman & Hall/CRC.
- Anderson TW. 1984. *An Introduction to Multivariate Statistical Analysis*. 2nd Ed. John Wiley.
- Arnold SF. 1981. *The Theory of Linear Models and Multivariate Analysis*. John Wiley.
- Giri NC. 1977. *Multivariate Statistical Inference*. Academic Press.
- Johnson RA and Wichern DW. 1988. *Applied Multivariate Statistical Analysis*. Prentice Hall.
- Kshirsagar AM. 1972. *Multivariate Analysis*. Marcel Dekker.
- Muirhead RJ. 1982. *Aspects of Multivariate Statistical Theory*. John Wiley. Muirhead, RJ. (2005) *Aspects of Multivariate Statistical Theory*. 2nd Ed. John Wiley.
- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Rencher AC. 2012. *Methods of Multivariate Analysis*. 3rd Ed. John Wiley.
- Srivastava MS and Khatri CG. 1979. *An Introduction to Multivariate Statistics*. North Holland.

I. Course Title : Regression Analysis

II. Course Code : STAT 572

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant to prepare the students in linear and non-linear regression methods useful for statistical data analysis. They would also be provided a mathematical foundation behind these techniques and their applications in agricultural data.

V. Theory

Unit I

Simple and Multiple linear regressions: Least squares fit, Properties and examples. Polynomial regression: Use of orthogonal polynomials.

Unit II

Assumptions of regression; diagnostics and transformations; residual analysis ~ Studentized residuals, applications of residuals in detecting outliers, identification of influential observations. Lack of fit, Pure error. Test of normality, test of linearity,Testing homoscedasticity and normality of errors, Durbin-Watson test. Test of goodness of fit for the model evaluation and validation.Concept of multi-collinearity

Unit III

Weighted least squares method: Properties, and examples. Box-Cox family of transformations. Use of dummy variables, Over fitting and under fitting of model, Selection of variables: Forward selection, Backward elimination. Stepwise and Stagewise regressions.

Unit IV

Introduction to non-linear models, nonlinear estimation: Least squares for nonlinear models.

VI. Practical

- Multiple regression fitting with three and four independent variables;
- Estimation of residuals, their applications in outlier detection, distribution of residuals;

- Test of homoscedasticity, and normality, Box-Cox transformation;
- Restricted estimation of parameters in the model, hypothesis testing, Step wise regression analysis;
- Least median of squares norm, Orthogonal polynomialfitting.

VII. Suggested Reading

- Barnett V and Lewis T. 1984. *Outliers in Statistical Data*. John Wiley.
- Belsley DA, Kuh E and Welsch RE. 2004. *Regression Diagnostics-Identifying Influential Data and Sources of Collinearity*. John Wiley.
- Chatterjee S and Hadi AS. 2013. *Regression Analysis* by *Example*. A John Wiley & sons Publication.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- McCullagh P and Nelder JA. 1999. *Generalized Linear Models*. 2nd Ed.*Chapman* & Hall.
- Montgomery DC, Peck EA and Vining GG. 2003. *Introduction to Linear Regression Analysis*. 3rd Ed. John Wiley.
- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd*Ed*. John Wiley.

I. Course Title : Statistical Computing

II. Course Code : STAT 573

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data.Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis.

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis.

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics;

- General linear models ~ fitting and analysis of residuals, outlier detection;
- Fitting and testing the goodness of fit of probability distributions;
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test, One way analysis of variance, contrast and its testing, pairwise comparisons;
- Mixed effect models, estimation of variance components;
- Categorical data analysis, dissimilarity measures, similarity measures;
- Analysis of discrete data, analysis of binary data;
- Numerical algorithms;
- Spatial modeling, cohort studies;
- Clinical trials, analysis of survival data;
- Handling missing data.Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. *Categorical Data Analysis*. 3rd Ed. John Wiley.
- Everitt BS and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gelman A & Hill J. 2006. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge Univ. Press.
- Gentle JE, Härdle W and Mori Y. 2012. *Handbook of Computational Statistics - Concepts and Methods*. 2nd Ed. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer.
- Kennedy WJ & Gentle JE. 1980. *Statistical Computing*. Marcel Dekker.
- Miller RG Jr. 1986. *Beyond ANOVA, Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Ryan BF and Joiner BL. 1994. *MINITAB Handbook*. 3rd Ed. Duxbury Press.
- Simonoff JS. 1996. *Smoothing Methods in Statistics*. Springer.
- Singh, AK. 2016. *Practical R-Book by Examples for Agricultural Statistics*. Deptt. Of Ag. Statistics, IGKV. Raipur
- Snell EJ. 1987. *Applied Statistics: A Handbook of BMDP Analyses*. Chapman & Hall.
- Thisted RA. 1988. *Elements of Statistical Computing*. Chapman & Hall.
- Venables WN and Ripley BD. 1999. *Modern Applied Statistics With S-Plus*. 3rd Ed. Springer.
- http: //www.r-project.org/
- http: //www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Time Series Analysis

II. Course Code : STAT 574

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant to teach the students the concepts involved in time series data. They would also be exposed to components of time series, stationary models and forecasting/ projecting the future scenarios based on time series data. It would also help them in understanding the concepts involved in time series data presentation, analysis and interpretation.

V. Theory

Unit I

Components of a time-series. Autocorrelation and Partial autocorrelation functions, Correlogram and periodogram analysis.

Unit II

Linear stationary models: Autoregressive, moving average and Mixed processes. Linear non-stationary models: Autoregressive integrated moving average processes.

Unit III

Forecasting: Minimum mean square forecasts and their properties, Calculating and updating forecasts.

Unit IV

Model identification: Objectives, Techniques, and Initial estimates. Model estimation: Likelihood function, Sum of squares function, Least squares estimates. Seasonal models. Intervention analysis models and Outlier detection.

VI. Practical

Time series analysis, autocorrelations, correlogram and periodogram; Linear stationary model; Linear non-stationary model; Model identification and model estimation; Intervention analysis and outlier detection.

VII. Suggested Reading

- Box GEP, Jenkins GM and Reinsel GC. 2007. *Time Series Analysis: Forecasting and Control*. 3rd Ed. Pearson Edu.
- Brockwell PJ and Davis RA. 2002. *Introduction to Time Series and Forecasting*. 2nd Ed. Springer.
- Chatterjee S, Hadi A and Price B.1999. *Regression* Analysis by Examples.John Wiley.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Jenkins, GM, Reinsel, GC, Greta M. L,George E.P.B. 2015. *Time Series Analysis: Forecasting and Control*, Wiley Series in Probability and Statistics
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge GG, Hill RC, Griffiths WE, Lutkepohl H and Lee TC. 1988. *Introduction to the Theory and Practice of Econometrics*. 2nd Ed. John Wiley.
- Montgomery DC and Johnson LA. 1976. *Forecasting and Time Series Analysis*. McGraw Hill.
- Montgomery DC, Jennings CA and Kulahci M. 2015. *Introduction to Time Series Analysis and Forecasting*, Wiley Series in Probability and Statistics
- Shumway RH and Stoffer DS. 2006. *Time Series Analysis and its Applications: With R Examples*. 2nd Ed. Springer.

I. Course Title : Demography

II. Course Code : STAT 575

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for training the students in measures of demographic indices, estimation procedures of demographic parameters. Students would also be exposed to population projection techniques and principle involved inbioassays.

V. Theory

Unit I

Introduction to vital statistics, crude and standard mortality and morbidity rates, Estimation of mortality, Measures of fertility and mortality, period and cohort measures.

Unit II

Life tables and their applications, methods of construction of abridged life tables, Increment-Decrement Life Tables.

Unit III

Stationary and stable populations, Migration and immigration. Application of stable population theory to estimate vital rates, migration and its estimation. Demographic relations in Nonstable populations. Measurement of population growth, Lotka's model (deterministic) and intrinsic rate of growth, Measures of mortality and morbidityPeriod.

Unit IV

Principle of biological assays, parallel line and slope ratio assays, choice of doses and efficiency in assays quantal responses, probit and logit transformations, epidemiological models.

VI. Suggested Reading

- Cox DR. 1957. *Demography*. Cambridge Univ. Press.
- Charles Griffin. Fleiss JL. 1981. *Statistical Methods for Rates and Proportions*. John Wiley.
- Finney DJ. 1981. *Statistical Methods in Biological Assays*.
- Grow A, Bavel JV. 2016. *Agent-Based Modelling in Population Studies: Concepts, Methods, and Applications* (The Springer Series on Demographic Methods and Population Analysis)
- Lawless JF. 1982. *Statistical Models and Methods for Lifetime Data*. John Wiley.
- MacMahon B and Pugh TF. 1970. *Epidemiology- Principles and Methods.*Little Brown, Boston.
- Mann NR, Schafer RE and Singpurwalla ND. 1974. *Methods for Statistical Analysis of Reliability and Life Data*. John Wiley.
- Newell C. 1988. *Methods and Models in Demography*. Guilford Publ.
- Preston S, Heuveline P and Guillot M. 2001. *Demography: Measuring and Modeling Population Processes*. Blackwell Publ.
- Rowland DT. 2004. *Demographic Methods and Concepts*. Oxford Press.
- Siegel JS and Swanson DA. 2004. *The Methods and Material ofDemography*. 2nd Ed. Elsevier.
- Woolson FR. 1987. *Statistical Methods for the Analysis of Biomedical Data*. JohnWiley.
- Yakovlev AY, Klebanov L and Gaile D. 2013. *Statistical Methods for Microarray Data Analysis: Methods and Protocols* (Methods in Molecular Biology)

I. Course Title : Statistical Methods for Life Sciences

II. Course Code : STAT 576

III. Credit Hours : 2+0

IV. Aim of the course

This course focuses on statistical methods for discrete data collected in public health, clinical and biological studies including survival analysis. This would enable the students to understand the principles of different statistical techniques useful in public health and clinical studies conducted.

V. Theory

Unit I

Proportions and counts, contingency tables, logistic regression models, Poisson regression and log-linear models, models for polytomous data and generalized linear models.

Unit II

Computing techniques, numerical methods, simulation and general implementation of biostatistical analysis techniques with emphasis on data applications. Analysis of survival time data using parametric and non- parametric models, hypothesis testing, and methods for analyzing censored (partially observed) data with covariates. Topics include marginal estimation of a survival function, estimation of a generalized multivariate linear regression model (allowing missing covariates and/or outcomes).

Unit III

Proportional Hazard model: Methods of estimation, estimation of survival functions, time-dependent covariates, estimation of a multiplicative intensity model (such as Cox proportional hazards model) and estimation of causal parameters assuming marginal structural models.

Unit IV

General theory for developing locally efficient estimators of the parameters of interest in censored data models. Rank tests with censored data. Computing techniques, numerical methods, simulation and general implementation of bio-statistical analysis techniques with emphasis on data applications.

Unit V

Newton, scoring, and EM algorithms for maximization; smoothing methods; bootstrapping; trees and neural networks; clustering; isotonic regression; Markov chain Monte Carlomethods.

VI. Suggested Reading

- Biswas S. 2007. *Applied Stochastic Processes. A Biostatistical and Population Oriented Approach*. Wiley Eastern Ltd.
- Collett D. 2003. *Modeling Survival Data in Medical Research*. Chapman & Hall.
- Cox D.R. and Oakes D. 1984. *Analysis of Survival Data*. Chapman & Hall.
- Hosmer DW Jr. and Lemeshow S. 1999. *Applied Survival Analysis: Regression Modeling or Time to Event*. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. *Survival Analysis: Techniques for Censored and Truncated Data*. Springer.
- Kleinbaum D.G. and Klein M 2005. *Survival Analysis. A Self Learning Text*. Springer.
- Kleinbaum D.G. and Klein M. 2005. *Logistic Regression*. 2nd Ed. Springer.
- Lee ET. 1992. *Statistical Methods for Survival Data Analysis*.
- John Wiley and Miller RG. 1981. *Survival Analysis*. John Wiley.
- Therneau T.M. and Grambsch P.M. 2000. *Modeling Survival Data: Extending the Cox Model*.Springer.

I. Course Title : Statistical Ecology

II. Course Code : STAT 577

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the importance and use of statistical methods in collections of ecological data, species-abundance relations, community classification and community interpretation.

V. Theory

Unit I

Ecological data, Ecological sampling; Spatial pattern analysis: Distribution methods, Quadrant-variance methods, Distancemethods.

Unit II

Species-abundance relations: Distribution models, Diversity indices; Species affinity: Niche-overlap indices, interspecific association, interspecificcovariation.

Unit III

Community classification: Resemblance functions, Association analysis, Cluster analysis; Community Ordination: Polar Ordination, Principal Component Analysis, Correspondence analysis, Nonlinear ordination.

Unit IV

Community interpretation: Classification Interpretation and Ordination Interpretation.

VI. Suggested Reading

- Gotelli N.J. and Ellison A.M. 2004. *A Primer of Ecological Statistics*
- Pielou E.C. 1970. *An introduction to Mathematical Ecology*. John Wiley.
- Reynolds J.F. and Ludwig J.A. 1988. *Statistical Ecology: A Primer on Methods and Computing*. JohnWiley.
- Young L.J., Young J.H. and Young J. 1998. *Statistical Ecology: A Population Perspective.* Kluwer.

Course Title with Credit load
Ph.D. in Agricultural Statistics

Course Code	Course Title	Credit Hours	Semester
*STAT 601	Advanced Data Analytics	1+2	I
*STAT 602	Simulation Techniques	1+1	I
*STAT 603	Linear Models	2+0	I
*STAT 604	Advanced Statistical Methods	2+1	I
*STAT 611	Baysian Inference	2+0	II
STAT 691	Seminar I	0+1	I
STAT 692	Seminar II	0+1	II
STAT 699	Research	0+75	II-VI
STAT 605	Modeling Techniques for Forecasting	2+1	I
STAT 606	Stochastic Processes	2+0	I
STAT 607	Survival Analysis	2+0	I
STAT 608	Spatial Statistics	1+1	I
STAT 612	Advanced Design of Experiments	2+1	II
STAT 613	Advanced Sampling Techniques	2+1	II
STAT 614	Advanced Statistical Genetics	2+1	II
STAT 615	Advanced Time Series Analysis	2+0	II
STAT 616	Advanced Bioinformatics	2+0	II
STAT 617	Advanced Econometrics	2+0	II
STAT 618	Recent Advances in the Field of Specialization	1+0	II

*Core Courses

Course Contents
Ph.D. in Agricultural Statistics

I. Course Title : Advanced Data Analytics
II. Course Code : STAT 601
III. Credit Hours : 1+2

IV. Aim of the course

This is an advanced course in Statistical Computing that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences and use of statistical packages.

V. Theory

Unit I

Measures of association. Structural models for discrete data in two or more dimensions.
Estimation in complete tables. Goodness of fit, choice of a model. Generalized Linear Model for discrete data, Poisson and Logistic regression models. Log-linearmodels.

Unit II

Elements of inference for cross-classification tables. Models for nominal and ordinal response.

Unit III

Computational problems and techniques for robust linear regression, nonlinear and generalized linear regression problem, tree-structured regression and classification, cluster analysis, smoothing and function estimation, robust multivariate analysis.

Unit IV

Analysis of incomplete data: EM algorithm, single and multiple imputations. Markov Chain, Monte Carlo and annealing techniques, Neural Networks, Association Rules and learning algorithms.

Unit V

Linear mixed effects models, generalized linear models for correlated data (including generalized estimating equations), computational issues and methods for fitting models, and dropout or other missing data.

Unit VI

Multivariate tests of linear hypotheses, multiple comparisons, confidence regions, prediction intervals, statistical power, transformations and diagnostics, growth curve models, dose-response models.

VI. Practical

- Analysis of qualitative data;
- Generalized linear for correlated data;
- Generalized linear models for discrete data;
- Robust methods of estimation and testing of non-normal data;
- Robust multivariate analysis;
- Cluster analysis;
- Analysis of Incomplete data;
- Classification and prediction using artificial neural networks;
- Markov Chain;
- Analysis of data having random effects using Linear mixed effects models;
- Analysis of data with missing observations;
- Applications of multiple comparison procedures;
- Building Simultaneous confidence intervals;
- Fitting of growth curve models to growth data;
- Fitting of dose-response curves and estimation of parameters.

Suggested Reading

- Everitt B.S. and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gentle J.E., Härdle W and Mori Y. 2004. *Handbook of Computational Statistics-Concepts and Methods*. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2017. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer. 2nd Ed.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Miller R.G. Jr. 1986. *Beyond ANOVA, Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Robert C.P. and Casella G. 2004. *Monte Carlo* Statistical *Methods*. 2nd Ed. Springer.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Simonoff J.S. 1996. *Smoothing Methods in Statistics*. Springer.
- Thisted R.A. 1988. *Elements of Statistical Computing*. Chapman & Hall.
- Venables W.N. and Ripley B.D. 1999. *Modern Applied Statistics With S-Plus*. 3rd Ed. Springer.
- Free Statistical Softwares: http: //freestatistics.altervista.org/en/stat.php.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Simulation Techniques

II. Course Code : STAT 602

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for students who have a good knowledge in Statistical Inference and Statistical Computing. This course would prepare students for undertaking research in the area of simulation techniques andtheir applications to agricultural sciences.

V. Theory

Unit I

Uses and purposes of simulation; Classification of models. Generation and testing of random numbers, Review of simulation methods; Implementation of simulation methods - for Discrete and continuous probability distribution, sampling and resampling methods: theory and application of the jackknife and thebootstrap.

Unit II

Randomization tests, analysis using computer software packages. Simulating multivariate distributions, MCMC methods and Gibbs sampler.

Unit III

Simulation of generalized linear models and time series models, Simulated data sets to be analyzed using popular computer software packages.

Unit IV

Stochastic simulation: Markov Chain, Monte Carlo, Hastings-Metropolis algorithms, critical slowing-down and remedies, auxiliary variables, simulated tempering, reversible- jump MCMC and multi-grid methods.

VI. Practical

- Simulation from various probability models;
- Resampling methods, jackknife and the bootstrap;
- Randomization tests;
- Simulating multivariate distributions, MCMC methods and Gibbs sampler;
- Simulated data sets to be analyzed using popular computer software packages;
- Markov Chain, Monte Carlo, Gibbs' sampling;
- Reversible- jump MCMC and multi-grid methods.

VII. Suggested Reading

- Averill M.L. 2017. *Simulation, Modeling and Analysis*. Tata McGraw Hill.
- Balakrishnan N, Melas V.B. and Ermakov S. (Ed.). 2000. *Advances in Stochastic Simulation Methods*. Basel-Birkhauser.
- Banks J. (Ed.). 1998. *Handbook of Simulation: Principles, Methodology, Advances, Applications and Practice*. John Wiley.
- Brately P, Fox B.L. and Scharge L.E. 1987. *A Guide to Simulation*. Springer. Davison A.C. and Hinkley D.V. 2003. *Bootstrap Methods and their Application*. Cambridge Univ. Press.
- Gamerman D, Lopes H.F. and Lopes H.F. 2006. *Markov Chain* Monte *Carlo: Stochastic Simulation for Bayesian Inference*. CRC Press.
- Gardner F.M. and Baker J.D. 1997. *Simulation Techniques Set*. John Wiley. Gentle J.E. 2005. *Random Number Generation and Monte Carlo Methods*. Springer.
- Janacek G and Louise S. 1993. *Time Series: Forecasting, Simulation, Applications*. Ellis Horwood Series in Mathematics and its Applications.
- Kleijnen J and Groenendaal W.V. 1992. *Simulation: A Statistical Perspective*. John Wiley.
- Kleijnen J. 1974 (Part I), 1975 (Part II). *Statistical Techniques in Simulation*. Marcel Dekker.
- Law A and Kelton D. 2000. *Simulation Modeling and Analysis*. McGraw Hill.
- Press W.H., Flannery B.P., Tenkolsky S.A. and Vetterling W.T. 1986. *Numerical Recipes*. Cambridge Univ.Press.
- Ripley B.D. 1987. *Stochastic Simulation*. John Wiley. Ross SM. 1997. *Simulation*. John Wiley.

I. Course Title : Linear Models

II. Course Code : STAT 603

III. Credit Hours : 2+0

IV. Aim of the course

The students would be exposed to the theory of linear models, estimation of variance components for unbalanced data and advanced techniques for analysis of data in agriculture.

V. Theory

Unit I

General Gauss Markoff set up, Gauss-Markoff's theorem, Aitken's transformation. Theory of linear estimation, test of hypothesis in linear models. Analysis of variance, partitioning of degrees of freedom. Restricted least squares. Special cases of one and two way classifications (including disproportionate cell frequencies and interaction, cross and nested classifications).

Unit II

Analysis of covariance. Variance components models, estimation of variance components from unbalanced data. Unified theory of least-squares, MINQUE, MIVQUE. Mixed models. LAR, LASSO.

VI. Suggested Reading

- Bapat, R.B. 2012. *Linear Algebra and Linear Models*. Springer-Verlag.
- Graybill, F. A. 1976. *Theory and Application of the Linear Model*. Duxbury, North Scituate.
- Joshi, D.D. 1987. *Linear Estimation and Design of Experiments*. Wiley Eastern.
- Rao, C. R. 2001. *Linear Inference and its Application*. Wiley Eastern.
- Searle, S. R. 1998. *Variance Components*. John Wiley.
- Searle, S.R. 1971. *Linear Models*. John Wiley.
- Seber, G.A. F. 1996. *The Linear Hypothesis: A General Theory*. Griffin, Charles and Co. Ltd.
- Sheffe, H. 1999. *Analysis of Variance*. John Wiley.

I. Course Title : Advanced Statistical Methods

II. Course Code : STAT 604

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Methods that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agriculturalsciences.

V. Theory

Unit I

Truncated and compound distributions. Fitting of orthogonal polynomials. Pearsonian curves.Categorical data analysis - loglinear models, Association between attributes. Variance stabilizingtransformations.

Unit II

Sampling distribution of correlation coefficient, regression coefficient, correlation ratio, intra class correlation coefficient.

Unit III

Non-central t, χ^2 and F distributions. Distribution of quadratic forms. Cochran's theorem. Tests for normality. Large sample tests. Tests of significance based on t, χ^2 and F distributions. Order statistics, distribution of r^{th} order statistics, joint distribution of several order statistics andtheir functions, marginal distributions of order statistics, distribution of range, median, etc.

Unit IV

Fitting of a generalized linear model, mixed model and variance components estimation, MINQUE, MIVQUE, REML.

VI. Practical

- Fitting of truncated distribution,
- Fitting of Pearsonian curves,
- Analysis of association between attributes, categorical data.
- Fitting of non-central t, χ^2 and F distributions.
- Computation of Tests of significance based on t, χ^2 and F distributions.
- Order statistics.

VII. Suggested Reading

- Chatterjee S, Hadi A and Price B. 2013. *Regression Analysis by Examples*. 5th Ed. John Wiley.
- Draper N.R. and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Rao C.R. 2009. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Searle S.R, Casella G and McCulloch C.E. 1992. *Variance Components*. John Wiley.
- Searle S.R. 1971. *Linear Models*. John Wiley.

I. Course Title : Modeling Techniques for Forecasting

II. Course Code : STAT 605

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Methods that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in the area of empirical and mechanistic models and nonlinear estimation and the replications in different disciplines of agricultural sciences.

V. Theory

Unit I

Empirical and mechanistic models. Nonlinear growth models: monomolecular, logistic, Gompertz, Richards. Applications in agriculture and fisheries.

Unit II

Nonlinear estimation: Least squares for nonlinear models, Methods for estimation of parameters like Linearization, Steepest, and Levenberg- Marquardt's Parameterization.

Unit III

Two-species systems. Lotka-Volterra, Leslie-Gower and Holling-Tanner non-linear prey-predator models. Volterra's principle and its applications. Gauss competition model.

Unit IV

Compartmental modelling - First and second order input-output systems, Dynamics of a multivariable system.

Unit V

Forecasting techniques with special reference to agriculture. Forecast based on time series data: exponential smoothing, Box – Jenkins approach and non-linear models. Forecast models using weather parameters, crop-weather relationships and their use in yield forecast. Forecast using plant characters.

Unit VI

Forecast surveys, between-year models (regression model, Markov chain probability model and group method of data handling) and within-year models. Agro-meteorological models: climatic water balance model and crop yield assessment. Forewarning of crop pests and diseases. Application of remote sensing techniques in forecasting. Use of ANN in forecasting.

VI. Practical

- Fitting of mechanistic non-linear models;
- Application of Schaefer and Fox non-linear models;
- Fitting of compartmental models.Fitting of forecast models using weather parameters.
- Time series analysis: plots, decomposition, stationarity tests, exponential smoothing. •Univariate Box – Jenkins ARIMA models and seasonal ARIMA models.
- Forecast models using plant characters,
- Agrometeorological models for crop forecasting, Markov chain models and ANN models.

VII. Suggested Reading

- Draper, N.R. and Smith, H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Efromovich S. 1999. *Nonparametric Curve Estimation*. Springer.
- Fan, J. and Yao, Q. 2003. *Nonlinear Time Series-Nonparametric and Parametric Methods*. Springer.
- France, J. and Thornley, J.H.M. 1984. *Mathematical Models in Agriculture*. Butterworths.
- Harvey, A.C. 1996. *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge Univ. Press.
- Makridakis, S., Wheelwright, S.C. and Hyndman, R.J. 1998. *Forecasting: Methods and Applications*. John Wiley.
- Pankratz, A. 1983. *Forecasting with Univariate Box Jenkins Models: Concepts and Cases*. John Wiley.
- Thornley, J. and France J. 2006. *Mathematical Models in Agriculture: Quantitative Methods for the Plant, Animal and Ecological Sciences* (Cabi) 2nd Ed.

I. Course Title : Stochastic Processes

II. Course Code : STAT 606

III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Stochastic Processes that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences.

V. Theory

Unit I

Introduction to stochastic process - classification according to state space and time domain. Finite and countable state Markov chains; time- homogeneity; Chapman-Kolmogorov equations, marginal distribution and finite dimensional distributions. Classification of Markov chain. Canonical form of transition probability matrix of a Markov chain. Fundamental matrix; probabilities of absorption from transient states into recurrent classes in a finite Markov chain, mean time for absorption. Ergodic state and Ergodic chain. Stationary distribution of a Markov chain, existence and evaluation of stationary distribution. Random walk and gamblers ruin problem.

Unit II

Discrete state continuous time Markov process: Kolmogorov difference – differential equations. Birth and death process, pure birth process (Yule- Fury process). Immigration-Emigration process. Linear growth process, pure death process.

Unit III

Renewal process: renewal process when time is discrete and continuous. Renewal function and renewal density. Statements of Elementary renewal theorem and Key renewal theorem.

Unit IV

Stochastic process in biological sciences: Markov models in population genetics, compartmental analysis. Simple deterministic and stochastic epidemic model. General epidemic models-Karmack and McKendrick's threshold theorem. Recurrent epidemics.

Unit V

Elements of queueing process; the queuing model M/M/1: steady state behaviors. Birth and death process in queuing theory- Multi channel models. Network of Markovian queuing system.

Unit VI

Branching process: Galton-Watson branching process. Mean and variance of size of nth generation, probability of ultimate extinction of a branching process. Fundamental theorem of branching process and applications.

Unit VII

Wiener process- Wiener process as a limit of random walk. First passage time for Wiener process. Kolmogorov backward and forward diffusion equations and their applications.

VI. Suggested Reading

- Adke SR and Manjunath SM. 1984. *Finite Markov Processes*. John Wiley.
- Bailey NTJ. 1964. *Elements of Stochastic Processes with Applications to the Natural Sciences*. Wiley Eastern.
- Bartlett MS. 1955. *Introduction to Stochastic Processes*. Cambridge Univ. Press.
- Basawa IV and Prakasa Rao BLS. 1980. *Statistical Inference for Stochastic Processes*. Academic Press.
- Bharucha-Reid AT. 2012. *Elements of the Theory of Markov Processes and their Applications*. McGraw Hill.
- Bhat BR. 2000. *Stochastic Models; Analysis and Applications*. New Age.

- Draper NR and Smith H. 1981. *Applied Regression Analysis*. Wiley Eastern. France J &Thornley JHM. 1984. *Mathematical Models in Agriculture*. Butterworths.
- Lawler GF. 2006. *Introduction to Stochastic Processes*. Chapman & Hall. 2nd Ed.
- Medhi J. 2001. *Stochastic Processes*. 2nd Ed. Wiley Eastern.
- Prakasa Rao BLS and Bhat BR.1996. *Stochastic Processes and Statistical Inference*. New Age.
- Ratkowsky DA. 1983. *Nonlinear Regression Modelling: a Unified Practical Approach*. Marcel Dekker.
- Ratkowsky DA. 1990. *Handbook of Nonlinear Regression Models*. Marcel Dekker.
- Seber GAF and Wild CJ. 1989. *Non-linear Regression*. John Wiley.

I. Course Title : Survival Analysis

II. Course Code : STAT 607

III. Credit Hours : 2+0

IV. Aim of the course

The course deals with the study of demographic profiles and survival times. In-depth statistical properties and analysis is an important component of this course.

V. Theory

Unit I

Measures of Mortality and Morbidity: Ratios and proportions, rates of continuous process, rates of repetitive events crude birth rate, Mortality measures used in vital statistics relationships between crude and age specific rates, standardized mortality ratios evaluation of person-year of exposed to risk in long term studies, prevalence and incidence of a disease, relative risk and odds ratio. Survival Distribution: Survival functions, hazard rate, hazard function, review of survival distributions: exponential, Weibull, Gamma, Rayleigh, Pareto, Lognormal~ IFR and TFRA, Gompertz and Makeham. Gompertz and logistic distributions. Parametric (m.l.e) estimation. Types of Censoring: Type I, Type II, random and other types of censoring, right and left truncated distributions. Expectation and variance of future life time, series and parallel system of failures. Life Tables: Fundamental and construction.

Unit II

Complete Mortality data, Estimation of Survival Function: Empirical survival function, estimation of survival function from grouped mortality data, joint distribution of the number of deaths, distribution of the estimation P_i covariance of estimate, estimation of curves of deaths and central death rate and force of mortality rate. Incomplete Mortality data (non-parametric models): Actuarial method, m.1.e method, moment and reduced sample method of estimation and their comparison. Product limit (Kaplan-Meier) method and cumulative hazard function (CHF) of estimation of survival function.

Unit III

Fitting Parametric Survival Distribution: Special form of survival function cumulative hazard function (CHF) plots, Nelson's method of ungrouped data, construction of the likelihood function for survival data, least squares fitting, fitting a Gompertz distribution to grouped data. Some tests of Goodness of fit: Graphical, Kolmogorov-Smirnov statistics for complete, censored and truncated data, Chi-Square test and Anderson- Darling A^2-statistics. Comparison of Mortality

Experiences: Comparison of two life tables, some distribution- free methods (two samples) for ungrouped data, Two samples Kolmogorov-Smirnov test, Wilcoxon test for complete data and modified Wilcoxon test for incomplete data .Gilbert and Gehan's test, mean and variance of Wilcoxon statistics, generalization of Gehan's test. Testing for Consistent Differences in Mortality: Mantel-Haenszel and log rank test. Generalized Mantel-Haenszel test (k-sample).

Unit IV

Concomitant Variables: General parametric model for hazard function with observed concomitant variables. Additive and multiplicative models of hazard rate functions. Estimating multiplicative models, selection of concomitant variables. Logistic linear model, Concomitant Variable regarded as random variable. Age of onset distributions: Models of onset distributions and their estimation. Gompertz distribution, parallel system and Weibull distribution, Fatal short models of failure. Two component series system.

Unit V

Interval Censoring Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations.Concept of COX regression Stochastic Epidemic Models: Simple epidemic models, general epidemic model definition and concept (without derivation). Duration of an epidemic.

VI. Suggested Reading

- Anderson B. 1990. *Methodological Errors in Medical Research*. Blackwell.
- Armitage P and Berry G. 1987. *Statistical* Methods *in Medical Research*. Blackwell.
- Biswas, S. 2007. *Applied Stochastic Processes: A Biostatistical and Population Oriented Approach*, 2nd Ed., New Central Book Agency.
- Collett D. 2014. *Modeling Survival Data in Medical Research*. Chapman & Hall. 3rd Ed.
- Cox D.R. and Oakes D. 1984. *Analysis of Survival Data*. Chapman & Hall.
- Elandt-Johnson R.C. and Johnson N.L. 1980. Survival *Models and Data Analysis*. John Wiley.
- Everitt B.S. and Dunn G. 1998. *Statistical Analysis of Medical Data*. Arnold. Hosmer D.W. Jr. and Lemeshow S. 1999. *Applied Survival Analysis: Regression Modeling or Time to Event*. John Wiley.
- Indrayan, A. 2008. *Medical Biostatistics*, 2nd Ed. Chapman and Hall/CRC.
- Lee E.T. 1980. *Statistical Methods for Survival Data Analysis*. Lifetime Learning Publ.
- Kalbfleisch J.D. and Prentice. R.L. 2002. *The Statistical Analysis of Failure Time Data*. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. *Survival Analysis: Techniques for Censored and Truncated Data*. Springer.
- Kleinbaum D.G. and Klein M. 2002. *Logistic Regression*.Springer.
- Kleinbaum D.G. and Klein M. 2005. *Survival Analysis*. Springer.

I. Course Title : Spatial Statistics

II. Course Code : STAT 608

III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Spatial statistics aims at exposing the students to some advanced level spatial methods and their applications to agricultural situations.

V. Theory

Unit I

Spatial Analysis and types of spatial data; Visualizing Spatial Data – Exploratory data Analysis.

Unit II

Spatial Relationship- Random forest, spatially autocorrelated data, weight matrix, measures of spatial Auto-correlation – Moran's I & Geary's C; Measuring of autocorrelation of spatially continuous data.

Unit III

Spatial Sampling – Methods and procedures, Statistical Analysis of Spatial Point Process – homogenous Poisson Process, Spatial interpolation – non-statistical methods; Variogram modelling; Spatial Prediction – Simple Kriging, Co-kriging;

Unit IV

Modelling Areal data – Autoregressive and spatial regression models and model diagnostics. Examples of Spatial Data analysis in Agriculture– Disease Mapping; Incorporating spatial effects in Agricultural Field experiments

VI. Practical

- Spatial Data – Import, export;
- Spatial Classes in R;
- Visualizing Spatial Data;
- Spatial Auto-correlation;
- Spatial Sampling, Spatial Interpolation, Spatial Autoregressive Models, Spatial Regression Model

VII. Suggested Reading

- Cressie, N.A.C. 1993.*Statistics for Spatial Data*. Revised Edition. JohnWiley
- Richard E.P. 2018. *Spatial Data Analysis in Ecology and Agriculture Using R*, 2nd Ed.
- Roger S. Bivand, E Pebesma J. and Rubio B.G. 2008. *Applied Spatial Data Analysis using R*. Springer-Verlog.

I. Course Title : Baysian Inference

II. Course Code : STAT 611

III. Credit Hours : 2+0

IV. Aim of the course

This course aims at describing the advanced level topics in statistical methods and statistical inference. This course would prepare students to have a strong base in basic statistics that would help them in undertake basic and applied research in Statistics.

V. Theory

Unit I

Introduction and history and criticism of Bayesian Approach; Subjective interpretation of Probability, Review of Bayes Theorem, Sufficiency, Likelihood Principle.

Unit II

Subjective Prior distribution of a parameter; Posterior Distribution of parameters using Bayes Theorem

Unit III

Informative and non-informative priors for Location and scale; Conjugate families –Discrete and Continuous and interpretation of Hyper-parameters of conjugates.

Unit IV

Non-informative, improper and invariant priors for location and scale and in general settings.

Unit V

Bayesian Point Estimation – squared error loss, absolute error loss etc. Bayesian Interval Estimation – Credible Interval, interpretation and comparison with frequentist confidence Intervals

Unit VI

Bayesian Hypothesis Testing - Specification of the appropriate form of the prior distribution for a Bayesian testing of hypothesis problem. Prior odds, Posterior odds, Bayes factor for various types of testing hypothesis problems

Unit VII

Bayesian Prediction; Numerical and Monte-Carlo Integrations

Unit VIII

Applications of Bayesian Inference - Bayesian Data Analysis

VI. Suggested Reading

- Berger, J.O. 1985. *Statistical Decision Theory and Bayesian Analysis*, Springer Verlag.
- Box, G.P. and Tiao, G.C. 1992. *Bayesian Inference in StatisticalAnalysis*,Addison – Wesley
- Pilon C.D. 2015. *Bayesian Methods for Hackers: Probabilistic Programming and Bayesian Inference* (Addison-Wesley Data and Analytics)

I. Course Title : Advanced Design of Experiments

II. Course Code : STAT 612

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Design of Experiments that aims at describing some advanced level topics for students who wish to pursue research in Design of Experiments. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences.

V. Theory

Unit I

General properties and analysis of block designs. Balancing criteria. *m*- associate PBIB designs, and their association schemes including lattice designs - properties and construction, Designs for test treatment – control(s) comparisons; Nested block designs, Mating designs.Structurally Incomplete block designs

Unit II

General properties and analysis of two-way heterogeneity designs, Youden type designs, generalized Youden designs, Pseudo Youdendesigns., Designs for two sets of treatments.

Unit III

Balanced factorial experiments - characterization and analysis (symmetrical and asymmetrical factorials). Factorial experiments with extra treatment(s). Orthogonal arrays, Mixed orthogonal arrays, balanced arrays, Fractional replication, Resolution plans, Regular and irregular fractions.

Unit IV

Response surface designs - Symmetrical and asymmetrical factorials, Response optimization and slope estimation, Blocking, Canonical analysis and ridge analysis, CCD, Box-Jenkins, Experiments with mixtures: design and analysis. Experiments with qualitative cum quantitative factors.

Unit V

Optimality criteria and optimality of designs, robustness of designs against loss of data, outliers, etc. Diagnostics in design of experiments.

VI. Practical

Analysis of block designs, Analysis of Latin square type designs, group divisible designs, triangular designs, lattice designs. Analysis of fractional replications of factorial experiments, analysis of asymmetrical factorials and block designs with factorial structure. Analysis of second order response surface designs.

VII. Suggested Reading

- Chakraborti M.C. 1962. *Mathematics of Design and Analysis of Experiments*. Asia Publ.House.
- Dean A.M. and Voss D. 1999. *Design and Analysis of Experiments*.
- pringer. Dey A and Mukerjee R. 1999. *Fractional Factorial Plans*. John Wiley.
- Dey A 1986. *Theory of Block Designs*. Wiley Eastern.
- Hall M Jr. 1986. *Combinatorial Theory*. John Wiley.
- Hedayat A.S., Sloane N.J.A. and Stufken J. 1999. *Orthogonal Arrays: Theory and Applications*. Springer.
- John J.A. and Quenouille M.H. 1977. *Experiments: Design and Analysis*. Charles and Griffin.
- Khuri A.I. and Cornell J.A. 1996. *Response Surface Designs and Analysis*. 2nd Ed. Marcel Dekker.
- Montgomery D.C. 2005. *Design and Analysis of Experiments*. John Wiley.
- Ogawa J. 1974. *Statistical Theory of the Analysis of Experimental Designs*. Marcel Dekker.
- Parsad R, Gupta V.K., Batra P.K., Satpati S.K. and Biswas P. 2007. *Monograph on a-designs*. IASRI, New Delhi.
- Raghavarao D. 1971. *Construction and Combinatorial Problems in Design of Experiments*. John Wiley.
- Shah K.R. and Sinha B.K. 1989. *Theory of Optimal Designs. Lecture notes in Statistics*. Vol. 54. Springer.
- Sharma M.K. 2012. *Design and Analysis of Experiments*. Kindle Ed. 1st Ed.
- Street A.P. and Street D.J. 1987. *Combinatorics of Experimental Designs*.Oxford Science Publ.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Advanced Sampling Techniques

II. Course Code : STAT 613

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Sampling Techniques that aims at describing some advanced level topics for students who wish to pursue research in Sampling Techniques. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to Statistical System in thecountry.

V. Theory

Unit I

Optimum Stratification, two-way stratification, collapsed strata, Controlled selection, Use of combinatorics in controlled selection, Systematic sampling in two dimensions. Sampling with varying probabilities without replacement, Horvitz – Thompson estimator

Unit II

Variance estimation in complex surveys. Taylor's series linearization, balanced repeated replication, Jackknife and bootstrap methods.Ordered and unordered estimators, Sampling strategies, Midzuno-Sen, Rao-Hartley-Cochran,ðPS Sampling: procedures such as Brewer, Durbin and Sampford,

Unit III

Unified theory of sampling from finite populations. UMV - Non-existence theorem and existence theorem under restricted conditions. Concept of sufficiency and likelihood in survey sampling. Admissibility and hyper- admissibility.

Unit IV

Post-stratified estimator, imperfect frames, multiple frames, randomized response techniques. Inference under super population models - concept of designs and model unbiasedness, prediction approach. Regression analysis and categorical data analysis with data from complex surveys. Domain estimation. Small area estimation. Longitudinal survey.

VI. Practical

- Sampling with varying probability,
- Ordered and un-ordered estimators,
- Sampling strategies due to Horvitz-Thompson, Midzuno-Sen, Rao-Hartley-Cochran and PPS sampling: procedures such as Brewer, Durbin and Sampford, etc.
- Imperfect frames, Randomized response technique.
- Small area estimation.

V. Suggested Reading

- Berger J.O. 1993. *Statistical Decision Theory and Bayesian Analysis*. Sringer.
- Bolfarine H and Zacks S. 1992. *Prediction Theory for Finite Population Sampling*. Springer.
- Cassel C.M., Sarndal C.E and Wretman J.H. 1977. *Foundations of Inference in Survey Sampling*. John Wiley.
- Des Raj and Chandhok P. 1998. *Sample Survey Theory*. Narosa Publ.
- House. Ghosh M and Meeden G. 1997. *Bayesian Method for Finite Population*
- *Sampling*. *Monograph on Statistics and Applied Probability*. Chapman and Hall.

- Mukhopadhyay P. 1998. *Theory and Methods of Survey Sampling*. Prentice Hall of India.
- Rao J.N.K. 2003. *Small Area Estimation*. John Wiley.
- Sarndal C.E., Swensson B and Wretman J.H. 1992. *Model Assisted Survey Sampling*. Springer.

I. Course Title : Advanced Statistical Genetics

II. Course Code : STAT 614

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Genetics that aims at describing some advanced level topics for students who wish to pursue research in Statistical Genetics. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject in plant and animal breeding.

V. Theory

Unit I

Hardy-Weinberg law with multiple allelic systems, auto-tetraploids and self-sterility alleles. Complex cases of selection with two or more loci.

Unit II

Different approaches to study inbreeding process, methods of path co- efficient, probability and generation matrix. Fisher's approach to inbreeding. Stochastic process of gene frequency change, transition matrix approach using finite Markov chains, diffusion approximation, Steady decay and distribution of gene frequency, Probability of fixation of a gene, Conditional process - Markov chains and diffusion approaches, Distribution of time until fixation, random fluctuations in selection intensity, stationary distribution of gene frequency. Effective population size.

Unit III

Prediction and estimation of genetic merit. Best linear unbiased prediction, Use of mixed model methodology in analysis of animal and plant breeding experiments. Newer reproductive technology and its effect in genetic evaluation of individual merit. Estimation of genetic parameters - problems relating to computational aspects of genetic variance components, parameter estimation in variance component models for binary response data.

Unit IV

Identification of genes with large effects, Use of molecular markers (RFLP, PCR-AFLP, RAPD and SSR), Gene mapping and Quantitative trait loci. Molecular manipulation for genetic variability.

Unit V

Variance component approach and linear regression approach for the analysis of GE interactions.Measurement of stability and adaptability for genotypes. Concepts of general and specific combining ability, diallel and partial diallel crosses: construction and analysis.

VI. Practical

- Hardy-Weinberg law,
- Estimation of genetic load and random genetic drift.
- Effect of finite population size.
- Estimation of path coefficients.
- Detection and estimation of multiple allelism in continuous variation, sexlinked genes, maternal effects.
- Analysis of G × E interaction, measurement of stability and adaptability.
- Analysis of data of diallel and partial diallel crosses.

VII. Suggested Reading

- Crow J.F. and Kimura M. 1970. *An Introduction of Population Genetics Theory*. Harper & Row.
- Ewens W.J. 1979. *Mathematical Population Genetics*. Springer.
- Falconer D.S. 1985. *Introduction to Quantitative Genetics*. ELBL.
- Fisher R.A. 1949. *The Theory of Inbreeding*. Oliver & Boyd.
- Fisher R.A. 1958. *The Genetical Theory of Natural Selection*. Dover Publ.
- Haldane J.B.S. 1932. *The Causes of Evolution*. Harper & Bros.
- Kempthorne O. 1957. *An Introduction to Genetic Statistics*. The Iowa State Univ. Press.
- Lerner I.M. 1950. *Population Genetics and Animal Improvement*. Cambridge Univ. Press.
- Lerner I.M. 1958. *The Genetic Theory of Selection*. John Wiley.
- Li C.C. 1982. *Population Genetics*. The University of Chicago Press.
- Mather K and Jinks J.L. 1982. *Biometrical Genetics*. Chapman & Hall.
- Mather K. 1951. *The Measurement of Linkage in Heredity*.
- Methuen. Nagilaki T. 1992. *Introduction to Theoretical PopulationGenetics*.Springer.
- Narain P. 1990. *Statistical Genetics*. Wiley Eastern.
- Nielsen R, Montgomery S. 2013. *An Introduction to Population Genetics: Theory and Applications* 1st Ed.

I. Course Title : Advanced Time Series Analysis

II. Course Code : STAT 615

III. Credit Hours : 2+0

IV. Aim of the course

This is an advanced course in Time Series Analysis that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agriculturalsciences.

V. Theory

Unit I

Multivariate time series: modelling the mean, stationary VAR models: properties, estimation, analysis and forecasting, VAR models with elements of nonlinearity, Non-stationary multivariate time series: spurious regression, co-integration, Vector Error Correction Model (VECM).

Unit II

Volatility: The class of ARCH and GARCH models; Extensions of GARCH models: TGARCH, IGARCH, PGARCH, EGARCH, GJR-GARCH, ARCH and GARCH model with-t distributed error; ARCD (Auto-Regressive Conditional Density), Multivariate GARCH model: estimation, analysis and forecasting, stochastic volatility.

Unit III

Structural time-series modelling: State space models, Kalman filter, Local level model, Local linear trend model, Seasonal models, Cyclical models. Threshold and Functional coefficient autoregressive models, Structural Break in time series.

Unit IV

Fuzzy time series models, Artificial Neural Network (ANN) methodology, Support vector machines, Wavelets for time series analysis, combinations of time series models.

VI. Suggested Reading

- Box G.E.P., Jenkins G.M. and Reinsel G.C. 2015. *Time Series Analysis: Forecasting and Control*. 5th Ed. John Wiley.
- Brockwell P.J. and Davis R.A. 1991. *Time Series: Theory and Methods*. 2nd Ed. Springer.
- Chatfield C. 2004. *The Analysis of Time Series: An Introduction*. 6th Ed. Chapman& Hall/ CRC.
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Singh, P. 2016. *Applications of Soft Computing in Time Series Forecasting: Simulation and Modeling Techniques*. Springer International Publishing AG
- Tong H. 1995. *Nonlinear Time Series: A Dynamical System Approach*.Oxford Univ. Press.
- Vapnik, V. N. (2000). *The Nature of Statistical Learning Theory*. Springer- Verlag, New York.
- Percival, D.B. and Walden, A.T. 2000. *Wavelet Methods for Time-Series Analysis.* Cambridge University Press, U.K.

I. Course Title : Advanced Bioinformatics

II. Course Code : STAT 616

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Bioinformatics that aims at exposing the students to some advanced statistical and computational techniques related to bioinformatics. This course would prepare the students in understanding bioinformatics principles and their applications.

V. Theory

Unit I

EM algorithm and other statistical methods to discover common motifs in biosequences. Concepts in phylogeny. Gene prediction based on codons, Decision trees, Clustering Techniques, Classificatory analysis, Neural Networks, Genetic algorithms, Pattern recognition, Hidden Markov models.

Unit II

Computational analysis of protein sequence, structure and function. Expression profiling by microarray/ gene chip/ RNAseq, proteomics etc., Multiple alignment of protein sequences, Modelling and prediction of structure of proteins, Designer proteins, Drug designing.

Unit III

Analysis of one DNA sequence (Modeling signals in DNA; Analysis of patterns; Overlaps and Generalizations), Analysis of multiple DNA or protein sequences (Alignment algorithms – Gapped global comparisons and Dynamic programming;

use of linear gap models; protein sequences and substitution matrices – BLOSUM, PAM; Multiple sequences), BLAST (Comparison of two aligned sequences – Parameter calculation; Choice of a score; Bounds for P-value; Normalized and Bit scores, Karlin – Altschul sum statistic; comparison of two unaligned sequences; Minimum significance Lengths).

Unit IV

Markov Chains (MC with no absorbing states, higher order Markov dependence, patterns insequences, Markov Chain Monte Carlo – Hastings-Metropolis algorithm, simulated annealing,MC with absorbing States). Bayesian techniques and use of Gibbs Sampling. Advanced topicsin design and analysis of DNA microarray experiments.

Unit V

Modeling protein families; Multiple sequence alignments; Pfam; Gene finding), Computationally intensive methods (Classical estimation methods; Bootstrap estimation and Confidence Intervals; Hypothesis testing; Multiple Hypothesis testing), Evolutionary models (Models of Nucleotide substitution; Discrete time models – The Jukes-Cantor Model, The Kimura Model, The Felsenstein Model; Continuous-time models)

Unit VI

Phylogenetic tree estimation (Distances; Tree reconstruction – Ultrametric and Neighbor-Joining cases; Surrogate distances; Tree reconstruction; Parsimony and Maximum Likelihood; Modeling, Estimation and Hypothesis Testing;) Neural Networks (Universal Approximation Properties; Priors and Likelihoods, Learning Algorithms – Backpropagation; Sequence encoding and output interpretation; Prediction of Protein Secondary Structure; Prediction of Signal Peptides and their cleavage sites; Application for DNA and RNA Nucleotide Sequences), Analysis of SNPs and Haplotypes.

VI. Practical

- Genomic databases and analysis of high-throughput data sets, BLAST and related sequence comparison methods.
- Statistical methods to discover common motifs in biosequences.
- Multiple alignment and database search using motif models, clustalw, classificatory analysis, neural networks, genetic algorithms, pattern recognition,
- Hidden Markov models.
- Computational analysis of protein sequence.
- Expression profiling by microarray/ gene chip, proteomics.
- Modelling and prediction of structure of proteins.
- Bayesian techniques and use of Gibbs Sampling.
- Analysis of DNA microarray experiments.
- Analysis of one DNA sequence, multiple DNA or protein sequences.
- Computationally intensive methods, multiple hypothesis testing,
- Phylogenetic tree estimation,
- Analysis of SNPs and haplotypes.

VII. Suggested Reading

- Baldi P and Brunak S. 2001. *Bioinformatics: The Machine Learning Approach*. MIT Press.
- Baxevanis AD and Francis BF. (Eds.). 2004. *Bioinformatics: A Practical Guide to the Analysis*

of Genes and Proteins. John Wiley.
- Duda RO, Hart PE and Stork DG. 1999. *Pattern Classification*. John Wiley.
- Ewens WJ and Grant GR. 2001. *Statistical Methods in Bioinformatics*.Springer.
- Jones NC and Pevzner PA. 2004. *Introduction to Bioinformatics Algorithms*. The MIT Press.
- Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.
- Krane DE and Raymer ML. 2002. *Fundamental Concepts of Bio-informatics*.
- Benjamin/ Cummings.
- Krawetz SA &Womble DD. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk AM. 2002. *Introduction to Bio-informatics*. Oxford Univ. Press.
- Linder E and Seefeld K. 2005. *R for Bioinformatics*. O'Reilly and Associates.
- Percus JK. 2001. *Mathematics of Genome Analysis*. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics*. Springer.
- Tisdall J.D. 2001. *Mastering Perl for Bioinformatics*. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.
- Wu C.H. and McLarty J.W. 2000. *Neural Networks and Genome Informatics*. Elsevier.
- Wunschiers R. 2004. *Computational Biology Unix/Linux, Data Processing and Programming*. Springer.
- Yang M.C.C. 2000. *Introduction to Statistical Methods in Modern Genetics*. Taylor & Francis.

I. Course Title : Advanced Econometrics

II. Course Code : STAT 617

III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Econometrics aims at exposing the students to some advanced level econometric methods and their applications to agricultural situations.

V. Theory

Unit I

Quantile regression, binary quantile regression, extreme values, copula, loss functions, Point and interval forecasting, unconditional and conditional forecasting, forecasting with serially correlated errors, bootstrap: asymptotic expansion, bootstrap consistency, asymptotic refinement, recent developments for dependent timeseries. Co integration analysis.

Unit II

Multivariate time series: modelling the mean, stationary VAR models: properties, estimation, analysis and forecasting, VAR models with elements of nonlinearity, Non-stationary multivariate time series: spurious regression, co-integration, common trends; Volatility: Modelling the variance, The class of ARCH models: properties, estimation, analysis and forecasting, stochastic volatility, realized volatility.

Unit III

Basic Concepts of Bayesian Inference, Probability and Inference, Posterior Distributions and Inference, Prior Distributions. The Bayesian linear model and autoregressive (AR) processes; Model selection with marginal likelihoods and fractional priors, Comparison of Bayesian Methods with Classical approaches, Bayes risk and their applications, and Sample Selection Monte Carlo integration, importance sampling and Gibbs sampling, The Regression Model with General

Error Covariance Matrix, Qualitative Choice Models, Bayesian information criterion (BIC), Markov Chain Monte Carlo (MCMC) Model Composition and stochastic search variable selection, BUGS [Bayesian Inference Using Gibbs Sampling], BUCC [Bayesian Analysis, Computation and Communication].

VI. Practical

Fitting of equation with serially correlated errors, ordinary least-squares and generalized least squares methods of estimation. Non-stationary multivariate time series analysis. Fitting of The Regression Model with General Error Covariance Matrix, Qualitative Choice Models, Bayesian information criterion (BIC), Markov Chain Monte Carlo (MCMC) Model Composition and stochastic search variable selection, BUGS Fitting of ARCH model.

VII. Suggested Reading

- Banerjee A, Dolado J, Galbraith J and Hendry D.F. 1993. *Co-integration, Error Correction, and the Econometric Analysis of Nonstationary Data*. Oxford Univ. Press.
- Bauwens L, Lubrano M. and Richard J.F. 1999. *Bayesian Inference in Dynamics of Econometric Models*. Oxford Univ. Press.
- Carlin B.P. and Louis T.A. 2008. *Bayes and Empirical Bayes Methods for Data Analysis*. Chapman & Hall.
- Gilks W.R., Richardson S and Spiegelhalter D. 1996. *MCMC in Practice*.Chapman & Hall.
- Greenberg E. 2012. *Introduction to Bayesian Econometrics*. Cambridge Univ. Press.
- Hamilton J.D. 1994. *Time Series Analysis*. Princeton Univ. Press.
- Judge G.G., Griffith W.E., Hill R.C., Lee C.H. and Lutkepohl H. 1985. *The Theory and Practice of Econometrics*. 2nd Ed. JohnWiley.
- Koop G, Poirier D and Tobias J. 2007. *Bayesian Econometric Methods*.Cambridge Univ. Press.
- Koop G. 2003. *Bayesian Econometrics*. John Wiley.
- Lancaster A. 2004. *An Introduction to Modern Bayesian Econometrics*. Blackwell.
- Pindyck R.S. and Rubinfeld D.L. 1981. *Econometric Models and Economic Forecasts*. McGraw Hill.

I. Course Title : Recent Advances in the Field of Specialization

II. Course Code : STAT 618

III. Credit Hours : 1+0

IV. Aim of the course

To familiarize the students with the recent advances in the areas of their specialization to prepare them for undertaking research.

V. Theory

Recent advances in the field of specialization - sample surveys / design of experiments /statistical genetics / statistical modeling / econometrics / statistical inference, etc. will be covered by various speakers from the University / Institute as well as from outside the University / Institute in the form of seminar talks.

VI. Suggested Reading

Recent journals related to the research works.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Statistical Sciences
– Computer Application

Course Title with Credit Load
M.Sc. (Ag) in Computer Application

Course Code	Course Title	Credit Hours	Semester
*MCA 513	Mathematics for Applied Sciences	2+0	I
*MCA 514	Statistical Computing	1+1	III
*MCA 551	Mathematical Foundations in Computer Science	3+0	I
*MCA 552	Object Oriented Programming	2+1	I
*MCA 553	Design And Analysis of Algorithms	2+1	I
*MCA 561	Data Structures	2+1	II
*MCA 562	System Software and Programming	2+1	II
*MCA 563	Internet Technologies	1+1	II
*MCA 571	Database Management Systems	2+1	III
*MCA 572	Software Engineering	2+0	III
MCA 591	Master's Seminar	0+1	I/II/III
MCA 599	Master's Research	0+30	II-IV
MCA 554	Information Security	2+0	I
MCA 555	Web Technologies and Applications	1+1	I
MCA 556	Computer Networks	2+0	I
MCA 564	Bioinformatics Computing	1+1	II
MCA 565	Soft Computing Techniques	1+1	II
MCA 573	Operating System	2+1	III
MCA 574	Compiler Construction	2+1	III
MCA 575	Data Warehousing and Data Mining	2+1	III
	Supporting Courses		
MCA 501	Computers Fundamentals and Programming	2+1	I
MCA 502	Computer Organization Andarchitecture	2+0	I
MCA 511	Introduction Tocommunication Technologies, Computer Networking and Internet	1+1	II
MCA 512	Information Technology in Agriculture	2+0	II

*Core Courses

Course Contents
M.Sc. (Ag) in Computer Application

I. Course Title : Computer Fundamentals and Programming

II. Course Code : MCA 501

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Computer Fundamentals and Programming that aims at exposing the students to understand how computer works, analytical skills to solve problems using computers. andto write computer programs using C.

V. Theory

Unit I

Functional units of computer, I/O devices, primary and secondary memories. Number systems: decimal, octal, binary and hexadecimal; Representation of integers, fixed and floating point numbers, Operator precedence, character representation; ASCII, Unicode.

Unit II

Programming Fundamentals with C - Algorithm, techniques of problem solving, flowcharting, stepwise refinement; Constants and variables; Data types: integer, character, real, data types; Arithmetic expressions, assignment statements, logical expressions. Control flow

Unit III

Arrays and structures. Pointers, dynamic memory allocations

Unit IV

Program Structures – functions, subroutines

Unit V

I/O operations, Program correctness; Debugging and testing of programs.

VI. Practical

- Conversion of different number types;
- Creation of flow chart, conversion of algorithm/flowchart to program;
- Mathematical operators, operator precedence;
- Sequence, control and iteration;
- Arrays and string processing;
- Matrix operations, Sorting, Pointers and File processing – Reading and writing text files.

VII. Suggested Reading

- Balaguruswamy E. 2019. *Programming with ANSI C*. Tata McGraw Hill.
- Gottfried B. 2017. *Programming with C, Schaum Outline Series*. Tata McGraw Hill.
- Kanetkar Y. 1999. *Let Us C*. BPB Publ.

- Malvino A.P. and Brown J.A.. 2017. *Digital Computer Electronics*. Tata McGrawHill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.

I. Course Title : Computer Organization and Architecture

II. Course Code : MCA 502

III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Computer Organization and Architecture that aims at exposing the students to understand basic knowledge of how computer works.

V. Theory

Unit I

Number systems; Boolean algebra - minimization of Boolean function using KarnaughMap.

Unit II

Logic Gates, Combinational circuits – multiplexer, de-multiplexer, encoder, decoder; Sequential circuits: Flip-flops, Half and Full adder, Shift register, Counters.

Unit III

Organization of CPU, Control Unit- Instruction and Execution cycle in CPU, Register Organization, The Instruction Cycle, Instruction Pipelining.

Unit IV

Memory organization - Internal memory: Semiconductor Main Memory (RAM, ROM, EPROM), Cache Memory, Advanced DRAM Organization; External Memory - Magnetic Disks, RAID, Optical Memory, Magnetic Tape.

Unit V

Basic structure of computer hardware and system software - Addressing methods and machine programme sequencing; Input-output organizations - accessing I/O devices - direct memory access (DMA) – interrupts.

Unit VI

Introduction to microprocessors – CISC and RISC Architecture, Study of functional units of microprocessors.

VI. Suggested Reading

- Gear C.W. 1974. *Computer Organization and Programming*. McGraw Hill.
- Hayes J.P. 1988. *Computer Architecture and Organisation*. McGraw Hill.
- Malvino A.P and Brown J.A. 1999. *Digital Computer Electronics*. Tata McGraw Hill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.
- Mano M.M. 2007. *Computer System Architecture*. Prentice Hall of India.
- Stallings W. 2016. *Computer Organization and Architecture: Designing for Performance*. Pearson Edu.

I. Course Title : Introduction to Networking and Internet Applications

II. Course Code : MCA 511

III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand Computer networking and web applications development.

V. Theory

Unit I

Networking fundamentals, types of networking, network topology; Introduction to File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP), Internet Protocol v4 & v6. Network infrastructure and Security-switches, routers, firewall, intranet, internet, Virtual Private Network

Unit II

World Wide Web (www), working with Internet; Web pages, web sites, web servers; Web Applications.

Unit III

Hyper Text Markup Language (HTML), DHTML, web based application development. Static websites, dynamic websites. Client Side processing – scripting languages, Jquery. Server Side processing ASP.NET/JSP

VI. Practical

- Network and mail configuration;
- Using Network Services;
- Browsing of Internet;
- Creation of web pages;
- Creation of websites using HTML and scripting languages.

VII. Suggested Reading

- Cox V, Wermers L and Reding E.E. 2006. *HTML Illustrated Complete*. 3rd Ed. Course Technology.
- Niederst J. 2001. *Web Design in a Nutshell*. O'Reilly Media.
- Tanenbaum A.S. 2003. Computer Networks. *Prentice* Hall of India.

I. Course Title : Information Technology in Agriculture

II. Course Code : MCA 512

III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand analogy of computer, basic knowledge of MS Office. Also to understand Internet and WWW, use of IT application and different IT tools in Agriculture

V. Theory

Unit I

Introduction to Computers, Anatomy of computer, Operating Systems, definition and types, Applications of MS Office for document creation & Editing, Data presentation, interpretation and graph creation, statistical analysis, mathematical expressions,

Unit II

Database, concepts and types, uses of DBMS in Agriculture, World Wide Web

(WWW): Concepts and components, Introduction to computer programming languages, concepts and standard input/output operations. e-Agriculture, concepts and applications,

Unit III

Use of ICT in Agriculture, Computer Models for understanding plant processes. IT application for computation of water and nutrient requirement of crops, Computer-controlled devices (automated systems) for Agri-input management, Smartphone Apps in Agriculture for farm advises, market price, postharvest management etc.,

Unit IV

Geospatial technology for generating valuable agri-information. Decision support systems, concepts, components and applications in Agriculture, Agriculture Expert System, Soil Information Systems etc. for supporting Farm decisions, Preparation of contingent crop-planning using IT tools.

VI. Suggested Reading

- Vanitha G. 2011. *Agro-informatics*
- http://www.*agrimoon*.com
- http://www.agriinfo.in
- http://www.eagri.org
- http://www.agriglance.com
- http://agritech.tnau.ac.in

I. Course Title : Mathematics for Applied Sciences

II. Course Code : MCA 513

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

V. Theory

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

VI. Suggested Reading

- Hohn FE. 2013. *Elementary Matrix Algebra*, 3rdEd., Kindle Edition
- Harville DA. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Searle SR. 1982. *Matrix Algebra Useful for Statistics*. John Wiley.
- Stewart J. 2007. *Calculus*. Thompson.
- Thomas GB. Jr. and Finney RL. 1996. *Calculus*. 9th Ed. Pearson Edu

I. Course Title : Statistical Computing

II. Course Code : MCA 514

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data.Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics
- General linear models ~ fitting and analysis of residuals, outlier detection
- Fitting and testing the goodness of fit of probability distributions
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test
- One way analysis of variance, contrast and its testing, pairwise comparisons

- Mixed effect models, estimation of variance components
- Categorical data analysis, dissimilarity measures, similarity measures
- Analysis of discrete data, analysis of binary data
- Numerical algorithms
- Spatial modeling, cohort studies
- Clinical trials, analysis of survival data
- Handling missing data
- Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. *Categorical Data Analysis*. 3rd Ed. John Wiley.
- Everitt B.S. and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gelman A and Hill J. 2006. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge Univ. Press.
- Gentle J.E., Härdle W and Mori Y. 2012. *Handbook of Computational Statistics - Concepts and Methods*. 2nd Ed. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Miller RG Jr. 1986. Beyond ANOVA, *Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Ryan B.F. and Joiner B.L. 1994. *Minitab Handbook*. 3rd Ed. Duxbury Press.
- Simonoff J.S. 1996. *Smoothing Methods in Statistics*. Springer.
- Singh, AK. 2016. *Practical R-Book by Examples for Agricultural Statistics*. Deptt. of Ag. Statistics, IGKV. Raipur
- Snell E.J. 1987. Applied Statistics: A Handbook of BMDP Analyses. Chapman & Hall.
- Thisted R.A. 1988. Elements of Statistical Computing. Chapman & Hall.
- Venables W.N. and Ripley B.D. 1999. Modern Applied Statistics With S-Plus. 3rd Ed. Springer.
- http://www.r-project.org/
- http://www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Mathematical Foundations in Computer Science

II. Course Code : MCA 551

III. Credit Hours : 3+0

IV. Aim of the course

This is a course on Mathematical Foundations in Computer Science that aims at exposing the students to provide basic foundations in Mathematics for problem solving.

V. Theory

Unit I

Mathematical Logic: Propositions – Simple and complex; Validity of Proposition-Truth Tables; Use of Propositions in computer programming.

Unit II

Mathematical data types: Sets, Functions, Bijective functions, pigeon-hole principle, Boolean functions, permutation functions, Boolean algebra, recursion relations.

Unit III

Number Theory: Binary arithmetic, exponentiation, induction, sequences, big-oh notation, GCD, Euclidean algorithm, partially ordered sets, congruence and equivalence relation, encryption scheme, Fibonacci sequence, linear homogenous recurrence relations with constant coefficients.

Unit IV

Matrix Algebra Basic operations on matrices, Rank and inverse of matrices. System of linear equations, Characteristic roots and equations, Eigen values and eigen vectors;

Unit V

Graph Theory: Graphs, trees, LAN, Eulerian cycles, Hamiltonian cycles, graph coloring, graph algorithms.

VI. Suggested Reading

- Abertson M.O. and Hutchinson J.P. 1988. *Discrete Mathematics with Algorithms*. John Wiley.
- Deo N. 1984. *Graph Theory with Application to Engineering and Computer Science*. Prentice Hall of India.
- Knuth D.E. 2011. *Art of Computer Programming*. Vol. I. *Fundamental Algorithms*. Addison Wesley.
- Tremblay J.P. and Manohar R.P. 2017. *Discrete Mathematical Structures with Applications to Computer Science*. McGraw Hill.

I. Course Title : Object Oriented Programming

II. Course Code : MCA 552

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Java that aims at exposing the students to understand basic concepts of object oriented design and to write computer programs for problem solving using object oriented.

V. Theory

Unit I

Introduction to Objected Oriented Programming(OOP), Introduction to C++, data types in C++, Compilation and execution of C++; data types, control flow, input/output operations, interaction with file systems – reading, writing and appending.

Unit II

Strings, string manipulations, Arrays, functions, scope of variables, structures in C++.

Unit III

Classes, data members, member functions, this Pointer, Friends, Friend Functions, Friend Classes, Constructors, destructors.

Unit IV

Operator Overloading, dynamic binding, parametric polymorphism. Inheritance, inheritance and dynamic binding, multiple inheritance.

Unit V

New Approaches to programming – Model-View-Controller (MVC) architecture, Single page applications.

VI. Practical

- Case studies using object oriented analysis and design (OOAD);
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and Implementation of a case study.

VII. Suggested Reading

- Arnold K and Gosling J. 1996. *The Java Programming Language. The Java Series*. Addison Wesley.
- Bergin J. 1994. *Data Abstraction: The Object-Oriented Approach Using C++*. McGraw Hill.
- Holzner S. 1997. *The Visual C++ Programming Language*. Prentice Hall of India.
- Johnsonbaugh R and Kalin M. 1995. *Object Oriented Programming in C++*. Prentice Hall.
- Khoshafian S and Abnous R. 1995. *Object Orientation Concepts, Languages, Databases, User Interfaces*. JohnWiley.
- Sengupta S and Korobkin C.P. 1994. *C++ Object Oriented Data Structures*.Springer.
- Stroustrup B. 1997. *The C++ Programming Language*. Addison Wesley.
- Troelsen A. 2005. *Pro C# 2005 and the .NET 2.0 Platform*. 3rd Ed. Apress.
- Kothari D.P. 2013. *Object Oriented Approach using C++*

I. Course Title : Design and Analysis of Algorithms

II. Course Code : MCA 553

III. Credit Hours : 2+1

IV. Aim of the course

This course provides a theoretical foundation in designing algorithms. The focus is on the advanced analysis of algorithms and on how the selections of different data structures affect the performanceof algorithms.

V. Theory

Unit I

Algorithm Analysis – Time Space Tradeoff – Asymptotic Notations – Conditional asymptotic notation – Removing condition from the conditional asymptotic notation - Properties of big-Oh notation – Recurrence equations – Solving recurrence equations – Analysis of linear search.

Unit II

Divide and Conquer: General Method – Binary Search – Finding Maximum and Minimum –Merge Sort – Greedy Algorithms: General Method – Container Loading – Knapsack Problem.

Unit III

Dynamic Programming: General Method – Multistage Graphs – All-Pair shortest paths – Optimal binary search trees – 0/1 Knapsack – Travelling salesperson problem.

Unit IV

Backtracking: General Method – 8 Queens problem – sum of subsets – graph coloring – Hamiltonian problem – knapsack problem.

Unit V

Graph Traversals – Connected Components – Spanning Trees – Biconnected components – Branch and Bound: General Methods (FIFO & LC) – 0/1 Knapsack problem – Introduction to NP-Hard and NP-Completeness.

VI. Practical

- Solving recurrence equations, Analysis of linear search,
- Programming Divide and Conquer Algorithms and their analysis,
- Programming Greedy Algorithms and their analysis,
- Implementing Dynamic Programming and their analysis,
- Implementing Backtracking examples,
- Implementing Graph Traversals,
- Implementing Spanning Trees.

VII. Suggested Reading

- Alfred V. Aho, John E. Hopcroft and Jeffrey D. Ullman. 1999. *The Design and Analysis of Computer Algorithms*. Pearson Education.
- Cormen, T.H., C.E. Leiserson, R.L. Rivest, and C. Stein. 2003. *Introduction to Algorithms*. Prentice Hall of India, New Delhi.
- Horowitz E, Sahni S and Rajasekaran S. 2007. *Computer Algorithms/ C++*. Universities Press.

I. Course Title : Information Security

II. Course Code : MCA 554

III. Credit Hours : 2+0

IV. Aim of the course

This course provides exposure to challenges and techniques for securing the information in servers and Web enabled systems. The course deals with theoretical as well as practical issues of Information Security.

V. Theory

Unit I

General introduction to security, Cryptographic techniques: classical cryptography, conventional cryptography (DES), public-key cryptography (RSA), and digital signatures (DSA), steganography.

Unit II

Security services: message integrity, confidentiality and authentication, certification and key management (PKI).

Unit III

Network security applications: IP security (IPsec), Web security (SSL, TLS, SET), Electronic mail security (PGP, S/MIME), and SNMP security.

Unit IV

Access control in computer networks: authentication protocols and services (Kerberos), firewalls and Virtual Private Networks (VPNs).

Unit V

System security: intrusion detection, viruses. E-commerce securities: e-payment systems, fair data exchange.

VI. Suggested Reading

- Amoroso E. 1994. *Fundamentals of Computer Security Technology*. Prentice-Hall.
- Bhushan M. 2017. *Fundamentals of Cyber Security* Prentice Hall
- Chapman B and Zwicky E.D. 2000. *Building Internet Firewalls*. O'Reilly.
- Ford W. 1994. *Computer Communications Security*. Prentice Hall. Pfleeger CP. 2006. *Security in Computing*. Prentice Hall.
- Stallings W. 2003. *Cryptography and Network Security: Principles and* Practice. Prentice-Hall.

I. Course Title : Web Technologies and Applications

II. Course Code : MCA555

III. Credit Hours : 1+1

IV. Aim of the course

The main objective of the course is to introduce the whole range of web technologies. Through the various examples, the course will describe how to design a specific page, dynamic web pages, forms and frames and interaction with adatabase.

V. Theory

Unit I

Survey of contemporary Internet Technologies - Role, use and implementation of currenttools.

Unit II

Application Layer Services and protocols - Domain name services, network management protocol, electronic mail and file transfer protocol.

Unit III

World Wide Web – Web pages, Web Sites, Web Servers; Intranet andxtranet Concepts; Web Application Architectures.

Unit IV

Hyper Text Markup Language (HTML); Building static and dynamic web pages.

Unit V

Scripting Languages - Client side and server side scripting; Interaction with database.

Unit VI

Latest trends in programming on the emerging technologies relating to web based software development.

VI. Practical

- Designing static website with features like tables, hyperlink among pages, pictures, frames and layers;
- Client side scripting for user interface validation;
- Server side scripting for database interaction;
- Designing of a information system.

VII. Suggested Reading

- Ayers D, Bergsten H, Bogovich M, Diamond J, Ferris M, Fleury M, Halberstadt A, Houle P, Mohseni P, Patzer A, Philips R, Li S, Vedati K, Wilcox M and Zeiger S. 1999. *Professional Java Server Programming*. Wrox Press Ltd.

- Boudreaux 2005. PHP 5: *Your Visual Blueprint for Creating Open Source, Server-side Content*. (Visual Blueprint). Visual.
- Ellis M.D. 2007. *ASP.NET AJAX Programming Tricks*. Magma Interactive.
- Esposito D 2007. *Introducing Microsoft ASP. NET AJAX (Pro Developer)*. Microsoft Press.
- Evjen B, Hanselman S and Rader D. 2008. *Professional ASP.NET 3.5: In C# and VB* (*Programmer to Programmer*). Wrox Press Ltd.
- Haefel-Monson R. 2003. *Enterprise JavaBeans*. O'Reilly & Associates.
- Naughton P and Schildt H. 2001.*The Complete Reference, Java 2*. TataMcGraw Hill.
- Neimke D. 2006. *ASP.NET 2.0 Web Parts in Action: Building Dynamic Web Portals (In Action)*. Manning Publ.
- Walther S. 2008. ASP.NET 3.5 Unleashed. Sams.

I. Course Title : Computer Networks

II. Course Code : MCA 556

III. Credit Hours : 2+0

IV. Aim of the course

This course addresses the principles, architectures and protocols that have gone into the development of the Internet and modern networked applications. The course examines network design principles, underlying protocols, technologies and architectures such as naming, data transport, routing and algorithms for networked applications including messaging, encryption and authentication.

V. Theory

Unit I

The importance of Networking, Types of Networking, Network Topology, Transmission Media, Data communication: Concepts of data, signal, channel, bandwidth, bit-rate and baud-rate; Maximum data-rate of channel; Analog and digital communications, asynchronous and synchronous transmission.

Unit II

Network adapters card, Multiplexer (FDM, TDM, STDM), Hub, Repeater. Network References Models: Layered architecture, protocol hierarchies, interface and services.

Unit III

ISO-OSI references model, TCP/IP reference model; Data link layer function and protocols: Framing, error-control, flow control; sliding window protocol; HDLC, SLIP and PPP protocol.

Unit IV

Network layer - routing algorithms, congestion control algorithms; Internetworking: bridges and gateway; Transport layer - connection management, addressing; Flow control and buffering, multiplexing.

Unit V

Session layer – RPC; Presentation layer - abstract syntax notation.

Unit VI

Application layer - File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP); World Wide Web(WWW) - Wide Area Indexed Servers (WAIS), WAP; Network Security; Data compression and cryptography.

VI. Suggested Reading

- Arick MR. 1994. *The TCP/IP Companion - A Guide for Common User*. Shroff Publ.
- Freer J. 1990. *Computer Communication and Networks*. Affiliated East West Press.
- Hayes J. 2001. *Modelling and Analysis of Computer Communication Networks*. KhannaPubl.
- Tanenbaum AS. 2003. *Computer Networks*. Prentice Hall of India.

I. Course Title : Data Structures

II. Course Code : MCA 561

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Data Structures that aims at exposing the students tounderstand data structures and their use in problem solving and to analyze different algorithms

V. Theory

Unit I

Algorithms and analysis of Algorithms, Big Oh notation. Arrays, Linked Lists, Elementary List Processing. Memory Allocation for Lists. Strings. Compound Data Structures.

Unit II

Recursive algorithms, Divide and conquer, Dynamic programming, Trees, different tree traversal algorithms, graph traversal.

Unit III

Sorting, Selection Sort. Insertion Sort. Bubble Sort. Performance Characteristics of Elementary Sorts. Shellsort. Sorting Other Types of Data. Index and Pointer Sorting. algorithms.

Unit IV

Quick sort, merging, merge sort, Heap structure, algorithm on heap structure, Queues, priority queues, Search Algorithms

VI. Practical

Implementation of various types of structures - linked lists, doubly linked lists, circular linked lists, queue, dequeue, stack and tree; String processing; Searching and sorting techniques; Graph and geometric algorithms and Casestudies

VII. Suggested Reading

- Aho A.V., Hopcroft J.E. and Ullman J.D. 1983. *Data Structures and Algorithms*. Addison Wesley.
- Cormen T.H., Leiserson CE, Rivest R.L. and Stein C. 2006. *Introduction toAlgorithms*. Prentice Hall of India.
- Goodrich M.T., Tamassia R and Mount D. 2004. *Data Structures and Algorithms in C^{++}*. John Wiley.
- Horowitz E and Sahani S. 1983. *Fundamentals of Data Structures*. Galgotia Publ.
- Jain H. 2018. *Problem Solving in Data Structures and Algorithms Using Java.*
- Kleinberg J and Tardos E. 2006. *Algorithm Design*. Pearson Edu.
- Knuth D.E. 1968. *Art of Computer Programming*. Vol. I. *Fundamental Algorithms*. Addison Wesley.
- Knuth D.E. 1973. *Art of Computer Programming*. Vol. III. *Sorting and Searching*. Addison Wesley.

- Kruse R.L. and Ryba A.J. 1998. *Data Structures and Program Design in C^{++}*. Prentice-Hall.
- Langsam Y, Augenstein M.J. and Tanenbum A.S. 1999. *Data Structures Using C and C^{++}*. Prentice Hall of India.
- Tremblay J.P. and Sorenson P.G. 2017. *An Introduction to Data Structures with Applications*. McGrawHill.
- Weiss M.A. 1994. *Data Structures and Algorithm Analysis in C^{++}*. Benjamin/Cummings.

I. Course Title : System Software and Programming

II. Course Code : MCA 562

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on System Software and Programming that aims at exposing the students to understand operating systems and its functions and to design and write simple low level programming.

V. Theory

Unit I

Systems software-introduction, system specific features; Operating Systems and its functions – device management, process management, memory management, file system management, security.

Unit II

Users, directory, files, file access rights; Terminal Controls and signals; Modularization and program assembly – Interfaces, APIs, header files, libraries, shared objects, dynamic and static links.

Unit III

Input/output at System Level – sequential and random access; indexes.

Unit IV

Memory Management –Allocating and deallocating memory; Threads, spawning processes, network access, sleep, Inter Process communications – pipes, shared memory, sockets, secured sockets, Certificates.

Unit V

Object oriented software design; Generic and reusable classes, Debugging and testing of programs

VI. Practical

- Low Level programming for input/output interface, memory, threads, listening and responding,
- Programming constructs, control statements: branching and looping, file operations,
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and a case study using and Object oriented language.

VII. Suggested Reading

- Ken A and Gosling, J. 1996. *The Java Programming Language*. The Java Series. Addison Wesley.
- Balaguruswamy, E. 2019. *Programming with ANSI C*. Tata McGraw Hill, New Delhi.
- Balaguruswamy, E. 2017. *Programming with Object Oriented Programming using C++*. Tata McGraw Hill, New Delhi.

- Bergin, J. 1994. *Data Abstraction: The Object-Oriented Approach Using C++*. McGraw Hill.
- Sethi, R. 1996. *Programming Language Concepts*. Addison Wesley.
- Stroustrup, B. 1997. *The C++ Programming Language*. Addison Wesley.

I. Course Title : Internet Technologies

II. Course Code : MCA 563

III. Credit Hours : 1+1

IV. Aim of the course

The main objective of the course is to introduce the whole range of web technologies. Through the various examples, the course will describe how to design a specific page, dynamic web pages, forms and frames and interaction with adatabase.

V. Theory

Unit I

World Wide Web – Web pages, Web Sites, Web Servers; Intranet and Extranet Concepts; Hyper Text Markup Language (HTML); Building static dynamic web pages.

Unit II

Web application architecture – (ASP.NET/Java) – Web Forms, Server Side Controls, handling events, Validation, JQuery

Unit III

Database Connectivity, read, write, update databases using web forms; data bound controls, sessions, session handling

Unit IV

Authentication of users, Personalization, Roles, role based access

Unit V

Using external libraries/ controls; Ajax, Jquery; Data Exchange – XML, JSON; Creating web services

VI. Practical

- Designing static website with features like tables, hyperlink among pages, pictures, frames and layers;
- Client side scripting for user interface validation;
- Server side scripting for database interaction;
- Designing of information system.

VII. Suggested Reading

- Ayers D, Bergsten H, Bogovich M, Diamond J, Ferris M, Fleury M, Halberstadt A, Houle P, Mohseni P, Patzer A, Philips R, Li S, Vedati K, Wilcox M and Zeiger S. 1999. *Professional Java Server Programming*. Wrox Press Ltd.
- Buest C and Allamaraju S. 2007. *Professional Java Server Programming*: J2EE 3rd Ed.
- Boudreaux 2005. PHP 5: *Your Visual Blueprint for Creating Open Source, Server-side Content*. (Visual Blueprint). Visual.
- Ellis M.D. 2007. *ASP.NET AJAX Programming Tricks*. Magma Interactive.
- Esposito D. 2007. *Introducing Microsoft ASP.NET AJAX* (*Pro-Developer*). Microsoft Press.
- Evjen B, Hanselman S and Rader D. 2008. *Professional ASP.NET 3.5: In C# and VB* (*Programmer to Programmer*). Wrox Press Ltd.
- Haefel-Monson R. 2003. *Enterprise Java Beans*. O'Reilly & Associates.

- Naughton P and Schildt H. 2001. *The Complete Reference, Java 2*. Tata McGraw Hill.
- Neimke D. 2006. *ASP.NET 2.0 Web Parts in Action: Building Dynamic Web Portals* (*In Action*). Manning Publ.
- Walther S. 2008. *ASP.NET 3.5 Unleashed*. Sams.

I. Course Title : Bioinformatics Computing

II. Course Code : MCA 564

III. Credit Hours : 1+1

IV. Aim of the course

The aim of the course is to introduce modern computational practices in bioinformatics at the algorithmic level that will train the students to complement researchers with biological background.

V. Theory

Unit I

The Central Dogma, Review and Utilization of Biological Databases.

Unit II

Overview of Algorithms: Pattern Matching, Biological Motivation Naïve Algorithm.

Unit III

Pre-processing: Suffix trees Time and Space Considerations. Approximate Pattern Matching: Sequence Comparisons, Dot Plots. Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters.

Unit IV

Similarity and Distance: PAM & BLOSUM matrices, Heuristic Approaches.

Unit V

Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly.

Unit VI

Graph Algorithms, Overlap Graphs, and Hamiltonian Path Wrap-up.

VI. Practical

- Suffix trees: Time and Space Considerations;
- Approximate Pattern Matching: Sequence Comparisons, Dot Plots;
- Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters;
- Similarity and Distance: PAM & BLOSUM matrices,
- Heuristic Approaches and Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly,
- Graph Algorithms, Overlap Graphs, and Hamiltonian PathWrap-up.

VII. Suggested Reading

- Bryan B. 2002. *Bioinformatics Computing*. Prentice Hall.
- Duda R.O., Hart P.E. and Stork D.G. 1999. *Pattern Classification*. John Wiley.
- Ewens W.J. and Grant G.R. 2001. *Statistical Methods in Bioinformatics*. Springer.
- Jones N.C. and Pavel A.P. 2004. *Introduction to Bioinformatics Algorithms*. MIT Press.
- Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.

- Krane D.E. & Raymer M.L. 2002. *Fundamental Concepts of Bioinformatics*. Benjamin / Cummings.
- Krawetz S.A. and Womble D.D. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk A.M. 2002. *Introduction to Bioinformatics*. Oxford Univ. Press.
- Shortliffe E.H. and Cimino J.J. 2006. *Biomedical Informatics: Computer Applications in Health Care and Biomedicine* (*Health Informatics*). Springer.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.

I. Course Title : Soft Computing Techniques

II. Course Code : MCA 565

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces the soft computing techniques and their applications in solving real world problems. The course is dealt with the perspective of using soft computing techniques in machine learning.

V. Theory

Unit I

Introduction to soft-computing tools – Fuzzy Logic, Genetic Algorithm, Neural Networks and Probabilistic Reasoning, Rough Sets.

Unit II

Applications of Fuzzy Logic concepts in Knowledge Management.

Unit III

Optimization problem solving using genetic algorithm.

Unit IV

Neuron as a simple computing element, the perceptron, multilayer neural networks, Neural network approaches in data analysis, design and diagnostics problems; Applications of probabilistic reasoning approaches.

VI. Practical

Classification using Fuzzy Logic, Genetic Algorithm, Neural Networks

VII. Suggested Reading

- Goldberg D.E. 2008. *Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison Wesley.
- Haykin S. 1998. *Neural Networks: A Comprehensive Foundation*. Prentice Hall.
- Jang J.R., Sun C and Mizutani E. 1996. *Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence*. Prentice Hall.
- Kecman V and Kecman V. 2001. *Learning and Soft Computing: Support Vector Machines, Neural Networks, and Fuzzy Logic Models*. MIT Press.
- Lee K.H. 2005. *First Course on Fuzzy Theory and Applications*. Springer.
- Mitra S and Acharya T. 2003. *Data Mining: Multimedia, Soft Computing, and Bioinformatics*. John Wiley.

I. Course Title : Database Management System

II. Course Code : MCA 571

III. Credit Hours : 2+1

IV. Aim of the course

Database systems are backbone of any information system, enterprise resource planning, research activities and other activity that require permanence of data storage. This course provides the basic introduction to database system technologies; design, concurrency, security and backup/recovery issues of database management systems. The major focus in this course is the Relational database model.

V. Theory

Unit I

Database system - Operational Data, Characteristics of database approach, architecture.

Unit II

Overview of DBMS; Data associations - Entities, Attributes and Associations, Relationship among Entities, Representation of Associations and Relationship, Data Model classification.

Unit III

Entity Relationship model; Relational Data Structure- Relations, Domains and Attributes, Relational Algebra and Operations, Retrieval Operations.

Unit IV

Relational Database Design - Anomalies in a Database, Normalization Theory, and Normal forms; Query processing.

Unit V

Distributed Databases- concepts, architecture, design; Structured Query Language (SQL) - Data Definition Language (DDL), Data Manipulation Language (DML).

Unit VI

PL/SQL - Stored procedure, Database triggers; Relational Data Base Management Package.

VI. Practical

E-R diagram construction; SQL - Command Syntax, Data types, DDL Statements, DML Statements, integrity constraints; Triggers, creating stored procedures/ functions; Normalization of database and Case study on a database design andimplementation.

VII. Suggested Reading

- Date C.J. 2000. *Introduction to Database System*. Addison Wesley.
- Desai B.C. 2000. *Introduction to Database Systems*. Galgotia Publ.
- Elmasri and Navathe. 2006. *Fundamentals of Database Systems*. 4th Ed. Addison Wesley.
- Garcia-Molina H., Ullman J.D. and Widom J. 2013. *Database Systems: The Complete Book*. Prentice Hall.
- Rob P. and Coronel C. 2006. *Database Systems: Design, Implementation and Management*. 7th Ed. Thomson Learning.
- Silberschartz A, Korth H.F. and Sudarshan S. 1997. *Database Systems Concepts*. Tata McGraw Hill.

I. Course Title : Software Engineering

II. Course Code : MCA 572

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the course is to make the learner efficiently work as software engineer so as to acquaint them with all the phases of Software Development Life Cycle.

V. Theory

Unit I

Software engineering definition; Software Development: Phases, Process models, Project structure, Project team structure, Role of metrics, Measurement, Software quality factors.

Unit II

Planning and Software Project: Requirement analysis, Cost estimation, Project Scheduling, Quality Assurance Plan, and Project Monitoring Plans, Gantt charts, PERT and CPM.

Unit III

System Design: Design Objectives, Design Principles, Design Tools, and Techniques, Prototyping.

Unit IV

Structured Programming Coding: Programming Practices, Verification, Monitoring and Control.

Unit V

Testing: Testing Fundamentals, Functional Testing, Structural Testing, Test Plan activities, Unit testing, IntegrationTesting.

Unit VI

Reliability: Concept of Software Reliability, Reliability Models, Limitations of Reliability Models, Software Maintenance. CASE tools.

VI. Suggested Reading

- Aggarwal K.K. and Singh Y. 2006. *Software Engineering*. 2nd Ed. New Age.
- Awad E.M. 1993. *System Analysis and Design*. Galgotia Publ.
- Fairley R. 2017. *Software Engineering Concepts*. Tata McGraw Hill.
- Jalote P. 2005. *An Integrated Approach to Software Engineering*. 3rd Ed. Narosa.
- Kerzner H. 1998. *Project Management: A System Approach to Planning, Scheduling and Controlling*. CBS.
- Mall R. 2006. *Fundamentals of Software Engineering*. 2nd Ed. Prentice- Hall ofIndia.
- Pressman R.S. 2017. *Software Engineering: A Practitioner's Approach*. 6th Ed. McGraw Hill.
- Sommerville I. 2004. *Software Engineering*. 6thEd. Pearson Edu.

I. Course Title : Operating System

II. Course Code : MCA 573

III. Credit Hours : 2+1

IV. Aim of the course

The main objective of this course is to provide core knowledge of Operating Systems features,functions and techniques.

V. Theory

Unit I

Operating system overview: operating system as an extended machine and resource manager; Operating system classifications; Operating system modes and system calls.

Unit II

Operating system architecture; Process model, Process synchronization, Concurrent processes,Process scheduling criterion and algorithms.

Unit III

Problem of mutual exclusion; Deadlock and prevention; Race conditions; Semaphores; Monitors; Process allocation.

Unit IV

Memory management; Multi-programming with fixed and variable number of tasks; Continuousallocation; Paging, Demand paging, Page fault; Virtual memory; Fragmentation; Segmentedmemory management, shared segments; Segmented and demand paged management, Overlaysand swapping, Thrashing.

Unit V

Multi-processor system, Master slave scheduling; Homogeneous scheduling; Device managementsystem; Dedicated share and virtual devices.

Unit VI

File Management System- Input-Output file protection; Remote Procedure Call; Distributedoperating system (Course to be taught in accordance to the Unix Operating System).

VI. Practical

- Problems using system calls for process management, signaling, file management, directorymanagement, protection;
- Critical section problem; Solution to mutual exclusion by Peterson method;
- Producer consumer problem with fatal race conditions;
- Comparison of various CPU scheduling algorithms and Paging, segmentation and demand paging.

VII. Suggested Reading

- Bach, M.J. 2015. *Design of the UNIX Operating System*. Pearson Education.
- Deitel, H.M. 1990. *An Introduction to Operating System*. Addison Wesley.
- Dhamdhere, D.M. 2007. *Operating Systems: A Concept Based Approach*. Tata McGraw Hill, NewDelhi.
- Kernighan, B.W. and Pike, R. 1996. *The UNIX Programming Environment*. Prentice Hall of India,New Delhi.
- Peterson, J. and Silberschatz, A. 1991. *Operating System*. Addison Wesley.
- Stallings, W. 2006. *Operating Systems: Internals and Design Principals*. Prentice Hall of India, New Delhi.
- Silberchatz, A., Galvin, P.B. and Gagne, G. 2006. *Operating System Principals*. Wiley India.
- Tanenbaum, A.S. 2001. *Modern Operating Systems*. Prentice Hall of India, New Delhi.

I. Course Title : Compiler Construction

II. Course Code : MCA 574

III. Credit Hours : 2+1

IV. Aim of the course

The purpose of the course is to acquaint various phases of compiler writing which will help anapplication/system programmer working on other projects besides compilers.

V. Theory

Unit I

Introduction to Compiler, Compilation Process, Compiler Structure.

Unit II

Programming Language Grammars, Elements of a Formal Language Grammar, Derivation,Reduction and Syntax Trees, Ambiguity Regular Grammar & Regular Expression – Context FreeGrammar.

Unit III

Introduction to Finite Automata, Deterministic Finite Automata.

Unit IV

Non-deterministic Finite Automata; Scanning & Parsing Techniques – The Scanner, RegularGrammar and FSA, Top Down Parsing, Parsing Algorithm, Top Down Parsing WithoutBacktracking, Predictive Parsers, Bottom Up Parsing, Parsing, LR Parsers, Shift Reduce Parsing; Symbol Table.

Unit V

Organization, Memory Allocation – Static & Dynamic Memory Allocation, Compilation Control Transfer, Procedure Calls, Conditional Execution, Iteration Control Construct; Lexical Syntax Errors, Semantic, Major Issues in Optimization, Optimizing.

Unit VI

Transformations, Local Optimization, Program Flow Analysis, Global Optimization.

VI. Practical

- Design of a lexical analyser for regular expression;
- Design of a finite state machine;
- Program for - magic squares, context free grammar, shift reduce parsing, operator precedence parsing, recursive decent parsing, predictive parser, simple LR parser and Post fix form for intermediate code.

VII. Suggested Reading

- Aho, A.V. and Ullman, J.D. 1993. *Principles of Compiler Design Theory*. NarosaPublishing House,New Delhi.
- Galles, G. 2007. *Modern Compiler Design*. Pearson Education.
- Holab, A. 2006. *Compiler Design in C*. Prentice-Hall of India, New Delhi.
- Lewis, P.M., Rosenkrantz, D.J. and Stearns, R.E. 1978. *Compiler Design Theory*. Addison Wesley.
- Tremblay, J.P. and Sorenson, P.G. 1985. *The Theory and Practice of Compiler Writing*. McGraw Hill.
- Raghavan V. 2017. *Principles of Compiler Design*. Addison Wesley

I. Course Title : Data Warehousing and Data Mining

II. Course Code : MCA 575

III. Credit Hours : 2+1

IV. Aim of the course

The basic objective of this course is to familiarize students about this state of art of setting datawarehouse for business intelligence in relation to agricultural research, development and planning.

V. Theory

Unit I

Concepts and principles of data warehousing; Project management and requirements. Introduction to Data Mining and its Tasks, Data Pre-processing, Data Discretization

Unit II

Dimensional modelling; Data warehousing architecture; System process and process architecture. Classification and Prediction, Decision Tree, Naive Bayes' Classifier.

Unit III

Data warehousing design; Database schema; Data staging. Output and Knowledge Representation, Evaluation and Credibility, Association Rule Mining.

Unit IV

Partitioning strategy; Aggregations; Data marts; Meta data management; OLAP Modelling, Querymanagement. Clustering: Similarity measures, Hierarchical Clustering, k-Means Clustering.

Unit V

Data warehouse security; Backup and recovery; Building end-user Applications; Capacity planning; Testing the warehouse.

Unit VI

Implementation and maintenance of data warehouse; Case study.

V. Practical

- Data warehouse design, selection of schema;
- Normalization and renormalization;
- Query planstrategy;
- Performance tuning, backup and recovery of data warehouse;
- Dynamic reports and OLAP Reports.
- Introduction to Data Mining software,
- Data Pre-processing, Discretization, Decision Tree: D3,Naïve Bayes' Classifier,
- Association Rule Mining: Apriori Algorithm,
- Clustering: Hierarchical Clustering, K-Means.

VI. Suggested Reading

- Gupta, G.K. 2014. *Introduction to Data Mining with Case Studies*. Prentice Hall of India, New Delhi.
- Han, J and Kamber, M. 2006. *Data Mining: Concepts and Techniques*. Morgan Kaufman.
- Inmon, B. 2005. *Building the Data Warehouse*. John Wiley.
- Kelly, S. 1997. *Data Warehousing in Action*. John Wiley.
- Kimball, R. 2000. *The Data Webhouse Toolkit: Building the Web-Enabled Data Warehouse*. John Wiley.

- Kimball, R. 2002. *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*. John Wiley.
- Kimball, R. 2004. *The Data Warehouse ETL Toolkit: Practical Techniques for Extracting, Cleaning, Conforming, and Delivering Data*. John Wiley.
- Kimball, R. 2005. *The Microsoft Data Warehouse Toolkit: With SQL Server 2005 and the Microsoft Business Intelligence Toolset*. John Wiley.
- Kimball, R. 2008. *The Data Warehouse Lifecycle Toolkit: Practical Techniques for Building Data Warehouse and Business Intelligence Systems.* John Wiley.
- Kimball, R and Ross M. 2013. *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*, John Wiley
- Lee, K.H. 2005. First Course on Fuzzy *Theory and Applications*. Springer.

Course Title with Credit Load
Ph.D. in Computer Application

Course Code	Course Title	Credit Hours	Semester
*MCA 601	Spatial Informatics, GIS and Remote Sensing	1+1	I
*MCA 602	Introduction to Computer Graphics	1+1	I
*MCA 611	Computer Oriented Numerical Analysis	2+1	II
*MCA 612	Artificial Intelligence and Machine Learning	2+1	II
*MCA 615	Bioinformatics Computing	2+0	II
MCA 691	Seminar I	0+1	I/II
MCA 692	Seminar II	0+1	I/II
MCA 699	Research	0+75	II-VI
MCA 603	Simulation and Modeling	1+1	I
MCA 604	Introduction to Big Data	2+1	I
MCA 605	Introduction to Iot	2+1	I
MCA 606	Management Information Systems	2+0	I
MCA 613	Multimedia And its Applications	1+1	II
MCA 614	Knowledge Based Systems for Semantic Web	1+1	II

*** Core Course**

Course Contents
Ph.D. in Computer Application

I. Course Title : Spatial Informatics, GIS and Remote Sensing Techniques

II. Course Code : MCA 601

III. Credit Hours : 1+1

IV. Aim of the course

The basic objective of this course is to teach concepts of GIS and remote sensing with specific applications in agriculture related statistics.

V. Theory

Unit I

Introduction to Geographical Information System (GIS); Introduction- maps and spatial information, components of a GIS; GIS Internals - data representation-raster and vector data structures and analysistechniques.

Unit II

Digital Elevation Models; Data input, verification, storage and output.

Unit III

Spatial modelling- manual and automatic digitizing process; Data errors in GIS; Classification methods-multivariate analysis and classification.

Unit IV

Spatial interpolation; Current and potential uses of GIS in agricultural planning; Software components used in GIS; GIS in India.

Unit V

Physics of remote sensing, atmospheric effects and remote sensing sensors; Spectral signatures of earth surface features, spectral characteristics of vegetation, soil and water.

Unit VI

Data acquisition system, satellite image acquisition; Data collections: pre- processing and data storage; Visual and digital image interpretation; Digital image processing.

VI. Practical

- Digitization of a map with the help of a digitizer;
- Map editing;
- Geo- referencing and map projections;
- Creation of attribute database and linking with spatial data;
- General analysis of the data with the help software;
- Applications of digital elevation models using GIS;
- Spatial interpolations using GIS;
- Visual interpretations of remote sensing data;

- Geometric corrections of remote sensing digital data;
- Methods for improving quality of digital data and Techniques of image classifications.

VII. Suggested Reading

- Annadurai S and Shanmugalakshmi R. 2007. *Fundamentals of Digital Image Processing*. Pearson Edu.
- Burrough P.A. 1986. *Principles of Geographic Information System for Land Resources Assessment*. Oxford Univ. Press.
- Curran P.J. 1985. *Principles of Remote Sensing*. Longman.
- Jensen J.R. 2017. *Introductory Digital Image Processing*. 4^{th} Ed. Prentice Hall.
- Lillesand T.M. and Kiefer R.W. 1987. *Remote Sensing and Image Interpretation*. John Wiley.
- Peuquet D.J. and Marble D.F. 1990. *Introductory Readings in Geographic Information System*. Taylor & Francis.

I. Course Title : Introduction to Computer Graphics

II. Course Code : MCA 602

III. Credit Hours : 1+1

IV. Aim of the course

This course examines the principles of computer graphics, with a focus on the mathematics and theory behind 2D and 3D graphics rendering.

V. Theory

Unit I

Introduction, Application of Graphics, Elements of Graphics Workstation, Graphics I/P Devices; Development of computer graphics: Basic graphics system and standards.

Unit II

Raster scan and random scan graphics; Continual refresh and storages displays; Display processors and character generators; Colour display techniques.

Unit III

Frame buffer and bit operations, Concepts in raster graphics; Points, Lines and Curves; Scan conversion; Line-drawing algorithms; Circle and ellipse generation; Polygon filling; Conic-section generation.

Unit IV

Antialiasing; Two-dimensional viewing: Basic transformations; Co- ordinate systems; Windowing and clipping; Segments; Interactive picture- construction techniques; Interactive input/output devices.

Unit V

Three-dimensional concepts: 3-D representations and transformations; 3-D viewing; Algorithm for 3-D volumes, Spline curves and surfaces.

Unit VI

Fractals; Quadtree and Octree data structures; Hidden line and surface rendering and animation.

VI. Practical

- Implementation of algorithms for drawing geometrical figures, rotation, charts;

- Pixel handling on screen;
- Clipping – Line clipping – Polygon Clipping, Windowing;
- Use of primitive transformations and/or their combinations;
- Implementation of 3D Object Representation and Fractal programming and animation.

VII. Suggested Reading

- Hearn D and Baker M.P. 2004. *Computer Graphics*. Prentice Hall of India. Marshal G. 1983. *Programming with Graphics*. Granada Publ.
- Newman W.M. and Sproull R.F. 1981. *Principles of Interactive Computer Graphics*. McGrawHill.
- Prince D.M. 1979. *Interactive Graphics for Computer Aided Design* (*CAD*). Addison Wesley.
- Rogers D.F. 2001. *Procedural Elements in Computer Graphics*. McGraw Hill.
- Shalini G.P. 2010. *Principles of Computer Graphics: Theory and Practice Using OpenGL and Maya*. McGraw Hill.

I. Course Title : Simulation and Modeling

II. Course Code : MCA 603

III. Credit Hours : 1+1

IV. Aim of the course

The courses aim at teaching simulation and modeling technique for conducting experiments on models that describe the behaviour, uncertainty and structure of real world systems. This course will help in simulation of agricultural research problems and systems.

V. Theory

Unit I

Uses and purposes of simulation; Classification of models.

Unit II

Generation and testing of random numbers.

Unit III

Simulation of stochastic events and processes, Discrete event simulation.

Unit IV

Design of simulation experiments. Analysis of data generated by simulation experiments. Verification and validation of simulation models.

Unit V

Simulation languages.

Unit VI

Simulation of agricultural problems and systems.

VI. Practical

- Generation of random numbers;
- Testing randomness of generated random numbers;
- Generation of random variates following Normal, Beta, Gamma, Exponential, Chi-square, Student's-t, F, Weibull, Binomial, Poisson distributions with the given parameters;

- Discrete event simulation and Simulation from specific models applicable in agriculture.

VII. Suggested Reading

- Averill M.L. and Kelton D. 2005. *Simulation, Modelling and Analysis*. Tata McGraw Hill.
- Banks J. 1998. *Handbook of Simulation*. John Wiley.
- Brately P, Fox B.L. and Scharge LE. 1987. *A Guide to Simulation*. Springer.
- Deo N. 1987. *System Simulation with Digital Computer*. Prentice Hall of India.
- Gentle G.E. 2005. *Random Number Generation and Monte Carlo Methods*. Springer.
- Gordan G. 2007. *System Simulation*. Pearson Edu.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Press W.H., Flannery B.P., Tenkolsky S.A. and Vetterling W.T. 1986. *Numerical Recipes: The Art of Scientific Computing*. Cambridge Univ. Press.
- Ripley B.D. 1987. *Stochastic Simulation*. John Wiley.
- Taha H.A. 2003. *Operations Research: An Introduction*. Prentice Hall of India.

Course Title : Introduction to Big Data
Course Code : MCA 604
Credit Hours : 2+1

Aim of the course

This course provides exposure to different aspects of use of big data in agriculture and industrial research. It helps in providing information about the analysis procedure for Big data.

Theory

Unit I

Introduction to Big Data; Big Data Foundations, Components of big data infrastructure; Hadoop; Spark 2.0, installation, Hadoop Distributed File System, reading and processing Big data

Unit II

Introduction to MapReduce, Algorithms for common problems; NoSQL, Scripting

Unit III

Data visualization and mining big data

Unit IV

Processing streaming data, text and natural language processing

Suggested Reading

- Davenport T.H. 2016. *Big Data at Work: Dispelling the Myths, Uncovering the Opportunities.* Kindle Ed.
- Maheshwari A. 2018. *Data Analytics Made Accessible*. Kindle Ed.
- Simon P. 2018. *Too Big to Ignore: The Business Case for Big Data*, Wiley and SAS Business Series
- Schönberger V.M. and Cukier K. 2015. *Big Data: A Revolution That Will Transform How We Live, Work, and Think,*Kindle Ed.

I. Course Title : Introduction to Internet of Things
II. Course Code : MCA 605
III. Credit Hours : 2+1
IV. Aim of the course

This course provides exposure to different aspects of research, implementation, and business with IoT. It also deals withchallenges and techniques for building different IoT solutions. IoT-based applications such as innovative shopping system, infrastructure management in both urban and rural areas, remote health monitoring and emergency notification systems, and transportation systems.

V. Theory

Unit I

Introduction to IoT: Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications

Unit II

Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry, Implementation of IoT with Raspberry.

Unit III

Introduction to SDN, SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud.

Unit IV

Fog Computing, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT.

VI. Practical

- Case Study: Agriculture, Healthcare, Activity Monitoring

VII. Suggested Reading

- Raj P. and Raman A.C. 2017. *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press.
- Bahga A. and Madisetti V. 2017. *Internet of Things: A Hands-on Approach*, Universities Press.

I. Course Title : Management Information System

II. Course Code : MCA 606

III. Credit Hours : 2+0

IV. Aim of the course

This course provides exposure to challenges and techniques for management Information Systems. The course deals with theoretical aspects on how to manage the information systems.

V. Theory

Unit I

Information Systems in Global Business – Role of Information Systems in Business; Emergence of Digital Firms, Perspectives on Information Systems.

Unit II

Business Processes and Information Systems; how Information Systems improve Businesses; Types of Information Systems – Transaction Processing Systems; Management Information Systems; Decision Support Systems; Executive Information System.

Unit III

Organizations and Information Systems – Impact of Information System on organization –Economic, Organization and behavioral impacts; Competitive Advantages using Information Systems.

Unit IV

Enterprise wide Applications – ERP, CRM, Business Intelligence, Collaboration Tools and its use; E-Commerce; Social Media; Ethical Issues, privacy and regulations.

VI. Suggested Reading

- Amoroso E. 1994. *Fundamentals of Computer Security Technology*. Prentice-Hall.
- Bhushan M. 2017. *Fundamentals of Cyber Security* Prentice Hall.
- Chapman B & Zwicky ED. 2000. *Building Internet Firewalls*. O'Reilly.

I. Course Title : Computer Oriented Numerical Methods

II. Course Code : MCA 611

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on computer oriented numerical methods that aims at exposing the students to introduce numerical algorithms and to solve mathematical problems using numerical approximations

V. Theory

Unit I

Errors in computations: Basic concepts: Floating point number system, Implication of finite precision, Rounding off errors

Unit II

Finite Differences, Interpolation: Polynomial interpolation, Inverse interpolation, Spline interpolation; Numerical integration: Trapezoidal rule, Simpson's 1/3rd and 3/8th rules; Ordinary differential equations: Runge-Kutta methods, Predictor - correctormethods.

Unit III

Linear system of equations: Gaussian's elimination, Operation counts, Implementation including pivoting and scaling, Direct factorization methods, Iterative techniques and their analysis.

Unit IV

Linear Difference equations; Non-linear equations: Bisection, Newton Raphson, false positions, Secant methods, Iterative methods.

Unit V

Inverse of Matrices; Computation of Eigen values and Eigen vectors: Error estimates, the power methods – Jaccobi and Householder Method.

VI. Practical

- Solving polynomial and algebraic equations using numerical approximations, finding minimum and maximum of functions;
- Inversion of matrices, rank of a matrix,

- Choleskey Decompositions,
- Structural Value Decomposition and Eigen Values.

VII. Suggested Reading

- Atkinson K.E. and Han W. 2003. *Elementary Numerical Analysis*. 3rd Ed. John Wiley.
- Atkinson K.E. 1978. *An Introduction to Numerical Analysis*. John Wiley.
- Jain M.K., Iyengar S.R.K. and Jain R.K. 2007. *Numerical Methods for Scientific and* Engineering *Computation*. 7th Ed. New Age.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Krishnamurthi E.V. and Sen S.K. 1986. *Computer-Based Numerical Algorithms*. East West Publ.
- MacMillan. C. 2012. *Elementary Numerical Analysis An Algorithmic Approach:* John Wiley

I. Course Title : Artificial Intelligence and Machine Learning

II. Course Code : MCA 612

III. Credit Hours : 2+1

IV. Aim of the course

The primary objective of this course is to provide an introduction to the basic principles and applications of Artificial Intelligence that includes problem solving, knowledge representation, reasoning, decision making, planning, perception & action, and learning.

V. Theory

Unit I

Introduction to Artificial Intelligence (AI); Scope of AI: Games, theorem proving, natural language processing, robotics, expert system.

Unit II

Knowledge: General concept of knowledge, Knowledge based system, Representation of knowledge, Knowledge organization and manipulation, Acquisition of knowledge.

Unit III

Symbolic approach: Syntax and Semantics for Prepositional Logic (PL) and First order predicates logic (FOPL), Properties of well-formed formulas (wffs), Conversion to clausal form, Inference rules, Resolution principle, Non deductive inference methods.

Unit IV

Search and Control strategies: Blind search, Breadth- first search, Depth – First search, Hill climbing method, Best – First search, Branch and Bound search.

Unit V

Learning: Concept of learning, learning automation, genetic algorithms, learning by induction.

Unit VI

Expert System: Introduction to expert system, Characteristics features of expert system, Applications, Importance of Expert system, Rule based system architecture.

VI. Practical

- Search and Control strategies: Blind search, Breadth- first search, Depth – First search, Hill climbing method, Best – First search, Branch and Bound search;

- Learning by induction;
- Genetic algorithms;
- Case study of a rule based expert system and Construction of Decision tree.

VII. Suggested Reading

- Akerkar R. 2005. *Introduction to Artificial Intelligence*. Prentice-Hall of India.
- Giarratano J. and Riley G. 1998. *Expert Systems - Principles and Programming*. 3rd Ed. PWS Publ.
- Gonzalez A. and Dankel D. 2004. *The Engineering of Knowledge-Based Systems*. Prentice Hall.
- Hill E.F. 2003. *Jess in Action*. Manning Publ.
- Jackson P. 1999. *Introduction to Expert Systems*. Addison Wesley.
- Nilson N.J. 2014. *Artificial Intelligence: A New Synthesis*. Maurgan Kaufman.
- Nilson N.J. 2001. *Principles of Artificial Intelligence*. Narosa.
- Rich E. and Knight K. 2002. *Artificial Intelligence*. Tata McGraw Hill.
- Russell S. and Norvig P. 2003. *Artificial Intelligence: A Modern Approach*. Prentice Hall.

I. Course Title : Multimedia and Applications

II. Course Code : MCA 613

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces students to current practices, technologies, methodologies, and authoring systems in the design and implementation of systems that incorporate text, audio, images, animation and full-motion video.

V. Theory

Unit I

Introduction to Multimedia Technology - Computers, communications and entertainment; Framework for multimedia systems.

Unit II

M/M devices, presentation devices and the user interface, M/M presentation and authoring.

Unit III

Digital representation of sound and transmission; Brief survey of speech recognition and generation; Digital video and image compression; JPEG image compression standard; MPEG motion video compression.

Unit IV

DVD technology, Time based media representation and delivery; M/M software environment; Limitation of workstation operating systems.

Unit V

M/M systems services; OS support for continuous media applications; Media stream protocol; M/M file system and information representation.

Unit VI

Data models for M/M and Hypermedia information.

VI. Practical

- Script Writing and Story Boards;

- Hot Spots and Buttons, Layouts and designing of visuals, Basics of colors;
- Working with text, presentations, charts and putting animations;
- Creating interactive presentations;
- Adobe Photoshop – Introduction, Working with images, Image editing and cleaning;
- Macromedia Flash - Introduction, Creating shapes, Inserting text, Concepts of colors, layers, frames and timelines;
- Creating Animation - Creating scenes, creating movie, testing and playing movie;
- Adobe Acrobat – Overview, Creating Adobe PDF e-Books;
- Macro Media Director Basics.

VII. Suggested Reading

- Furhet B. 1998. *Multimedia Technologies and Applications for the 21st Century*. Kluwer.
- Gibbs S.J. and Tsischritziz D.C. 1995. *Multimedia Programming - Objects, Environment & Framework*. Addison-Wesley.
- Kerman P. 2002. *Teach Yourself Macromedia Flash MX*. Sams Publ. Luther AC. 1994. *Authoring Interactive Multimedia*. Academic Press. Parekh R. 2006. *Principles of Multimedia*. TataMcGraw-Hill.
- Vaughan T. 2017. *Multimedia-Making it Work*.McGraw-Hill.

List of Journals

Agricultural Statistics

- *American Statistician*
- *Annals of Institute of Statistical Mathematics*
- *Annals of Statistics*
- *Australian and New Zealand Journal of Statistics*
- *Biometrical Journal*
- *Biometrics*
- *Biometrika*
- *Bulletin of Calcutta StatisticalAssociation*
- *Canadian Journal of Statistics*
- *Communication in Statistics (Simulation and Computation)*
- *Communication in Statistics (Theory and Methods)*
- *Experimental Agriculture*
- *Institute of Mathematical Statistics Bulletin (IMSB)*
- *Journal of American Statistical Association*
- *Journal of Applied Statistics*
- *Journal of the Indian Society of Agricultural Statistics*
- *Journal of the International Statistical Review*
- *Journal of Statistical Planning and Inference*
- *Journal of Statistical Theory andPractice*
- *Journal of Statistics, Computer and Applications*
- *Journal of Royal Statistical Society, Series A*
- *Journal of Royal Statistical Society, Series B*
- *Journal of Royal Statistical Society, Series C*
- *Metrika*
- *Metron*
- *Scandinavian Journal of Statistics (Theory & Applied)*
- *Sankhya*
- *Statistica*
- *Statistical Science*
- *Statistics and Probability Letters*
- *Technometrics*
- *Utilitas Mathematica*

Computer Application

- *ACM Transactions on Knowledge Discovery from Data*
- *Applied Intelligence–The International Journal of Artificial Intelligence, Neural Networks, and Complex Problem-Solving Technologies*
- *Computational Statistics and Data Analysis, Elsevier Inc.*
- *Computers and Electronics in Agriculture, Elsevier Inc.*
- *Data Mining and Knowledge Discovery: An International Journal (DMKD)*
- *Expert Systems with Applications, Elsevier Inc.*
- *IEEE Transactions on Knowledge and Data Engineering*
- *IEEE Transactions on Neural Networks*
- *IEEE Transactions on Pattern Analysis and Machine Intelligence*
- *International Journal of Computing and Information Sciences*
- *International Journal of Information and Management Sciences*
- *International Journal of Information Technology*
- *Journal of Artificial Intelligence Research*
- *Journal of Combinatorics, Information and System Sciences*
- *Journal of Computer Sciences and Technology*
- *Journal of Computer Society of India*
- *Journal of Indian Society of Agricultural Statistics*
- *Journal of Intelligent Information Systems - Integrating Artificial Intelligence and Database Technologies*
- *Journal of Machine Learning Research*
- *Journal of Statistics, Computer and Applications*
- *Journal of Systems and Software*
- *Journal of Theoretical and Applied Information Technology*
- *Knowledge and Information Systems: An International Journal (KAIS)*
- *Lecture Notes in Computer Science, Springer Verlag.*
- *Machine Learning*
- *Transactions on Rough Set*

e-Resources

- Design Resources Server. *Indian Agricultural Statistics Research Institute (ICAR), New Delhi 110 012, India*.www.drs.icar.gov.in.
- Free Encyclopedia on Design of Experiments
- http: //en.wikipedia.org/wiki/Design_of_experiments
- Statistics Glossaryhttp: //www.cas.lancs.ac.uk/glossary_v1.1/main.html.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html.
- Hadamard Matriceshttp: //www.research.att.com/~njas/hadamard;
- Hadamard Matrices http: //www.uow.edu.au/~jennie/WILLIAMSON/williamson.html.
- Course on Experimental design: http://www.stat.sc.edu/~grego/courses/stat706/.
- Learning Statistics: http: //freestatistics.altervista.org/en/learning.php.
- Free Statistical Softwares: http://freestatistics.altervista.org/en/stat.php.
- Statistics Glossaryhttp: //www.cas.lancs.ac.uk/glossary_v1.1/main.html.
- Statistical Calculators: http: //www.graphpad.com/quickcalcs/index.cfm
- SAS Online Doc 9.1.3: http: //support.sas.com/onlinedoc/913/docMainpage.jsp

Suggested Broad Topics for Research Agricultural Statistics

- Design and analysis of multi-response experiments
- Design and analysis of micro-array experiments
- Design and analysis of experiments for precision agriculture
- Design and analysis of agroforestry experiments
- Designs for computer experiments.
- Bayesian designing of experiments, Bayesian optimality and Bayesian analysis of experimental data

- Computer aided search of efficient experimental designs for various experimental settings
- Fractional factorials including search designs, supersaturated designs, computer experiments, etc.
- Statistical techniques in bioinformatics, biotechnology, microbiology, genomics, etc.
- Optimality aspects and robustness of designs against several disturbances under various experimental settings (single factor, multi-factor, nested classifications, etc.)
- Small area estimation
- Computer intensive techniques in sample surveys
- Analysis of survey data, regression analysis, categorical data analysis, analysis of complex survey data
- Assessment and impact survey methodologies, valuation of natural resources, its degradation, depletion, etc.
- Linear and non-linear modeling of biological and economical phenomena
- Non-linear time series modeling
- Non-linear stochastic modeling
- Forecast models for both temporal and spatial data
- Innovative applications of resampling techniques
- Applications of remote sensing, GIS, ANN, etc. in modeling various phenomena
- Econometric models for risk, uncertainty, insurance, market analysis, technical efficiency, policy planning, etc.
- Statistical studies on value addition to crop produce

Computer Application

- Web solutions inagriculture
- Decision Support/ Expert Systems/ Information Management Systems in Agriculture
- Software for Statistical DataAnalysis
- Modelling and Simulation of Agricultural Systems
- Application Software for GIS and Remote Sensing
- Office Automation and Management System

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VOL. 3

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Basic Veterinary Sciences
- Veterinary Clinical Subjects
- Veterinary Para-Clinical Subjects
- Animal Production Sciences

भाकृअनुप
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त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the

syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language*.
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing*.
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

  (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

  (b) An application is made by the student concerned duly supported by the Advisory Committee;

  (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

  (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 3

Basic Veterinary Sciences

– Veterinary Anatomy
– Veterinary Biochemistry
– Veterinary Biotechnology
– Veterinary Extension Education
– Veterinary Physiology

Contents

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Basic Veterinary Sciences
– Veterinary Anatomy

Preamble
(Veterinary Anatomy)

To enhance the comprehension, the courses of Veterinary Anatomy have been redesigned facilitating learning of Regional Anatomy and to encourage hands on training to PG students. Major emphasis in re-designed courses has been clinical application of the basic knowledge of Anatomy and Histology. Wild life and Forensic Anatomy course and Clinical Anatomy course have been newly introduced at Masters level in view of the importance of wild life and Forensic applications and clinical approaches. Courses like Cross sectional Anatomy first of its kind in Veterinary Anatomy and Animal alternatives in Veterinary Anatomy which is important in view of ban on usage of animas for dissection have been introduced at doctorate level. Similarly some courses are reorganized.

Course Title with Credit Load
M.V.Sc. in Veterinary Anatomy

Course Code	Course Title	Credit Hours
ANA 601	Comparative osteology and arthrology	1+2
ANA 602	Comparative splanchnology	2+2
ANA 603	Myology, angiology, neurology and aesthesiology of Ox	2+2
ANA 604	Gross, histological and histochemical techniques	1+3
ANA 605	Clinical anatomy	0+1
ANA 606	General histology and ultrastructure	1+1
ANA 607	Systemic histology and ultrastructure	3+1
ANA 608	Developmental anatomy	2+1
ANA 609	Wild life and forensic anatomy	1+0
ANA 610	Master's seminar	1+0
ANA 611	Master's research	0+30

Course Contents
M.V.Sc. in Veterinary Anatomy

I. Course Title : Comparative Osteology and Arthrology

II. Course Code : ANA 601

III. Credit Hours : 1+2

IV. Aim of the course

To make a student well versed with the bones and joints of different domestic animals.

V. Theory

Unit I

Technical terms, structure, chemical composition and classification of bones.

Unit II

Bones of appendicular skeleton of ox as a type and their comparison with those of horse, sheep, goat, dog, pig and poultry.

Unit III

Bones of axial skeleton of ox as a type and their comparison with those of horse, sheep, goat, dog, pig and poultry.

Unit IV

Classification and detailed study of different joints of the body.

Unit V

Study the various indices for estimating race, sex and age of different animals. Basics of biomechanics of the locomotor system. Radiography of normal and developing bones.

VI. Practical

Demonstration of all bones and dissection of joints of buffalo/ Cattle. Radiographic study of bones and joints

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Technical terms, structure, chemical and physical composition and classification of bones	1
2.	Study on scapula and humerus of ox, horse, dog, pig, sheep, goat and poultry (including clavicle and coracoid).	1
3.	Study on radius andulna of ox, horse, dog, pig, sheep, goat and poultry.	1
4.	Study on carpals of ox, horse, dog, pig, sheep, goat and poultry.	1
5.	Study on metacarpals and digits including sesamoids of ox, horse, dog, pig, sheep, goat and poultry.	1

S. No.	Topic	No. of Lectures/ Practicals
6.	Comparative study on os-coxae including pelvimetry and femur of ox, horse, dog, pig, sheep, goat and poultry.	1
7.	Comparative study on tibia and fibula of ox, horse, dog, pig, sheep, goat and poultry.	1
8.	Comparative study on tarsal and metatarsal of ox, horse, dog, pig, sheep, goat and poultry.	1
9.	Study on the ethmoid, occipital and sphenoid bone of ox, horse, dog, pig, sheep, goat and poultry.	1
10	Study on the frontal, parietal, interparietal and temporal bones of ox, horse, dog, pig, sheep, goat and poultry.	1
11	Study on the maxilla, premaxilla, palatine, pterygoid, nasal, lacrimal and malar bones of ox, horse, dog, pig, sheep, goat and poultry.	1
12	Study on vomer, hyoid and mandible bones of ox, horse, dog, pig, sheep, goat and poultry	1
13	Study on cervical, thoracic, lumbar, sacral and coccygeal vertebrae of ox, horse, dog, pig, sheep, goat and poultry	1
14	Study on ribs and sternum of ox, horse, dog, pig, sheep, goat and poultry.	1
15	Detailed study of different joints of the body	2
16	Biomechanics of the locomotor system	1
17	Radiographic anatomy	1
	Total	18
Practical		
1	Topographic terms.	1
2	Classification of bones	1
3-4	Comparative study on scapula and humerus	2
5-6	Comparative study on radius and ulna	2
7-8	Comparative study on carpals	2
9-10	Comparative study on metacarpals and digits	2
11	Comparative study on os-coxae and femur	1
12-13	Comparative study on tibia and fibula	2
14	Comparative study on tarsal and metatarsal	2
15-16	Comparative study on the ethmoid, occipital and sphenoid bone	3
17-18	Comparative study on the frontal, parietal, interparietal and temporal bones	2
19-20	Comparative study on the maxilla, premaxilla, palatine pterygoid, nasal, lacrimal and malar bones	2
21-22	Comparative study on vomer, hyoid and mandible bones	2
23-24	Comparative study on cervical and thoracic vertebrae	2
25-27	Comparative study on bones of lumbar, sacral and coccygeal vertebrae.	2
28-30	Comparative study on ribs and sternum	2
31-32	Classification and detailed study of different joints of the body.	2
33-34	Biomechanics of the locomotor system	2
35-36	Radiographic anatomy	2
	Total	36

I. Course Title : Comparative Splanchnology

II. Course Code : ANA 602

III. Credit Hours : 2+2

IV. Aim of the course

To give a detailed overview of different systems constituting splanchnology.

V. Theory

Unit I

Overview of different systems constituting descriptive anatomy of various organs of digestive system and associated glands of ox and their comparison with those of horse, sheep, goat, dog, pig and poultry. Study of formation of thoracic, abdominal and pelvic cavities; reflection of these cavities.

Unit II

Study of various organs/ structures and associated glands constituting the respiratory system of ox and their comparison with those of horse, sheep, goat, dog, pig and poultry.

Unit III

Detailed study of organs and associated glands comprising the urinary system of ox as a type and their comparison with those of horse, sheep, goat, dog, pig and poultry.

Unit IV

Complete study of various organs and associated glands of male and female genital systems.

Unit V

Surgical sites for various operations and clinically significant areas for performing auscultation, percussion and for carrying out surgical procedures such as laryngotomy, oesophagotomy, gastrotomy, rumenotomy, cystotomy, urethrotomy, caesarian section, exploratory laparotomy, mammectomy, thoracotomy, thoracocentesis, etc.

Unit VI

Study of various endocrine organs of ox and their comparison with horse, sheep, goat, dog, pig and poultry

VI. Practical

Demonstration of structure and placement of organs in body cavities of all the animals. Sonographic appearance of different organs.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction	1
2.	Study of topographic anatomy and reflection of thoracic, abdominal and pelvic cavities in ox, horse, dog, pig, sheep, goat and poultry	2
3.	Comparative anatomy of oral cavity in ox, horse, dog, sheep, goat and pig.	2
4.	Comparative anatomy of dentition in ox, horse, dog, sheep, goat and pig,	1
5.	Comparative anatomy of tongue in ox, horse, dog, sheep, goat and pig.	1
6.	Comparative anatomy of esophagus in different species	1
7.	Study of the salivary glands of various species	1
8.	Study of ruminant stomach along with omentum	2
9.	Study of monogastric stomach and omentum of various species	2
10.	Comparative anatomy of small intestines of various species	1
11.	Comparative anatomy of large intestines of various species	1

S. No.	Topic	No. of Lectures/ Practicals
12.	Study of liver and gall bladder of various species	1
13.	Study of spleen and pancreas of various species	1
14.	Study of digestive system of poultry	1
15-16.	Study of nasal cavity in ox, horse, dog, sheep, goat and pig	2
17.	Study of larynx of various species	1
18.	Study of trachea of various species	1
19.	Comparative anatomy of lungs of various species	2
20.	Study of digestive system of fowl	1
21.	Study of kidneys of various species	1
22.	Study of ureter and urinary bladder	1
23.	Study of urethra	1
24.	Study of male genital system and associated organs of various species	1
25.	Study of female genital system and associated organs of various species	2
26.	Study of male and female genital system of fowl	1
27.	Study of udder of different species of animals	1
28.	Study of body cavities	1
	Total	35
Practical		
1.	Introduction	1
2.	Study of topographic anatomy of thoracic, abdominal and pelvic cavities in different animals.	2
3.	Comparative anatomy of oral cavity in ox, horse, dog, sheep, goat and pig.	2
4.	Comparative anatomy of dentition in ox, horse, dog, sheep, goat and pig,	1
5.	Comparative anatomy of tongue in ox, horse, dog, sheep, goat and pig.	1
6.	Comparative anatomy of esophagus in different species	1
7.	Study of the salivary glands of various species.	1
8.	Study of ruminant stomach along with omentum	2
9.	Study of monogastric stomach and omentum of various species	2
10.	Comparative anatomy of small and large intestines and anus of various species	2
11.	Study of liver and gall bladder, spleen, pancreas of various species	2
12.	Study of larynx of various species	1
13.	Comparative anatomy of lungs of various species	2
14.	Study of body cavities	2
15-16.	Study of urinary system and associated organs of various species	2
17.	Study of male genital system and associated organs of various species	2
18.	Comparative study of accessory sex glands in different species	1
19.	Study of female genital system and associated organs of various species	2
20.	Study of endocrine organs of various species	2
21.	Study of udder of different species of animals	1
	Total	32

I. Course Title : Myology, Angiology, Neurology and Aesthesiology of Ox

II. Course Code : ANA 603

III. Credit Hours : 2 +2

IV. Aim of the course

To give a thorough knowledge about the muscles, course of blood vessels and nerves of the body in addition to various organs of circulatory, nervous and sensory systems of ox as a type animal.

V. Theory

Unit I

Classification of muscle fibres. Origin, insertion and relations of muscles of different body parts.

Unit II

Topographic anatomy of the vascular system comprising of heart, arteries, veins and lymphatics.

Unit III

Study of various components of central nervous system, peripheral nervous system and autonomic nervous system.

Unit IV

Complete study of the gross anatomy of various sense organs.

Unit V

Study of different nerve blocks, intravenous sites and enucleation of eye ball.

VI. Practical

Dissection of heart, different vessels, brain, cranial nerves, brachial plexuses and lumbo-sacral plexus. Dissection of eye, ear, hoof and horn of buffalo/ cattle.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Myology and organization of various types of muscles	2
2.	Heart and pericardium	4
3.	Muscles and blood supply to the head and neck	3
4.	Muscles and blood supply to the forelimb	3
5.	Muscles of thorax and abdomen and thoracic aorta, abdominal aorta and its branches	2
6.	Muscles and blood supply to the hind limb	2
7	Venous system	2
8	Lymph glands and its afferent and efferent vessels	2
9	Study of brain	2
10	Study of cranial nerves	2
11	Study of spinal cord and spinal nerves	2
12	Brachial and lumbo-sacral plexus	2
14	Structure of eye ball	2
15	Structure of external, middle and internal ear of different species	2
16	Study of hoof	2
17	Study of horn	2
	Total	36
Practical		
1	Introduction to general myology	1
2	Structure of heart	2
3	Brachiocephalic trunk, course of aorta, coronary arteries and pulmonary trunk	1
4	Bicarotid trunk	1

S. No.	Topic	No. of Lectures/ Practicals
5	Blood supply to the forelimb	1
6	Thoracic aorta and its branches abdominal aorta	1
7	Abdominal aorta and its branches	1
8	Blood supply to the hind limb	1
9	Meninges	1
10	Dorsal and ventral aspect of brain and ventricles of brain, sagittal sections of brain of different species	1
11	Cranial nerves,	1
12	Spinal cord and spinal nerves	1
13	Brachial plexus	1
14	Lumbo-sacral plexus	1
15	Venous drainage and lymphatic system	1
16	Blood supply to the brain	2
17	Study of eye	1
18	Study of ear	1
19	Autonomic nervous system	1
20	Muscle of face, larynx, mastication, soft palate, tongue, pharynx and ear	4
21	Muscles of neck	2
22	Muscles of fore limb	2
23	Muscles of thorax	1
24	Muscles of, abdomen	1
25	Muscles of hip and thigh	2
26	Extensors and flexors of hind limb	1
27	Muscles of tail and penis	1
	Total	**34**

I. Course Title : Gross, Histological and Histochemical Techniques

II. Course Code : ANA 604

III. Credit Hours : 1+3

IV. Aim of the course

Hands-on training for preparation of gross anatomical specimens and processing of tissues to demonstrate structural components by different stains for research and teaching purposes.

V. Theory

Unit I

Preparation of tissues for microtomy and lightmicroscopy using different fixatives.

Unit II

Different staining methods for routine light microscopy and special staining methods.

Unit III

Frozen sectioning techniques and staining methods for enzymes, carbohydrates, lipids, proteins, pigments, etc.

Unit IV

Silver staining techniques for nervous tissue.

Unit V

Preparation of tissue for electron microscopic studies

VI. Practical

Embalming fluids, embalming of animals, maceration and preparation of skeletons. Gross staining of brain sections. Demonstration of sites of ossifications. Preparation of transparent specimens, preparation of casts of various organs, blood vessels and ducts, etc. Study of different techniques for collection, fixation and processing of animal tissues; preparation of paraffin and frozen sections; handling and care of microtomes. Demonstration of staining of carbohydrates, lipids, proteins, nucleic acids and enzymes.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Embalming fluid and its preparation	1
2	Embalming techniques, formalin and modified gravity feed embalming technique.	1
3	Maceration and preparation of skeletons; taxidermy, burial method, chemical method(sodium hydroxide method) gross staining of brain specimens different species; Tompsett 1955, Mulligam 1931 for gray matter, Waldman and Michaels (1954) for white matter, Hewitt method	1
4	Demonstration of sites of ossifications alizarin red technique	1
5	Preparation of transparent specimens of various organs, plastination	1
5	Preparation of transparent specimens of various organs, plastination	1
7	Chemical composition of a living cell	1
8	Fixation of tissue samples with different fixatives and post fixation of tissue samples	1
9	Embedding, block preparation and paraffin sectioning.	1
10	Natural and synthetic dyes	1
11	Metachromasia and supravital staining	1
12	Routine hematoxylin and eosin staining	1
13	Special staining for connective, muscular and nervous tissue.	1
14	Staining for carbohydrates and proteins and lipids.	1
15	Special stain for demonstration of nucleic acids	1
16	Special staining for cytoplasmic granules and pigments and minerals	1
17	Differential staining for cell types	1
18	Demonstration of silver staining techniques	1
	Total	18
Practical		
1	Embalming fluid and its preparation	2
2	Embalming techniques, formalin and modified gravity feed embalming technique.	2
3	Maceration and preparation of skeletons; taxidermy, burial method, chemical method(sodium hydroxide method) gross staining of brain specimens different species; Tompsett 1955, Mulligam 1931 for gray matter, Waldman and Michaels (1954) for white matter, Hewitt method	2
4	Demonstration of sites of ossifications alizarin red technique	2
5	Preparation of transparent specimens of various organs, plastination	2
6	Preparation of casts of various organs, vinyl acetate cast	2
7	Chemical composition of a living cell	2
8	Fixation of tissue samples with different fixatives	4

S. No.	Topic	No. of Lectures/ Practicals
9	Post fixation of tissue samples	2
10	Embedding, block preparation and paraffin sectioning.	4
11	Natural and synthetic dyes	2
12	Metachromasia and supravital staining	2
13	Routine hematoxylin and eosin staining	2
14	Special staining for connective: elastic, reticular and collagen fibres, muscular and nervous tissue.	4
15	Staining for carbohydrates: pas, amp and proteins.	2
16	Special stain for demonstration of nucleic acids, lipids and enzymes	2
17	Special staining for cytoplasmic granules	2
18	Special staining for pigments and minerals	2
19	Differential staining for cell types	2
20	Demonstration of silver staining techniques	2
	Total	48

I. Course Title : Clinical Anatomy

II. Course Code : ANA 605

III. Credit Hours : 0+1

IV. Aim of the course

To give exposure to different clinical conditions.

V. Practicals

Clinical examination of animal in health and disease, auscultation of different organs, different types of nerve blocks, surgical conditions of different body systems, radiographical techniques and post-mortem examination.

S. No.	Topic	No. of Lectures/ Practicals
Practical		
1.	Clinical examination of animal by palpation, percussion and auscultation	1
2.	Site to record temperature, pulse, palpable lymph nodes, collection of blood and pregnancy diagnosis in domestic animals	1
3.	Area of auscultation for lungs and heart, passing of probang	1
4.	Preferable site for injections in domestic animals (intradermal, subcutaneous, intramuscular, intravenous, intracardiac, intratracheal, subconjunctival, intra-articular, epidural)	1
5.	Nerve blocks of head region (frontal, infraorbital, mandibulo-alveolar, mental, retrobulbar, Peterson, auriculopalpebral and cornual) for different surgical conditions (exraction of tooth, trephining of frontal and maxillary sinuses, extirpation of eye ball, amputation of horn, haematoma)	2
6.	Surgical conditions of respiratory system (catheterization of guttural pouch, ventriculectomy in horse, tracheotomy, thoracocentesis)	1
7.	Paravertebral nerve block, paracentesis, rumenocentesis. Surgical conditions of digestive system (passing of stomach tube, ligation of parotid duct, oesophagotomy, abdominocentesis, rumenotomy, laparotomy/ celiotomy, gastrotomy, splenectomy, enterotomy, extirpation of anal sacs in dog)	2

S. No.	Topic	No. of Lectures/ Practicals
8.	Surgical conditions of urinary system (urethrotomy, puncturing of urinary bladder, catheterization of urinary bladder, cystotomy)	1
9.	Surgical conditions of genital system (hysterotomy/ caesarean section, ovario-hysterectomy (spaying), castration, vasectomy, caponing in fowl)	1
10.	Nerve blocks of fore limb (radial, median, ulnar, volar digital nerves) for surgical affections	1
11.	Nerve blocks of hind limb (tibial, peroneal, saphenous, plantar digital nerves) for surgical affections including patellar desmotomy	1
12.	Nerve blocks (pudic, cranial epidural, caudal epidural) for surgical affections including docking	1
13.	Radiographical techniques, contrast radiography	1
14.	Radiographic visualization of organs of thoracic and abdominal cavity	1
15.	Radiographic visualization of organs of pelvic cavity	1
16.	Post-mortem examination and collection of material for teaching and research	1
	Total	16

I. Course Title : General Histology and Ultrastructure

II. Course Code : ANA 606

III. Credit Hours : 1+1

IV. Aim of the course

To understand basic principles of light microscopy and light and ultrastructure of four basic tissues.

V. Theory

Unit I

Light and ultrastructural details of animal cell.

Unit II

Light and ultrastructural details of epithelial tissue.

Unit III

Light and ultrastructural details of muscular tissue.

Unit IV

Light and ultrastructural details of connective tissue.

Unit V

Light and ultrastructural details of nervous tissue.

VI. Practical

Demonstration of different components of cells and intercellular substances of the above referred tissues by special staining through the use of light, phase contrast, dark field, fluorescent and electron microscopes.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to animal cell and Study of plasma membrane	1
2.	Study of nucleus and nuclear membrane and Study of mitochondria and endoplasmic reticulum	1
3.	Study of Golgi apparatus, centriole, lysosomes, microtubules, microfilaments, etc.	1
4.	Cell division and Cell wall modifications and junctional complexes	1
5.	Light and ultrastructural study of different types of epithelial tissue and glands	2
6.	Light and ultrastructural study of different types of muscular tissue	1
7.	Introduction to different types of connective tissue and Detailed study of connective tissue fibres; collagen, reticular and elastic	1
8.	Study of different cell types of connective tissue, constituents of ground substance	1
9.	Study of different types of connective tissues	1
10.	Light and ultrastructural details of different cartilages; hyaline, elastic and fibrous cartilage	1
11.	Light and ultrastructural details of bone	1
12.	Structural details of blood and its different constituents	2
13.	Light and ultrastructural study of neurons and neuroglial cells of CNS and PNS, nerves, ganglion, etc.	2
	Total	16
Practical		
1.	Study on electron micrographs of an animal cell to distinguish different organelles	1
2.	Study of electron micrographs of plasma membrane, nucleus and nuclear membrane	2
3.	Study of electron micrographs of mitochondria, Golgi apparatus and endoplasmic reticulum	1
4.	Study of different types of epithelial tissues by light microscope	1
5.	Study of different types of epithelial tissues and glands by electron micrographs	1
6.	Study of different types of Muscle tissues by light microscope	1
7.	Study of different types of Muscle tissues by electron micrographs	1
8.	Study of different types of connective tissue fibres and cells	1
9.	Study of different types of connective tissues	3
10.	Study of different types of cartilages	1
11.	Study of Bone; ground bone and decalcified bone	1
12.	Study of different constituents of blood	1
13.	Light and ultrastructural study of nervous tissue	2
	Total	17

I. Course Title : Systemic Histology and Ultrastructure

II. Course Code : ANA 607

III. Credit Hours : 3+1

IV. Aim of the course

To understand and identify arrangement of four basic tissues in organs of different body systems

V. Theory

Unit I

Light and ultrastructure of different organs of digestive system of ruminants with differential features among domestic animals.

Unit II

Light and ultrastructure of different organs of respiratory, lymphoid and cardiovascular systems.

Unit III

Light and ultrastructure of different organs of urino-genital systems.

Unit IV

Light and ultrastructure of different sense organs and nervous system.

Unit V

Light and ultrastructure of different organs of endocrine system

VI. Practical

Study of histological structure of organs of digestive, respiratory, urinary, genital and cardiovascular systems of buffalo, horse and dog/ cat.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	General organization of the wall of tubular organs	1
2.	Light microscopic and ultra structural study of tongue, lip and cheek	2
3.	Light microscopic and ultra structural study of salivary gland	2
4.	Light microscopic and ultra structural study of pharynx and oesophagus	2
5.	Light microscopic and ultra structural study of rumen, reticulum and omasum	2
6.	Light microscopic and ultra structural study of abomasum	2
7.	Light microscopic and ultra structural study of small intestine	2
8.	Light microscopic and ultra structural study of large intestine	2
9.	Light microscopic and ultra structural study of liver	2
10.	Light microscopic and ultra structural study of pancreas and gall bladder	2
11.	Light microscopic and ultra structural study of nasal cavity	1
12.	Light microscopic and ultra structural study of larynx and trachea	2
13.	Light microscopic and ultra structural study of lungs	2
14.	Light microscopic and ultra structural study of cardiovascular system including heart	2
15.	Light microscopic and ultra structural study of lymphoid organs	2
16.	Light microscopic and ultra structural study of ovary	2
17.	Light microscopic and ultra structural study of oviduct and uterus	2
18.	Light microscopic and ultra structural study of cervix, vagina and mammary glands	2
19.	Light microscopic and ultra structural study of testes	2
20.	Light microscopic and ultra structural study of epididymis and vas deferens	1
21.	Light microscopic and ultra structural study of urethra and accessory sex glands and penis	2

S. No.	Topic	No. of Lectures/ Practicals
22.	Light microscopic and ultra structural study of kidney	2
23.	Light microscopic and ultra structural study of ureter, urinary bladder and urethra	1
24.	Light microscopic and ultra structural study of endocrine glands; thyroid, pituitary, adrenal gland, parathyroid, pineal gland	2
25.	Light and ultrastructural details of Spinal cord, cerebrum and cerebrum	1
26.	Light microscopic and ultra structural study of integument	1
27.	Light microscopic and ultra structural study of eye	2
28.	Light microscopic and ultra structural study of ear	2
	Total	50
Practical		
1.	Light microscopic and ultra structural study of lip and cheek, tongue and salivary glands	1
2.	Light microscopic and ultra structural study of pharynx and oesophagus	1
3.	Light microscopic and ultra structural study of rumen, reticulum, Omasum and abomasum	1
4.	Light microscopic and ultra structural study of small intestine	1
5.	Light microscopic and ultra structural study of large intestine	1
6.	Light microscopic and ultra structural study of liver, pancreas and gall bladder	1
7.	Light microscopic and ultra structural study of larynx and trachea	1
8.	Light microscopic and ultra structural study of lungs	1
9.	Light microscopic and ultra structural study of cardiovascular system including heart	1
10.	Light microscopic and ultra structural study of lymphoid organs	1
11.	Light microscopic and ultra structural study of ovary and oviduct	1
12.	Light microscopic and ultra structural study of uterus, cervix, vagina and mammary glands	1
13.	Light microscopic and ultra structural study of male reproductive system	1
14.	Light microscopic and ultra structural study of kidney, ureter, urinary bladder and Urethra	1
15.	Light microscopic and ultra structural study of endocrine glands; thyroid, pituitary, adrenal gland, parathyroid, pineal gland	1
16.	Light and ultrastructural study of Spinal cord, cerebrum and cerebrum	1
17.	Light microscopic and ultra structural study of sense organs	1
	Total	17

I. Course Title : Developmental Anatomy

II. Course Code : ANA 608

III. Credit Hours : 2+1

IV. Aim of the course

To understand the developmental processes of different body systems at various stages of pregnancy.

V. Theory

Unit I

Gametogenesis, Classification of eggs, fertilization, cleavage and gastrulation

Unit II

Development of foetal membranes and placenta in domestic animals.

Unit III

Histogenesis of nervous system, sense organs, lymphoid organs, endocrine organs and cardiovascular system

Unit IV

Embryonic development of digestive, respiratory, uro-genital and musculoskeletal system.

VI. Practical

Study of serial sections of the chick and pig embryos at different stages of development.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to Embryology, history of embryology, term used in embryology Gametogenesis; Spermatogenesis	2
2.	Oogenesis; classification of eggs, structure of mammalian and avian eggs	2
3.	Fertilization, Cleavage Implantation Placentation	2
4.	Blastulation Gastrulation, formation of extra embryonic membranes	2
5.	Formation of extra embryonic membranes	2
6.	Organogenesis and histogenesis of nervous system,	2
7.	Development of sense organs	2
8.	Development of endocrine organs	2
9.	Cardiovascular system including fetal circulation.	2
10.	Embryonic development of gastro-intestinal tract	2
11.	Development of liver, pancreas and gall bladder	2
12.	Development of Respiratory system	2
13.	Development of urinary system	2
14.	Male reproductive system	2
15.	Female reproductive system	2
16.	Musculoskeletal system	2
	Total	32
Practical		
1.	Study of sperm and ova	1
2.	Cleavage, Blastulation and Gastrulation	1
3.	Study of whole mount sections of chick embryo and serial sections of chick embryo	1
4.	Organogenesis, Development of nervous system	1
5.	Organogenesis, Development of digestive system	2
6.	Organogenesis. Development of respiratory system	2
7.	Organogenesis, Development of cardiovascular system	2
8.	Organogenesis, Development of endocrine system	1
9.	Organogenesis, Development of urinary system	2
10.	Organogenesis, Development of male and female reproductive system	2
11.	Determination of age of different species of embryo	1
	Total	16

I. Course Title : Wild Life and Forensic Anatomy

II. Course Code : ANA 609

III. Credit Hours : 1+0

IV. Aim of the course

To give exposure to different body systems of wild animals of local region for the forensic purpose.

V. Theory

Unit I

Importance of anatomy of wild animals in veterinary anatomy.

Unit II

Anatomy of different body systems of wild animals.

Unit III

Anatomy of different body systems of wild birds.

Unit IV

Application of wild life anatomy in forensic veterinary medicine

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction, scope and importance of anatomy of wild animals	1
2.	Origin, evolution and classification of wild mammals and birds	1
3.	Morphological adaptations of wild mammals and birds	1
4.	Radiography and ultrasonography as a tool to study wild life anatomy	1
5.	Anatomy of skeletal system of Elephants with special emphasis on dentition and ageing and sexual dimorphism	1
6.	Anatomy of digestive, respiratory, reproductive and urinary systems of elephants	1
7.	Anatomy of skeletal system of wild carnivores including lion, tiger, leopard, cheetah, wolf and fox.	1
8.	Anatomy of digestive, respiratory, reproductive and urinary systems of wild carnivores	1
9.	Anatomy of skeletal, digestive, respiratory, reproductive and urinary systems of wild ruminants	1
10.	Anatomy of skeletal, digestive, respiratory, reproductive and urinary systems of wild primates	1
11.	Anatomy of skeletal system of Cervidae family	1
12.	Anatomy of digestive, respiratory, reproductive and urinary systems of Cervidae family	1
13.	Anatomy of cardio-vascular system of wild animals	1
14.	Anatomy of nervous system of wild animals	1
15.	Anatomy of sense organs of wild animals	1
16.	Anatomy of wild birds	1
17.	Application of wild life anatomy in forensic veterinary medicine	1
18.	Clinical anatomy of captive wild animals	1
	Total	18

Course Title with Credit Load
Ph.D. in Veterinary Anatomy

Course Code	Course Title	Credit Hours
RPE 700	Research and Publication Ethics*	1+1
ANA 701	Myology, angiology, neurology and aesthesiology of equine, canine and porcine	2+1
ANA 702	Principles and applications of biomechanics	1+0
ANA 703	Avian anatomy	1+1
ANA 704	Neuroanatomy	2+1
ANA 705	Comparative endocrine anatomy	1+1
ANA 706	Theory and applications of electronmicroscopy	1+1
ANA 707	Histoenzymology and immunocytochemistry	2+1
ANA 708	Applied embryology and teratology	1+1
ANA 709	Functional veterinary anatomy	1+0
ANA 710	Gross anatomy of laboratory animals	1+1
ANA 711	Cross sectional anatomy of ox	0+1
ANA 712	Animal alternatives in veterinary anatomy	1+1
ANA 713	Special problem	0+2
ANA 714	Doctoral seminar- I	1+0
ANA 715	Doctoral seminar- II	1+0
ANA 716	Doctoral research	0+75

*Compulsory Major course for Doctorate programme. The other 10 credits can be registered from remaining 700 Series courses listed above. Suggested list of specified Minor subjects (Departments).

Major Subject	Supporting subjects (Departments)*
Veterinary Anatomy	Biochemistry, Physiology, Veterinary Pathology, Veterinary Gynaecology and Obstetrics, Veterinary Surgery and Radiology, Biotechnology.

*The Minor courses may be taken from any number of disciplines/ departments listed against major discipline limiting to credits prescribed as decided by the Chairman of Advisory Committee of the student.

Minor courses may also be taken from the disciplines/ departments other than those listed above on the recommendations of advisory committee, if essentially required as per the research problem with the concurrence of Head of the Department and Concerned Authorities.

Course Contents
Ph.D. in Veterinary Anatomy

I. Course Title : Myology, Angiology, Neurology And Aesthesiology Of Equine, Canine And Porcine

II. Course Code : ANA 701

III. Credit Hours : 2+1

IV. Aim of the course

To teach students about anatomy of muscles, blood vessels, nervous tissue and sense organs in equine, canine and porcine.

V. Theory

Unit I

Comparative study of mycology of horse, dog and pig.

Unit II

Comparative study of angiology of horse, dog and pig.

Unit III

Comparative study of neurology of horse, dog and pig.

Unit IV

Comparative study of aesthesiology of horse, dog and pig.

VI. Practical

Dissection of different body regions with respect to muscles, blood vessels and nerves; and see the topographic positioning of different organs in different body cavities in equine, canine and porcine.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Comparative study of muscles of head and neck of horse, dog and pig	2
2.	Comparative study of muscles of forelimb: shoulder and arm	1
3.	Comparative study of extensor and flexors of forelimb	1
5.	Comparative study of muscles of abdomen	1
7.	Comparative study of muscles of pelvic region, hind limb and tail	2
8.	Comparative study of topography and structure of heart, blood supply to heart	2
9.	Study of arterial supply to head and neck	2
10.	Comparative study of blood supply to the forelimb	1
11.	Study of the collateral and terminal branches of aorta	2
12.	Comparative study of blood supply to the hind limb	2
13.	Comparative study of venous system	1
14.	Study the lymphatic system	1
15.	Comparative study of brain and spinal cord	2
16.	Study of cranial nerves	2

S. No.	Topic	No. of Lectures/ Practicals
17.	Study of brachial plexus and its branches	1
18.	Study of cervical, thoracic and lumbar nerves	1
19.	Comparative study of lumbo-sacral plexus	2
20.	Comparative study of eye	1
21.	Comparative study of ear	1
22.	Comparative study of hoof	1
23.	Comparative study of gustatory and olfactory organs	1
	Total	32
Practical		
1.	Comparative study of muscles of head and neck of horse, dog and pig	1
2.	Comparative study of muscles of forelimb: shoulder, arm extensors and flexors	1
3.	Comparative study of muscles of abdomen	1
4.	Comparative study of muscles of pelvic region, hind limb and tail	1
5.	Comparative study of topography and structure of heart, blood supply to heart	1
6.	Study of arterial supply to head and neck	1
7.	Comparative study of blood supply to the forelimb	1
8.	Study of the collateral and terminal branches of aorta	1
9.	Comparative study of blood supply to the hind limb	1
10.	Comparative study of venous and lymphatic system	1
11.	Comparative study of brain and spinal cord	1
12.	Study of cranial nerves	1
13.	Study of brachial plexus and its branches	1
14.	Study of cervical, thoracic and lumbar nerves	1
15.	Comparative study of lumbo-sacral plexus	1
16.	Comparative study of eye and ear	1
17.	Comparative study of hoof	1
18.	Comparative study of gustatory and olfactory organs	1
	Total	18

I. Course Title : Principles and Applications of Biomechanics

II. Course Code : ANA 702

III. Credit Hours : 1+0

IV. Aim of the course

To sensitize the student about the importance of biomechanics.

V. Theory

Unit I

Biomechanics, its definition and scope with reference to anatomy and physiology of domestic animals and musculo-skeletal dynamics.

Unit II

Locomotion and clinical applications. Biomechanics of cortical and trabecular bones.

Unit III

Biomechanics of fracture fixation. Instrumentation and techniques in locomotion and their applications in lameness.

S. No.	Topic	No. of Lectures
Theory		
1.	Definition of Biomechanics and its classification.	1
2.	Scope Biomechanics of with reference to anatomy and physiology of domestic animals	1
3.	Musculo-skeletal dynamics	2
4.	Locomotion and its type in domestic animals	2
5.	Instrumentation and techniques in locomotion and their applications in lameness.	2
6.	Biomechanics of microscopic structures	1
7.	Polariscope, its principle and application	2
8.	Biomechanics of cortical and trabecular bones.	1
9.	Biomechanics of articular cartilages	2
10.	Biomechanics of mammalian body; bow and string theory	2
11.	Biomechanics of fracture fixation	1
12.	Biomechanics of heart	1
	Total	18

I. Course Title : Avian Anatomy

II. Course Code : ANA 703

III. Credit Hours : 1+1

IV. Aim of the course

To give detailed overview of poultry anatomy.

V. Theory

Unit I

The study of the gross features of different body systems of domestic fowl.

Unit II

The study of microscopic features of different body systems of domestic fowl.

VI. Practical

Dissection and demonstration of various body systems of fowl and different domestic birds. Microscopic examination of slides of various organ systems of fowl.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	The study of gross features of axial and appendicular skeleton of domestic fowl	1
2	Study of various joints of axial and appendicular skeleton of domestic fowl	2
3	Gross and microscopic study of muscular system of domestic fowl	1
4	Gross and microscopic study of digestive system of domestic fowl.	2
5	Gross and microscopic study of respiratory organs of domestic fowl.	1
6	Gross and microscopic study of urinary organs of domestic fowl.	1
7	Gross and microscopic study of reproductive system of domestic fowl.	1
8	Study of the blood of domestic fowl.	2
9	Gross and microscopic study of circulatory system of domestic fowl.	1
10	Gross and microscopic study of nervous system of domestic fowl.	1

S. No.	Topic	No. of Lectures/ Practicals
11	Gross and microscopic study of eye and its appendages of domestic fowl.	1
12	Gross and microscopic study of ear of domestic fowl.	1
13	Gross and microscopic study of skin and its appendages of domestic fowl.	1
14	Gross and microscopic study of lymphoid organ of domestic fowl.	1
15	Gross and microscopic study of endocrine system of domestic fowl.	1
	Total	18
Practical		
1	The study of gross features of axial and appendicular skeleton of domestic fowl and turkey	1
2	Study of various joints of axial and appendicular skeleton of domestic fowl	2
3	Gross and microscopic study of muscular system of domestic fowl	1
4	Gross and microscopic study of digestive system of domestic fowl.	2
5	Gross and microscopic study of respiratory organs of domestic fowl.	1
6	Gross and microscopic study of urinary organs of domestic fowl.	1
7	Gross and microscopic study of reproductive system of domestic fowl.	1
8	Study of the blood of domestic fowl.	2
9	Gross and microscopic study of circulatory system of domestic fowl.	1
10	Gross and microscopic study of nervous system of domestic fowl.	1
11	Gross and microscopic study of eye and its appendages of domestic fowl.	1
12	Gross and microscopic study of ear of domestic fowl.	1
13	Gross and microscopic study of skin and its appendages of domestic fowl.	1
14	Gross and microscopic study of lymphoid organ of domestic fowl.	1
15	Gross and microscopic study of endocrine system of domestic fowl.	1
	Total	**18**

I. Course Title : Neuroanatomy
II. Course Code : ANA 704
III. Credit Hours : 2+1

IV. Aim of the course

To provide in-depth knowledge of nervous system.

V. Theory

Unit I

The gross and microscopic anatomy of the brain and spinal cord.

Unit II

Study of various cranial and spinal nerves along with their associated nuclei and ganglia.

Unit III

Motor and sensory pathways, different ascending and ascending tracts of brain and spinal cord and autonomic nervous system.

VI. Practical

Gross dissection and microscopic examination of the brain and spinal cord; demonstration of the nerves, nerve plexuses, ganglia of cranial importance, study of the serial sections of the brain and spinal cord in domestic animals.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	The gross and microscopic study of anatomy of brain, limbic system, reticular formation, lemniscal system, pyramidal system, extrapyramidal system	5
2.	Study of cranial nerves along with their associated nuclei and ganglia	5
3.	The gross and microscopic study of spinal cord including tracts and pathways	4
4.	Study of spinal nerves along with their associated nuclei and ganglia	4
5.	Hypothalamo-hypophysial system	4
6.	Brachial plexus	3
7.	Lumbo-sacral plexus	3
8.	Study of autonomic nervous system	5
	Total	33
Practical		
1.	The gross and microscopic study of anatomy of brain, limbic system, reticular formation, lemniscal system, pyramidal system, extrapyramidal system	2
2.	Study of cranial nerves along with their associated nuclei and ganglia	2
3.	The gross and microscopic study of Spinal cord including tracts and pathways	2
4.	Study of spinal nerves along with their associated nuclei and ganglia	2
5.	Hypothalamo-hypophysial system	2
6.	Brachial plexus	2
7.	Lumbo-sacral plexus	2
8.	Nerve blocks	2
9.	Study of autonomic nervous system	2
	Total	18

I. Course Title : Comparative Endocrine Anatomy

II. Course Code : ANA 705

III. Credit Hours : 1+1

IV. Aim of the course

To project the importance and details of endocrine glands.

V. Theory

Unit I

Advanced gross and microscopic anatomy of the pituitary gland.

Unit II

Advanced gross and microscopic anatomy of the thyroid, parathyroid and thymus.

Unit III

Advanced gross and microscopic anatomy of the adrenal gland, islets of Langerhans, corpus luteum, Leydig cells, pineal body and other tissues associated with endocrine secretions

VI. Practical

Demonstration of the topographic anatomy in the embalmed specimens and microscopic examination of the endocrine glands of ruminants.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction and general characteristics of endocrine gland	2
2.	Gross, microscopic and ultra structural study of Pituitary gland	1
3.	Gross, microscopic and ultra structural study of thyroid gland	1
4.	Gross, microscopic and ultra structural study of parathyroid gland	2
5.	Gross, microscopic and ultra structural study of thymus	2
6.	Gross, microscopic and ultra structural study of adrenal gland	1
7.	Gross, microscopic and ultra structural study of hypothalamus and Pineal	1
8.	Microscopic and ultra structural study of islets of Langerhans	2
9.	Gross, microscopic and ultra structural study of endocrine glands of male reproductive system	1
10.	Gross, microscopic and ultra structural study of endocrine glands of female reproductive system including corpus luteum	2
11.	Study of paraganglia, diffused endocrine system cells, endocrine cells of heart and kidney	2
12.	Advances in gross and microscopic anatomy of endocrine glands of gastro-intestinal tract	1
	Total	18
Practical		
1.	Introduction and general characteristics of endocrine gland	1
2.	Gross, microscopic and ultra structural study of Pituitary gland	2
3.	Gross, microscopic and ultra structural study of thyroid gland	1
4.	Gross, microscopic and ultra structural study of parathyroid gland	1
5.	Gross, microscopic and ultra structural study of thymus	1
6.	Gross, microscopic and ultra structural study of adrenal gland	1
7.	Gross, microscopic and ultra structural study of hypothalamus and Pineal	2
8.	Microscopic and ultra structural study of islets of Langerhans	1
9.	Gross, microscopic and ultra structural study of endocrine glands of male reproductive system	2
10.	Gross, microscopic and ultra structural study of endocrine glands of female reproductive system including corpus luteum	2
11.	Study of paraganglia, diffused endocrine system cells, endocrine cells of heart and kidney	2
12.	Advances in gross and microscopic anatomy of endocrine glands of gastro-intestinal tract	2
	Total	18

I. Course Title : Theory and Applications of Electron Microscope

II. Course Code : ANA 706

III. Credit Hours : 1+1

IV. Aim of the course

To give an overview of the electron microscope.

V. Theory

Unit I

Introduction and principles of electron microscopy.

Unit II

Methods for transmission electron microscopy.

Unit III

Methods for scanning electron microscopy.

VI. Practical

Preparation of blocks and demonstration of various techniques used for carrying out TEM and SEM.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction of the electron microscope	1
2.	Principles of transmission electron microscopy	1
4.	Collection and fixation of samples for electron microscopy, various fixatives used in electron microscopy	2
5.	Principles of scanning electron microscopy and processing of samples for transmission electron microscopy	1
6.	Processing of samples for scanning electron microscopy	1
9.	Ultramicrotomy (semithin and ultra thin sections)	1
10.	Coating of grids with supportive films	1
11.	Staining of semi thin and ultra thin sections	1
12.	Negative staining	1
13.	Applications of scanning and transmission electron microscopy	1
14.	Cryo-electron microscopy	1
15.	Immuno electron microscopy	1
16.	Strategies in immunolabelling	1
17.	Applications in nano science	1
	Total	19
Practical		
1.	Collection of tissue samples for em	1
2.	Fixation of samples for electron microscopy	1
3.	Processing of samples for scanning electron microscopy	2
4.	Processing of samples for transmission electron microscopy	2
5.	Ultramicrotomy (semithin and ultra thin sections)	2
6.	Coating of grids with supportive films	2
7.	Staining of semi thin and ultra thin sections	1
8.	Negative staining	1
9.	Cryo-electron microscopy	2
10.	Immunolabelling	2
11.	Atomic force microscope	1
	Total	**17**

I. Course Title : Histoenzymology and Immunocytochemistry

II. Course Code : ANA 707

III. Credit Hours : 2+1

IV. Aim of the course

To give a student hands-on practice for various advanced histoenzymic and histochemical techniques.

V. Theory

Unit I

Classification of enzymes – Principles of enzymes histochemistry methods.

Unit II

Substrates –combination–coupling azo-dye methods –capture reagents.

Unit III

Localization of enzymes and controls in enzyme histochemistry.

Unit IV

Fluorescence microscopy in enzyme histochemistry. Principles and techniques of immunohistochemistry.

VI. Practical

Preparation of fixatives and buffers used in histochemistry. Methods of preparations and microscopical examination of routine and special preparations showing different cell organelles and inclusions. Methods for tryptophan-SS, SH groups; Glycogen-glycoproteins; Mucopolysaccharides and lipids. Methods and identification of alkaline and acid phosphatases-succinic dehydrogenase, cytochrome-oxidase, choline-esterase, catecholamines by fluorescence microscopy. Immunohistochemistry-principles and techniques.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Classification of enzymes	3
2.	Principles of enzyme histochemistry methods	3
3.	Substrate and coenzymes	2
4.	Different methods of enzyme study	3
5.	Hydrolytic enzyme histochemistry	2
6.	Alkaline and acid phosphatase	2
7.	Oxidases and peroxidases	2
8.	Diaphorases and dehydrogenases	2
9.	Peptidases	2
10.	Fluorescence microscopy	2
11.	Principles of immunohistochemistry	3
12.	Techniques in immunohistochemistry	3
13.	Study of part different parts of cryotome and their functions	3
	Total	32
Practical		
1.	Preparation of fixatives and buffers	3
2.	Demonstration of alkaline and acid phosphatase	2
3.	Demonstration of succinic dehydrogenase	2
4.	Demonstration of cytochrome oxidase	2
5.	Localization of diaphorases and choline esterase	2
6.	Fluorescence microscopy	2
7.	Principles and techniques in immunohistochemistry	3
	Total	**16**

I. Course Title : Applied Embryology and Teratology

II. Course Code : ANA 708

III. Credit Hours : 1+1

IV. Aim of the course

To apprise the students about the current trends in developmental processes.

V. Theory

Unit I

Principles of experimental embryology and teratology.

Unit II

Factors affecting the developmental mechanisms of embryo.

Unit III

Use of organizers implants, chemical and hormonal preparations in the developmental models and available literature on teratogenic experimentation.

VI. Practical

Collection and study of various teratological specimens from domestic animals. Class discussions on experimental models and available literature on teratogenic experimentation. To apprise the students about the current trends in developmental processes.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to embryology and teratology.	1
2.	Principles of experimental embryology and teratology.	2
3.	Factors affecting the developmental mechanisms of embryo.	2
4.	Developmental anomalies of cardiovascular system	2
5.	Immunodeficiency and inherited defects in natural immunity	1
6.	Developmental anomalies of brain and spinal cord	2
7.	Developmental anomalies of skeletal system	1
8.	Developmental anomalies of digestive system	2
9.	Developmental anomalies of urinary system	1
10.	Developmental anomalies of male and female reproductive system	1
11.	Congenital malformations of face and oral cavity	1
12.	Congenital and inherited defects of skin	1
13.	Genetic, chromosomal and environmental factors adversely affecting prenatal development	1
	Total	18
Practical		
1.	Discussion on principles and factors affecting developmental embryology and teratology in the available literature.	2
2.	Study on different teratological models/ specimens of cardiovascular system	2
3.	Immunodeficiency and inherited defects in natural immunity	1
4.	Study on different teratological models/ specimens of brain and spinal cord	2
5.	Study on different teratological models/ specimens of skeletal system	1
6.	Study on different teratological models/ specimens of digestive system	2
7.	Study on different teratological models/ specimens of urinary system	1
8.	Study on different teratological models/ specimens of male and female reproductive system	2
9.	Congenital malformations of face and oral cavity	1
10.	Congenital and inherited defects of skin	1
11.	Study on mutations and chromosomal abnormalities	1
12.	Study of teratogenic agents	1
13.	Assessing the aetiology of different congenital diseases	1
	Total	18

I. Course Title : Functional Veterinary Anatomy

II. Course Code : ANA 709

III. Credit Hours : 1+0

IV. Aim of the course

To make the student understand the functional anatomy of various organs/ systems in relation to structure.

V. Theory

Unit I

The relationship of structure to form and function.

Unit II

The relationship of structure for adaptation and behaviour.

Unit III

Relationship of structure in relation to clinical conditions/ applications.

S. No.	Topic	No. of Lectures
Theory		
1.	Introduction to functional anatomy	1
2.	Tissue organization and function	1
3.	Functional anatomy of digestive system: mouth cavity, tongue, salivary gland, esophagus and stomach including mastication, regurgitation	2
4.	Functional anatomy of digestive system: small intestine, large intestine, liver, gall bladder and pancreas	2
5.	Study of functional anatomy of respiratory system	1
6.	Functional anatomy of urinary system	1
7.	Functional anatomy of reproductive system	1
8.	Functional anatomy of mammary gland	1
9.	Functional anatomy of cardiovascular system	1
10.	Functional anatomy of central nervous system	1
11.	Functional anatomy of peripheral and autonomic nervous system	1
12.	Functional anatomy of special senses (vision, hearing)	1
13.	Functional anatomy of skeleton system including synovial fluid	1
14.	Functional anatomy of muscular system	1
15.	Functional anatomy of endocrine system	1
16.	Functional anatomy of integumentary system	1
	Total	18

I. Course Title : Gross Anatomy of Laboratory Animals

II. Course Code : ANA 710

III. Credit Hours : 1+1

IV. Aim of the course

To give an overview of different body systems of laboratory animals.

V. Theory

Unit I

Study of different organs of digestive system of different laboratory animals.

Unit II

Detailed study of urinary, male and female reproductive systems of different laboratory animals.

Unit III

Complete study of respiratory system of different laboratory animals.

Unit IV

Study of organs of circulation and nervous system of different laboratory animals.

Unit V

Descriptive anatomy of endocrine glands of different laboratory animals.

VI. Practical

Demonstration of placement and relations of different organs in the body cavities of different laboratory animals.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	An overview of skeleton of rabbit, guinea pig, mice and rat	1
2.	Digestive system of rabbit and guinea pig	1
3.	Digestive system of mice and rat	1
4.	Respiratory system of rabbit and guinea pig	1
5.	Respiratory system of mice and rat	1
6.	Urinary system of rabbit and guinea pig	1
7.	Urinary system of mice and rat	1
8.	Male reproductive system of rabbit and guinea pig	1
9.	Male reproductive system of mice and rat	1
10.	Female reproductive system of rabbit and guinea pig	1
11.	Female reproductive system of mice and rat	1
12.	Endocrine glands of rabbit and guinea pig	1
13.	Endocrine glands of mice and rat	1
14.	Circulatory system of rabbit and guinea pig	1
15.	Circulatory system of mice and rat	1
16.	Nervous system of rabbit and guinea pig	1
17.	Nervous system of rat and mice	1
18.	Lymphoid organs of laboratory animals	1
	Total	18
Practical		
1.	Study of skeleton of rabbit, guinea pig, mice and rat	1
2.	Study of digestive system of rabbit and guinea pig	1
3.	Study of digestive system of mice and rat	1
4.	Study of respiratory system of rabbit and guinea pig	1
5.	Study of respiratory system of mice and rat	1
6.	Study of urinary system of rabbit and guinea pig	1
7.	Study of urinary system of mice and rat	1
8.	Study of male reproductive system of rabbit and guinea pig	1
9.	Study of male reproductive system of mice and rat	1
10.	Female reproductive system of rabbit and guinea pig	1
11.	Study of female reproductive system of mice and rat	1
12.	Study of endocrine glands of rabbit and guinea pig	1
13.	Study of endocrine glands of mice and rat	1

S. No.	Topic	No. of Lectures/ Practicals
14.	Study of circulatory system of rabbit, guinea pig, rat and mice	1
15.	Study of circulatory system of mice and rat	1
16.	Study of nervous system of rabbit and guinea pig	1
17.	Study of nervous system of rat and mice	1
18.	Lymphoid organs of laboratory animals	1
	Total	18

I. Course Title : Cross Sectional Anatomy of Ox

II. Course Code : ANA 711

III. Credit Hours : 0+1

IV. Aim of the course

To study Gross cross sectional profiles of various parts in ox

V. Practical

Demonstration and topographic anatomy of various structures and organs at different levels of cross sections of the body. Correlation of different structures in different cross sections.

S. No.	Topic	No. of Practicals
Practical		
1.	Cross sectional profile of head at the level of 4th incisor and first cheek tooth	1
2.	Cross sectional profile of head at the level of third cheek tooth and 6th cheek tooth	1
3.	Cross sectional profile of head at the level of orbit and external acoustic meatus	1
4.	Cross sectional profile of the neck at the level of upper third and middle third.	1
5.	Cross sectional profile of the neck at the level of lower third	1
6.	Cross sectional profile of the thoracic inlet.	1
7.	Cross sectional profile of the thorax at the level of 3rd rib	1
8.	Cross sectional profile of the thorax at the level of 6th rib and 12th rib	1
9.	Cross sectional profile of the abdomen at the level of 2nd lumbar and 5th lumbar	1
10.	Cross sectional profile of the mid pelvis and tail.	1
11.	Cross sectional profile at the middle and lower level of the shoulder and middle level of the arm.	1
12.	Cross sectional profile at the proximal level of forearm, lower level of the forearm and mid level of metacarpus.	1
13.	Cross sectional profile at the mid level of the first phalanges and mid level of second phalanges	1
14.	Cross sectional profile at the upper and middle and lower levels of the thigh	1
15.	Cross sectional profile at the lower levels of the thigh	1
16.	Cross sectional profile at the upper and middle levels of the leg.	1
17.	Cross sectional profile at the lower level of the leg and mid level of metatarsus	1
	Total	17

I. Course Title : Animal Alternatives in Veterinary Anatomy

II. Course Code : ANA 712

III. Credit Hours : 1+1

IV. Aim of the course

Alternatives of animals in veterinary anatomy teaching to avoid usage of Animals.

V. Theory

Unit I

Introduction and ethical issues, scope, advantages and disadvantages of alternatives.

Unit II

Plastination, 2D and 3D Models.

Unit III

Taxidermy, computer simulations.

Unit IV

Maannequins, interactive mutimedia.

Unit V

Museum specimen preparation.

VI. Practical

Techniques of Plastination, 2D and 3D Models, Taxidermy, computer simulations Maannequins, interactive mutimedia.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to animal alternatives	1
2.	Ethical issues on alternatives used	1
3.	Necessity of animal alternatives- advantages and disadvantages of alternatives	1
4.	Scope for animal alternatives	1
5.	Plastination, basic principles	1
6.	Methodology involved in plastination	1
7.	Types of plastination- advantages, disadvantages of plastination	1
8.	Three-D, Two-D models as alternatives in veterinary anatomy: advantages/ disadvantages of models used	1
9.	Drawings, Charts, Power points as self explanatory alternatives in Veterinary anatomy-An overview	1
10.	Taxidermy in veterinary anatomy-methodology involved-limitations	1
11.	Computer simulation-screen based simulations	1
12.	Virtual lab.-E-learning as alternatives	1
13.	Interactive digital tool-multimedia and Videos as effective audio visual tools- benefits and weakness of digital alternatives	1
14.	Mannequins as alternatives in veterinary anatomy, advantages and disadvantages -scope for mannequins in veterinary anatomy	1
15.	Museum specimen preparation	1
16.	Procedures involved in museum preservation- advantages and disadvantages involved in museum specimens	1
	Total	16

S. No.	Topic	No. of Lectures/ Practicals
Practical		
1	Methodology involved in plastination and preparation of plastinated specimens	3
2	Three-D, Two-D Models as alternatives in veterinary anatomy	2
3	Methodology involved taxidermy -preparation of specimens	2
4	Computer Simulation-screen based simulations	2
5	Virtual lab -E-learning as alternatives	2
6	Interactive digital tool-multimedia and Videos	1
7	Mannequins as alternatives in veterinary anatomy	2
8	Museum specimen preparation	2
	Total	16

I. Course Title : Special Problem

II. Course Code : ANA 713

III. Credit Hours : 0+2

IV. Aim of the course

To provide expertise in handling practical research problem(s).

V. Practical

S. No.	Topic	No. of Practicals
1.	Short research problem(s) involving contemporary issues and research techniques.	32

VI. Recommended list of Books

Gross Anatomy

- Dyce KM, Sack WO and Wensing CJG. 1996. *Text Book of Veterinary Anatomy*. W.B. Saunders Co.
- Konig HE and Liebich HG. 2004. *Veterinary Anatomy of Domestic Animals: Textbook and Colour Atlas.* 1stedn., Stuttgart, Schattauer Co., Germany.
- Nickel R, Schumer A, Seiferle E, Freewin J and Wills KH. 1986. *The Locomotor System of Domestic Mammals*. Verlag Paul Parey.
- Schummer A, Nickel R and Sack WO. 1979. *The Viscera of the Domestic Mammals*. Verlag Paul Parey.
- Seiferle E. 1975. *Nervous System, Sensory Organs, Endocrine Glands of DomesticMammals*. Verlag Paul Parey.
- Sisson S and Grossman JD. 1975. *The Anatomy of the Domestic Animals*. Vols. I, II. W.B. Saunders Co.

Histology

- Banks WJ. 1993. *Applied Veterinary Histology*. Mosby Year Book, USA.
- Dellmann HD. 1993. *Textbook of Histology*. Lea and Febiger, USA.
- DiFiore MS, Mancini R and Derbertis EDP. 2006. *New Atlas of Histology*. Williams and Wilkins, Lippincott, USA.
- Eurell JA and Frappier BL. 2006. *Dellmann's Textbook of Veterinary Histology*. 6thedn., Blackwell Publishing, Ames, Iowa, USA.
- Greep RO. 1977. *Histology*. McGraw-Hill Book Co., New York, USA.

- Ham AW and Cormack DH. 1979. *Histology*. J.B. Lippincott, Philadelphia, USA.
- Stinson AW and Calhoun ML. 1993. *Text book of Veterinary Histology*. 4th edn., Lea and Febiger, Philadelphia, USA.

Embryology

- Arey LB 1965. *Developmental Anatomy*. W.B. Saunders.
- Freeman WH and Brace Girdle B. 1967. *Atlas of Embryology*. Heilemann Edu. Books Ltd.
- Langman J. 1976. *Medical Embryology*. William and Wilkin, Lippincott, USA.
- Latshaw WK. 1984. *Veterinary Developmental Anatomy; A Clinically Oriented Approach*. B.C. Decker Inc., Philadelphia, USA.
- Patten BM. 1985. *Foundation of Embryology*. Tata McGraw-Hill Book Co., USA.
- Patten BM. 2014. *Foundation of Embryology*. 6th edn., Tata McGraw-Hill Education, India.
- Tuchmann-Duplessis, MH David G, and Haegel P. 1972. *Illustrated Human Embryology*. Vol. I, II. Embryogenesis. Springer Verlag, USA.

Anatomical Techniques

- Durry RAB and Wallington EA. 1967. *Carleton's Histological Techniques*. Oxford University Press, London.
- Luna LG 1968. *Manual of Histologic Staining Methods of the Armed Forces Institute of Pathology*. McGraw-Hill Book Co., USA.
- Pearse AGE. 1968. *Histochemistry-Theoretical and Applied*. 3rd edn., Vol. I, Churchill Livingstone, London.
- Tompsett DH and Wakeley SC. 1956. *Anatomical Techniques*. E. and W. Living Stone, London.
- Bancroft JD and Stevens A. 1977. *Theory and Practice of Histological Techniques*. Churchill Livingstone.
- Thomson SW and Hunt RD. 1968. *Selected Histochemical and Histopathological Methods*. Charles C. Thomas Publication, Springfield, Illinois, USA.

List of Journals

- *Acta Anatomica*
- *American Journal of Anatomy*
- *Anatomia Histologia and Embryologia*
- *Anatomical Record*
- *Anatomy and Embryology*
- *Indian Journal of Veterinary Anatomy*
- *Journal of Anatomy*

e-Resources

- http://www.interscience.wiley.com/journal/117927935/grouphome/home. (American Journalof Anatomy)
- http://www.ovid.com/site/catalog/Journal/1057.jsp (Journal of Anatomy)
- http:http:www.interscience.wilety.com/jpages/0003-276X/(Anatomical Record)
- http://www.blackwellpublishing.com/submit.asp (Anatomia Histologia and Embryologia)

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Basic Veterinary Sciences
– Veterinary Biochemistry

Preamble
(Veterinary Biochemistry)

At Masters level in Veterinary Biochemistry new courses, Biophysical Chemistry, Analytical Techniques and Instrumentation in Biochemistry, Intermediary Metabolism and Regulation, Molecular Biochemistry, Biochemistry of Ruminants and Wild Animals and Introduction to Bioinformatics and Computational Biology are introduced. Similarly at Doctorate level new courses, Applied Molecular Biochemistry and Systems Biology, Diagnostic Techniques in Clinical Biochemistry, Bioinformatic Tools in Biochemistry, Environmental and Toxicological Biochemistry, Biochemistry of Diseases and Disorders and Immuno-Biochemistry are introduced keeping latest trends and requirements in mind.

Course Title with Credit Load
M.V.Sc. in Veterinary Biochemistry

Course Code	Course Title	Credit Hours
BCT 601	Biophysical Chemistry	2 + 0
BCT 602	Biochemistry of Biomolecules	2 + 0
BCT 603	Enzymology	2 + 1
BCT 604	Analytical Techniques and Instrumentation in Biochemistry	1 + 1
BCT 605	Clinical Biochemistry of Animals	2 + 1
BCT 606	Intermediary Metabolism and Regulation	3 + 0
BCT 607	Molecular Biochemistry	2 + 1
BCT 608	Nutritional and Industrial Biochemistry	2 + 0
BCT 609	Endocrinology and Reproductive Biochemistry	2 + 0
BCT 610	Biochemistry of Ruminants and Wild Animals	1 + 1
BCT 611	Introduction to Bioinformatics and Computational Biology	1 + 1
BCT 612	Master’s Seminar	1 + 0
BCT 613	Master’s Research	0 + 30

Suggested list of specified Minor subjects (Departments)

Major Subject	Minor subjects (Departments)*
Veterinary Biochemistry	Physiology, Medicine, Animal Nutrition, Animal Genetics and Breeding, Biotechnology, Livestock Production Management, Pharmacology and Toxicology, Microbiology, Parasitology, Pathology, Gynaecology.

*The Minor courses may be taken from any number of disciplines/ departments listed against major discipline limiting to credits prescribed as decided by the Chairman of Advisory Committee of the student. Minor courses may also be taken from the disciplines/ departments other than those listed above on the recommendations of advisory committee, if essentially required as per the research problem with the concurrence of Head of the Department and Concerned Authorities.

Course Contents
M.V.Sc. in Veterinary Biochemistry

I. Course Title : Biophysical Chemistry

II. Course Code : BCT 601

III. Credit Hours : 2 + 0

IV. Aim of the course

Teaching of principles of physical chemistry as applicable to veterinary sciences.

V. Theory

Unit I

Physical properties of water-the medium of life, Acids and bases, ionic strength and activity, Henderson-Hasselbach equation, pH, indicators and buffers, Colloids and their properties, Mechanism of osmosis, osmotic pressure, Donnan membrane equilibrium, Viscosity, surface tension, surface forces, Adsorption and light scattering, Membrane filtration, dialysis, diffusion coefficient and partial specific volume.

Unit II

Laws of thermodynamics, Concepts of enthalpy, free energy and entropy in biochemical reactions. High energy compounds, Redox potential and free energy changes, Bioenergetics and biological oxidation, Components of mitochondrial electron transport chain. Formation of ATP and ATP cycle. Energy transformation in living cells.

Unit III

Basic Methods in Biophysical Chemistry: Basic Optical Principles, Optical Properties of Biomolecules, Optical spectroscopy, Basic Fluorescence Techniques, Chiroptical and Scattering Methods; Conventional and Confocal Fluorescence Microscopy, Basics of Super-Resolution Fluorescence Microscopy, Fluorescence spectroscopy, Patch Clamping.

VI. Suggested Reading

- David L Nelson and Cox Michael M. 2008. *Lehninger's Principles of Biochemistry*. 5th Ed. Freeman.
- James P Allen. 2008. *Biophysical Chemistry*. 1st Ed. Wiley-Blackwell Publication.
- Peter Jomo Walla. 2014. *Modern Biophysical Chemistry: Detection and Analysis of Biomolecules*. 2nd Ed. Wiley-VCH Publication.

Course Outline

S. No.	Topic	No. of Lectures
Theory		
1.	Physical properties of water-the medium of life, Acids and bases, ionic strength and activity	2
2.	Henderson-Hasselbach equation, pH, indicators and buffers	2

S. No.	Topic	No. of Lectures
3.	Colloids and their properties, Mechanism of osmosis, osmotic pressure, Donnan membrane equilibrium, Viscosity, surface tension, surface forces, Adsorption and light scattering	3
4.	Membrane filtration, dialysis, diffusion coefficient and partial specific volume.	2
5.	Laws of thermodynamics, Concepts of enthalpy, free energy and entropy in biochemical reactions, High energy compounds, Redox potential and free energy changes	3
6.	Bioenergetics and biological oxidation, Components of mitochondrial electron transport chain. Formation of ATP and ATP cycle. Energy transformation in living cells	4
7.	Basic Methods in Biophysical Chemistry: Basic Optical Principles, Optical Properties of Biomolecules, Optical spectroscopy	4
8.	Basic Fluorescence Techniques	2
9.	Chiroptical and Scattering Methods	2
10.	Conventional and Confocal Fluorescence Microscopy	3
11.	Basics of Super-Resolution Fluorescence Microscopy	2
12.	Fluorescence spectroscopy.	2
13.	Patch Clamping	1
	Total	**32**

I. Course Title : Biochemistry of Biomolecules

II. Course Code : BCT 602

III. Credit Hours : 2 + 0

IV. Aim of the course

Teaching molecular basis of structure and functional aspects of carbohydrates, lipids, amino acids and nucleic acids.

V. Theory

Unit I

Carbohydrates: Structure and biological significance of important monosaccharides:Ribose, Glucose, Fructose, Galactose, Mannose and Amino Sugars; Chemical reactions of monosaccharides; Isomerism of carbohydrates; Structure and biological significance of Disaccharides (Maltose, Isomaltose, Lactose, Sucrose and Cellobiose); Structure and biological significance of polysaccharides (Starch, Dextrins, Dextrans, Glycogen, Cellulose, Inulin, Chitin), and Mucopolysaccharides including Blood group substances and Bacterial cell wall polysaccharides. Glycoconjugates in cell surface, extra cellular matrix, sugar code functions, peptidoglycan-specific antibiotics; Basic principles of separation, purification and characterization of carbohydrates; Methods of structural analysis of carbohydrates.

Unit II

Lipids: Definition, Classification, Properties and Biological significance of simple, compound and derived lipids; Fat indices; Structure and functions of prostaglandins, steroids, steroid hormones and fat soluble vitamins. Basic principles of extraction and analysis of lipids; Lipid bilayers, lipid motility, integral membrane proteins, lipid linked proteins, peripheral membrane proteins, fluid mosaic model, membrane skeleton, lipid asymmetry, cardiac glycosides, abnormalities in cell membrane fluidity, signaling biomolecules.

Unit III

Proteins: Amino acids - Structure and classification. Physical and chemical properties of amino acids - amphoteric nature, acid-base property, optical activity and peptide bond formation; Structure and geometry of peptide bond. Chemical synthesis of polypeptide and Oligopeptides of biological significance; Classification of proteins; Structure – primary, secondary, tertiary and quaternary; Physico-chemical, acid-base and colloidal properties of proteins; Biological significance of proteins; Denaturation, extraction and purification criteria for proteins.

Unit IV

Nucleic acids: Chemistry of purines, pyrimidines, nucleosides and nucleotides. Biological significance of nucleosides and nucleotides. Structures and functions of Watson-crick model of deoxyribonucleic acid (DNA) and a typical ribonucleic acid (RNA). Different types of DNA, acid-base properties, sedimentation behaviour, hyperchromic effect, melting of DNA, Chemical and enzymatic hydrolysis of nucleic acids. Base sequence analysis of DNA, Nucleic acid- protein interaction - histone and non-histone proteins.

VI. Suggested reading

- David L Nelson and Cox Michael M. 2017. *Lehninger's Principles of Biochemistry*. 7th Ed. Freeman.
- Voet D, Voet JG and Pratt CW. 2016. *Fundamentals of Biochemistry of Life at the Molecular Level*. 5th Ed. John Wiley and Sons.
- Berg JM, Tymoczko JL, Stryer L and Clarke ND 2015. *Biochemistry*. 8th Ed. WH Freeman and Co.
- Zubay GL. 1998. *Biochemistry*. 4th Ed. WCB London.

Course Outline

S. No.	Topic	No. of Lectures
Theory		
1	Carbohydrates: Structure and Biological Significance of Important Monosaccharides: Ribose, Glucose, Fructose, Galactose, Mannose and Amino Sugars;	1
2	Chemical reactions of monosaccharides; Isomerism of carbohydrates; Structure and Biological Significance of Disaccharides (Maltose, Isomaltose, Lactose, Sucrose and Cellobiose);	1
3	Structure and Biological Significance of Polysaccharides (Starch, Dextrins, Dextrans, Glycogen, Cellulose, Inulin, Chitin), and Mucopolysaccharides including Blood group substances and Bacterial Cell Wall polysaccharides;	1
4	Glycoconjugates in cell surface, extra cellular matrix, sugar code functions, peptidoglycan-specific antibiotics;	2
5	Basic principles of separation, purification and characterization of carbohydrates;	1
6	Methods of Structural analysis of carbohydrates.	1
7	Definition, Classification, Properties and Biological Significance of simple, compound and derived lipids;	1
8	Fat indices; Structure and functions of prostaglandins, steroids, steroid hormones and fat soluble vitamins;	2

S. No.	Topic	No. of Lectures
9	Basic principles of extraction and analysis of lipids;	1
10	Lipid bilayers, lipid motility, integral membrane proteins, lipid linked proteins, peripheral membrane proteins;	2
11	Fluid mosaic model, membrane skeleton, lipid asymmetry, cardiac glycosides, abnormalities in cell membrane fluidity, signaling biomolecules.	3
12	Amino acids – Structure and classification.	1
13	Physical and chemical properties of amino acids – amphoteric nature, acid-base property, optical activity and peptide bond formation.	1
14	Structure and geometry of peptide bond; Chemical synthesis of polypeptide; Oligopeptides of biological significance;	2
15	Classification of proteins; Structure – primary, secondary, tertiary and quaternary; Physico-chemical, acid-base and colloidal properties of proteins;	2
16	Biological significance of proteins; Denaturation, extraction and purification criteria for proteins.	1
17	Chemistry of purines, pyrimidines, nucleosides and nucleotides;	1
18	Biological significance of nucleosides and nucleotides;	1
19	Structures and functions of Watson-crick model of deoxyribonucleic acid (DNA) and a typical ribonucleic acid (RNA).	1
20	Different types of DNA, acid-base properties, sedimentation behaviour;	2
21	Hyperchromic effect, melting of DNA; Chemical and enzymatic hydrolysis of nucleic acids;	2
22	Base sequence analysis of DNA, Nucleic acid- protein interaction – histone and non-histone proteins.	2
	Total	**32**

I. Course Title : Enzymology

II. Course Code : BCT 603

III. Credit Hours : 2 + 1

IV. Aim of the course

To give thorough knowledge of molecular basis of enzyme action in relation to diagnostic importance.

V. Theory

Unit I

Introduction and historical perspective, Enzyme nomenclature and classification, enzyme compartmentalization in cell organelles, measurement of enzyme activity. ribozymes, isozymes, abzymes, restriction endonucleases.

Unit II

Enzyme structure, enzyme specificity, active site, active site mapping, mechanism of enzyme catalysis. cofactors, coenzymes- their structure and role.

Unit III

Enzyme kinetics, enzyme inhibition and activation, multienzyme complexes, allosteric enzymes and their kinetics, regulation of enzyme activity. qualitative description of “concerted” and “sequential” models for allosteric enzymes. Half site reactivity, Flip-flop mechanism, positive and negative co-operativity. Monod Koshland Model.

Concept of ES complex, active site, specificity derivation of Michaelis-Menten equation for uni- substrate reactions. Different plots for the determination of Km and Vmax and their physiological significances. Importance of Kcat/ Km. Kinetics of zero and first order reactions. Significance and evaluation of energy of activation.

Unit IV

Isolation, purification and characterization of enzymes, Applications of enzymes in chemical and feed industry, enzyme immobilization, biosensors, clinical and diagnostic applications of enzymes.

VI. Practical

- Enzyme assay by taking any model enzyme like alpha-amylase or alkaline phosphatase.
- Isolation, purification and characterization of any model enzyme like B-galoctosidase or acid phosphatase.
- Study of the effect of enzyme and substrate concentrations and determination of Km and Vmax.
- Determination of pH and temperature optima of alkaline phospatase.
- To study the effect of various inhibitors of enzymatic activity.
- Determination of the pH and temperature stability of alkaline phosphatase.
- Assay of Diagnostic enzymes from Clinical samples.
- Application of enzymes in ELISA and Western Blotting

VII. Suggested Reading

- Bergmeyer HU. 1983. *Methods of Enzymatic Analysis*. Vol. II. Verlag Chemie, Academic Press.
- Dixon M, Webb EC, Thorne CJR and Tipton KF. 1979. *Enzymes*. 3rd Ed. Longman.
- Maragoni AG. 2003. *Enzyme Kinetics - A Modern Approach*. John Wiley.
- Palmer T. 2001. *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry*. 5th Ed. Horwood Publ.
- Price NC and Stevens L. 2003. *Fundamentals of Enzymology*. Oxford Univ. Press.
- Wilson K and Walker J. (Eds.). 2000. *Principles and Techniques of Practical Biochemistry*. 5th Ed. Cambridge Univ. Press.
- David L Nelson and Cox Michael M. 2008. *Lehninger's Principles of Biochemistry*. 5th Ed. Freeman.
- Kaneko JJ, Harvey JH and Bruss ML. 2008. *Clinical Biochemistry of Domestic Animals*. 6th Ed. Academic Press.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Introduction and historical perspective, Enzyme nomenclature and classification	2
2	Enzyme compartmentalization in cell organelles	1
3	Ribozymes, isozymes, abzymes, restriction endonucleases.	2
4	Enzyme structure	1
5	Enzyme specificity, active site, active site mapping,	2
6	Mechanism of enzyme catalysis.	2

S. No.	Topic	No. of Lectures/ Practicals
7	Cofactors, coenzymes- their structure and role.	2
8	Enzyme kinetics	1
9	Enzyme inhibition and activation	2
10	Multienzyme complexes, allosteric enzymes and their kinetics, regulation of enzyme activity.	2
11	Qualitative description of “concerted” and “sequential” models for allosteric enzymes. Half site reactivity, Flip-flop mechanism, positive and negative co-operativity. Monod Koshland Model.	3
12	Concept of ES complex, active site, specificity derivation of Michaelis-Menten equation for uni- substrate reactions.	2
13	Different plots for the determination of Km and Vmax and their physiological significances. Importance of Kcat/ Km.	2
14	Kinetics of zero and first order reactions. Significance and evaluation of energy of activation.	2
15	Isolation, purification and characterization of enzymes	2
16	Applications of enzymes in chemical and feed industry	2
17	Enzyme immobilization, biosensors, clinical and diagnostic applications of enzymes.	2
	Total	32
Practical		
1	Enzyme assay by taking any model enzyme like alpha-amylase or alkaline phosphatase.	1
2	Isolation, purification and characterization of any model enzyme like β-galoctosidase or acid phosphatase.	3
3	Study of the effect of enzyme and substrate concentrations and determination of Km and Vmax.	2
4	Determination of pH and temperature optima of alkaline phosphatase.	2
5	To study the effect of various inhibitors of enzymatic activity.	2
6	Determination of the pH and temperature stability of alkaline phosphatase.	2
7	Assay of Diagnostic enzymes from Clinical samples.	1
8	Application of enzymes in ELISA and Western Blotting.	3
	Total	**16**

I. Course Title : Analytical Techniques and Instrumentation in Biochemistry

II. Course Code : BCT 604

III. Credit Hours : 1 + 1

IV. Aim of the course

To make students well versed with certain basic methodologies used in biochemistry to carry out independent research.

V. Theory

Unit I

Solutions and Buffers: Units of expression of concentration of solutions - Preparation of solutions - Preparation of Buffers - Henderson-Hasselbalch equation in the preparation of buffers. Spectroscopy: Theory and applications of Colorimetry and Spectrophotometry; Major components of the following instruments and their functions: UV-Visible Spectrophotometer, Spectrofluorometer, Flame photometer, Atomic absorption spectrophotometer, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES).

Unit II

Chromatographic Techniques: Basic principle and applications of Paper, Column and Thin layer chromatography including HPTLC; Factors affecting chromatographic resolution; Methods of preparation of biological samples for chromatographic analysis and common methods for qualitative and quantitative chromatography of amino acids, lipids and sugars including elution and densitometry. Molecular Sieving and its application in Biochemistry – General properties of dextran, acrylamide, agar and other media used for gel filtration. Principles and applications of chromatographic techniques, viz., ion-exchange, gel-filtration, affinity, hydrophobic interaction chromatography, metal chelate chromatography, planar chromatography, lateral flow immunochromatographic assays, Introduction to GLC and HPLC (Normal and Reverse Phase).

Unit III

Theory and applications of Electrophoresis: Factors affecting migration of charged particles – Moving boundary, paper and gel electrophoresis - Electrophoresis of amino acids, proteins and nucleic acids – Use of SDS PAGE in molecular weight determination. Isoelectric focusing and Isotachophoresis - Densitometry procedures and quantitative assays. Introduction to 2-D gel electrophoresis; Immuno-electrophoresis and other techniques like ELISA, RIA and Immuno-blotting.

Unit IV

Theory and applications of Centrifugation: Basic principle of sedimentation – Types, care and safety aspects of Centrifuges – Preparative centrifugation and Analytical centrifugation - Introduction to Ultracentrifugation - Fractionation of sub-cellular components - Density Gradient centrifugation – Determination of relative molecular mass.

N.B.: GLC and HPLC at length are to be discussed under BCT 705 (Ph.D. course); here only introduction.

VI. Practical

- Preparation of solutions and buffers; Solving problems using Henderson–Hasselbalch equation, pH, pKa and buffer concentration, normality; Verification of Beer's – Lambert's law; Estimation of glucose and total cholesterol in serum; Determination of absorption maxima and molar extinction coefficient of p-Nitrophenol from its absorption spectrum; Estimation of proteins using biuret, foiln-ciocalteau methods and UV spectrophotometry; Estimation of enzyme activity by spectrophotometry (Kinetic mode).
- Separation of Lipids/ amino acids using paper chromatography and TLC; Fractionation of proteins by ammonium sulphate precipitation and desalting by dialysis; Separation of proteins using Ion-exchange chromatography, affinity chromatography and gel-filtration chromatography; Demonstration of separation of fatty acid methyl esters using GLC.

- Electrophoretic analysis of albumin using non-denaturing and denaturing conditions – Detection of molecular weight of protein by SDS-PAGE - Characterization of immunoglobulins by PAGE - Demonstration of sub-cellular fractionation by centrifugation.

VII. Suggested Reading

- David L Nelson and Cox Michael M. 2017. *Lehninger's Principles of Biochemistry*. 7th Ed. Freeman.
- Wilson K and Walker J. (Eds.). 2010. *Principles and Techniques of Biochemistry and Molecular Biology*. 7th Ed. Cambridge Univ. Press.
- Willard *et al*. 1988. *Instrumental Methods of Analysis*. 7th Ed. Wadsworth Pub Co.
- Garrity S. 1999. *Experimental Biochemistry*. 3rd Ed. Academic Press.
- Gowenlock AH. 2002. *Varley's Practical Clinical Biochemistry*. 6th Ed. CBS.
- Holme DJ and Hazel P. 1998. *Analytical Biochemistry*. 3rd Ed. Longman.
- George W. Latimer, Jr. 2016. *Official Methods of Analysis of AOAC International*, 20th Ed. AOAC International.
- Carl A. Burtis, Edward R. Ashwood and David E. Burns, 2014. *Tietz Textbook of clinical Biochemistry and Molecular Diagnostics*. 5th Edition. Elsevier

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Concentration of Solutions and units of expression, preparation of solutions and buffers, Henderson-Hasselbalch equation and its significance in preparation of buffers	1
2	Introduction to Spectroscopy and Principle of Colorimetry and Spectrophotometry, basic components, principle and applications of UV-Visible Spectrophotometer, Reflectance Spectrophotometer and Spectro-fluorometer	1
3	Basic components, principle and applications of Flame photometer and Atomic Absorption Spectrophotometer	1
4	Basic components, principle and applications of Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)	1
5	Introduction to Chromatography – Principle, types and applications; Theory, components and applications of Paper Chromatography, TLC and HPTLC	1
6	Theory, components and applications of Column Chromatography, factors affecting chromatographic resolution and methods of preparation of biological samples for chromatographic analysis	1
7	Methods for qualitative and quantitative chromatography of amino acids, lipids and sugars including elution and densitometry	1
8	Molecular sieving and its application in biochemistry, general properties of dextran, acrylamide, agar and other media used for gel filtration	1
9	Principles and applications of ion-exchange, gel-filtration, hydrophobic interaction, planar chromatography and lateral flow immuno-chromatographic assays	1
10	Introduction to GLC and HPLC (Normal and Reversed Phase)	1
11	Introduction to Electrophoresis - Principle, types and applications, factors affecting migration of charged particles	1
12	Principle and applications of Moving boundary, paper and gel electrophoresis, Common methods for electrophoresis of amino acids,	

S. No.	Topic	No. of Lectures/ Practicals
	proteins and nucleic acids with the components of electrophoretic apparatus	1
13	Use of SDS-PAGE in molecular weight determination, Isoelectric focusing, Isotachophoresis, densitometry procedures and quantitative assays applied to electrophoresis, introduction to Immuno-electrophoresis and 2-D gel electrophoresis	1
14	ELISA, RIA and Immuno-blotting	1
15	Basic principle of sedimentation – Types, care and safety aspects of Centrifuges – Preparative and Analytical; introduction to Ultracentrifugation and Fractionation of sub-cellular components	1
16	Density Gradient centrifugation and Determination of relative molecular mass	1
	Total	16
Practical		
1	Preparation of solutions and buffers – dil. Acids, bases, phosphate buffer, etc.	1
2	Problem solving based on Henderson-Hasselbalch equation	1
3	Verification of Beer-Lambert's Law	1
4	Estimation of glucose and total cholesterol in serum	1
5	Determination of absorption maxima and molar extinction coefficient of p-Nitrophenol from its absorption spectrum	1
6	Estimation of proteins using biuret, foiln-ciocalteau methods and UV spectrophotometry	1
7	Estimation of enzyme activity by spectrophotometry - kinetic mode	1
8	Separation of amino acids by TLC/ paper chromatography	1
9	Separation of proteins by Affinity chromatography	1
10	Separation of proteins by Ion-exchange chromatography	1
11	Separation of proteins by Gel filtration chromatography	1
12	Demonstration of GLC for separation of fatty acids	1
13	Electrophoretic analysis of albumin using non-denaturing and denaturing conditions	1
14	Detection of molecular weight of protein by SDS-PAGE	1
15	Salt fractionation, dialysis and PAGE of immunoglobulins	1
16	Demonstration of sub-cellular fractionation by Ultra Centrifugation	1
	Total	**16**

I. Course Title : Clinical Biochemistry of Animals

II. Course Code : BCT 605

III. Credit Hours : 2 + 1

IV. Aim of the course

To give a detailed overview of role of biomolecules in health and diseases and aid in diagnosis and prognosis of diseases in animals and poultry.

V. Theory

Unit I

Quality control and automation in clinical biochemistry. Disturbance in water, electrolytes and acid-base balance - electrolyte abnormalities - respiratory acidosis and alkalosis - metabolic acidosis and alkalosis – compensation – biochemical tests for diagnosis.

Unit II

Disorders of Carbohydrate metabolism: Diabetes mellitus, hyperinsulemia, glactosemia, hypoglycaemia, Glycogen storage disease and glycated proteins. Carbohydrate and protein balance for optimum rumen microflora. Ruminant ketosis – Ketosis associated with fasting, diabetes, pregnancy, lactation and post-exercise.

Unit III

Disorders of Lipid metabolism: Hypercholesterlemia, atherosclerosis, hyperlipidemia in canine, feline, equine – pathophysiology of ketonemia. Disorders of proteins, amino acids and nucleic acids metabolism: Normal and abnormal plasma proteins – Dysproteinemia – acute phase proteins – inborn errors of amino acid metabolism– Phenylketonuria, alkaptonuria, albinism, tyrosinosis, maple syrup urine disease, Lesch-Nyhan syndrome, sickle cell anemia, Histidinemia – defect in collagen biosynthesis. Abnormalities in Nitrogen Metabolism – Uremia, hyperuricemia, porphyria and factors affecting nitrogen balance. Composition and diagnostic significance of cerebrospinal fluid and amniotic fluid. Doping in horses.

Unit IV

Liver function tests - indications and limitations - classification of tests – Biochemical tests for liver function - serum enzyme activities to asses liver function - Hepatic encephalopathy – Hepatic photosensitivity – Ascites. Renal function: Direct and indirect test for glomerular filtration – tests for tubular function – test for kidney damage Gastrointestinal function: Disturbances in gastrointestinal function – disturbance in rumen function.

Unit V

Clinical enzymology - functional and non-functional plasma enzymes - plasma enzymes of diagnostic importance - ALP, CK, LDH, AST, ALT, OCT - Iso-enzymes and their diagnostic importance. Oxidative Stress: Biochemical basis of disease progression and diagnostic enzymes. Biochemical markers of cardiac diseases: Hypertension, myocardial infarction and heart failure. Respiratory distress syndrome, COPD, Ischemia, shock.

Unit VI

Disorders of mineral metabolism: Hypercalcaemia, hypocalcaemia, normocalcaemia, hypophosphataemia, hyperphosphataemia. Biochemistry of tumours and various types of tumour markers for the diagnosis of prostate cancer, ovarian cancer, mammary tumour, lymphoma, bladder cancer and pancreatic cancer.

Unit VII

Biochemical basis and diagnosis of prevalent diseases and metabolic disorders in wild animals, and poultry.

VI. Practical

Urine analysis - Physical and chemical tests for normal and pathological constituents of urine. Quality Control-Precision, Accuracy, Sensitivity and Specificity; Estimation of Blood glucose - Serum biochemical parameters – Total protein, A/G ratio, Cholesterol, urea, uric acid, bilirubin, creatinine – Serum enymes – ALP, ACP, AST and ALT – Electrophoresis of plasma proteins - Separation of Iso-enzymes. Estimation of Ca, Mg, P, K, Na in serum samples. Estimation of Vit C, D and E.

VII. Suggested Reading

- David L Nelson and Cox Michael M. 2007. *Lehninger's Principles of Biochemistry*. 4th Ed. Freeman.
- Kaneko JJ, Harvey JH, Bruss ML. 2008. *Clinical Biochemistry of Domestic Animals*. 6th Ed. Academic Press.
- Racek J and Rajdl D. 2016. *Clinical Biochemistry*. 1st Ed. Karolinum Press.
- Voet D, Voet JG and Pratt CW. 2006. *Fundamentals of Biochemistry of Life at the Molecular Level*. 2nd Ed. John Wiley and Sons.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Quality control and automation in clinical biochemistry	1
2	Disturbance in water, electrolytes and acid-base balance - electrolyte abnormalities	1
3	Respiratory acidosis and alkalosis: compensation and biochemical tests for diagnosis.	1
4	Metabolic acidosis and alkalosis: compensation and biochemical tests for diagnosis.	1
5	Diabetes mellitus, classification and diagnosis	1
6	Hyperinsulemia, galactosemia, hypoglycaemia of baby pigs	1
7	Glycogen storage disease and glycated proteins	1
8	Carbohydrate balance in ruminants.	1
9	Biochemical alterations in body fluids of ruminants in hypoglycaemia	1
10	Ruminant ketosis – Ketosis associated with fasting, diabetes, pregnancy, lactation and post-exercise	1
11	Disorders of Lipid metabolism: Hypercholesterolemia, atherosclerosis, hyperlipidemia in canines, felines and equines	1
12	Pathophysiology of ketonemia.	1
13	Disorders of proteins, amino acids and nucleic acids metabolism: Normal and abnormal plasma proteins – Dysproteinemias, acute phase proteins	1
14	Inborn errors of amino acid metabolism– Phenylketonuria, alkaptonuria, albinism, tyrosinosis, maple syrup urine disease, Lesch-Nyhan syndrome, sickle cell anemia, Histidinemia – defect in collagen biosynthesis	1
15	Abnormalities in Nitrogen Metabolism – Uremia, hyperuricemia, porphyria and factors affecting nitrogen balance	1
16	Composition and diagnostic significance of cerebrospinal fluid and amniotic fluid	1
17	Doping in horses	1
18	Liver function tests - indications and limitations	1
19	Classification of tests – Biochemical tests for liver function - serum enzyme activities to asses liver function	1
20	Hepatic encephalopathy – Hepatic photosensitivity – Ascites	1
21	Renal function: Direct and indirect test for glomerular filtration – tests for tubular function – test for kidney damage	1

S. No.	Topic	No. of Lectures/ Practicals
22	Gastrointestinal function: Disturbances in gastrointestinal function – disturbance in rumen function	1
23	Clinical enzymology - functional and non-functional plasma enzymes	1
24	Plasma enzymes of diagnostic importance - ALP, CK, LDH, AST, ALT, OCT - Iso-enzymes and their diagnostic importance	1
25	Oxidative Stress: Biochemical basis of disease progression and diagnostic enzymes	1
26	Biochemical markers of cardiac diseases: Hypertension, myocardial infarction and heart failure.	1
27	Respiratory distress syndrome, COPD, Ischemia, shock	1
28	Disorders of mineral metabolism: Hypercalcaemia, hypocalcaemia, normocalcaemia, hypophosphataemia, hyperphosphataemia.	1
29	Biochemistry of tumours and various types of tumour markers	1
30	Role of tumour markers for the diagnosis of prostate cancer, ovarian cancer, mammary tumour, lymphoma, bladder cancer and pancreatic cancer	3
31	Biochemical basis and diagnosis of prevalent diseases and metabolic disorders in wild animals	1
32	Biochemical basis and diagnosis of prevalent diseases and metabolic disorders in poultry	1
	Total	34
Practical		
1.	Urine analysis - volume, colour, acidity, pH, specific gravity - normal urinary constituents - pathological constituents and sediments	2
2.	Quality Control - Precision, Accuracy, Sensitivity and Specificity	1
3.	Estimation of Blood glucose	1
4.	Estimation of Total protein and A/G ratio	1
5.	Estimation of Cholesterol from serum	1
6.	Estimation of urea from serum	1
7.	Estimation of uric acid from serum	1
8.	Estimation of bilirubin from serum	1
9.	Estimation of creatinine from serum	1
10.	Estimation of serum enzymes: ALP, ACP, AST, ALT	1
11.	Electrophoresis of plasma proteins	1
12.	Separation of Isoenzymes	1
13.	Estimation of Ca, Mg, P, K, Na in serum samples	1
14.	Estimation of Vit C	1
15.	Estimation of Vit D and Vit E	1
16.	Estimation of total antioxidant activity	1
	Total	**17**

I. Course Title : Intermediary Metabolism and Regulation

II. Course Code : BCT 606

III. Credit Hours : 3 + 0

IV. Aim of the course

To teach regulatory mechanisms concerned with the metabolism of carbohydrates, lipids, amino acids, proteins and nucleotides in health and diseases and to give exposure in inter-relationship of cellular metabolism of various macromolecules.

V. Theory

Unit I

Carbohydrate metabolism and regulation - Major pathways - Glycolysis - Reactions, functions and its control - Metabolism of other sugars - Fructose, Galactose, Mannose and Lactose - Pyruvate dehydrogenase and reactions of Citric acid cycle - Anaplerotic reactions - Energetics of glucose oxidations. Alternate pathways of glucose metabolism - HMP pathway and its importance - Glucuronic acid cycle - Gluconeogenesis - Substrates - pathway and control of amino sugar - Glycogen metabolism - Glycogenolysis and Glycogenesis reactions - Metabolic disorders - Glycogen storage diseases (GSD).

Unit II

Lipid metabolism and regulation - Lipid transport and storage - Plasma lipoproteins - Role of liver and adipose tissue in fat metabolism - Role of brown adipose tissue in thermogenesis - Catabolism of triacylglycerols – Beta oxidation of fatty acids – Ketogenesis and utilization of ketone bodies - Biosynthesis of fatty acids, triacylglycerols, phopholipids and cholesterol – Production of Bile acids - Metabolism of Eicosanoids - Lipid storage diseases.

Unit III

Amino acids metabolism - Protein turnover and regulation - amino acid pools and absorption of amino acids - catabolism of amino acids - Deamination, transamination. Ammonia carriers; Excretion of nitrogen - urea cycle. Catabolism of carbon skeletons of amino acids. Conversion of amino acids to specialized products – Heme Biosynthesis - Physiologically active amines. Biosynthesis of non-essential amino acids. Metabolic disorders.

Unit IV

Catabolism and regulation of purine and pyrimidine nucleotides/ deoxynucleotides - Biosynthesis and regulation of purine and pyrimidine nucleotides - Biosynthesis of nucleotide coenzymes and regulation - Inhibitors of purine and pyrimidine metabolism and role in cancer therapy – Metabolic disorders.

Unit V

Structural and functional relationships of specialized tissues and organs; Organ specialization in fuel metabolism: Brain, muscle, adipose tissue, liver, kidney; Inter organ metabolic pathways, hormonal control of fuel metabolism. Tracing metabolic fates, perturbing the system. Metabolic interrelationships in obesity, diabetes, cancer, aerobic and anaerobic exercise in horses, pregnancy, lactation and stress injury.

VI. Suggested Reading

- Berg JM, Tymoczko JL, Stryer L and Clarke ND 2015. *Biochemistry*. 8th Ed. WH Freeman and Co.
- David L Nelson and Cox Michael M. 2017. *Lehninger's Principles of Biochemistry*. 7th Ed. Freeman.
- Kaneko JJ, Harvey JH and Bruss ML. 2008. *Clinical Biochemistry of Domestic Animals*. 6th Ed. Academic Press.
- Metzler DE. *Biochemistry*. John Wiley.
- Swenson MJ and Reece WO.2015. *Dukes' Physiology of Domestic Animals*. 13th Ed. Panima.
- Voet D, Voet JG and Pratt CW. 2016. *Fundamentals of Biochemistry of Life at the Molecular Level*. 5th Ed. John Wiley and Sons.
- Zubay GL. 1998. *Biochemistry*. 4th Ed. WCB London.

Course Outline

S. No.	Topics	No. of Lectures
Theory		
1.	Glycolysis - Reactions, functions and its control	1
2.	Metabolism and regulation of other sugars – Fructose and Galactose	1
3.	Metabolism and regulation of other sugars - Mannose and Lactose	1
4.	Pyruvate dehydrogenase Complex, Reactions of Citric acid cycle and its regulation	1
5.	Anaplerotic reactions - Energetics of Glucose oxidations;Introduction to Alternate pathways of Glucose metabolism.	1
6.	Reactions of HMP pathway and its regulation	1
7.	Glucuronic acid cycle and its regulation	1
8.	Gluconeogenesis with its regulation – Substrates - Pyruvate and Lactate	1
9.	Gluconeogenesis with its regulation – Substrates - Glucogenic amino acids, Glycerol and Propionate	1
10.	Glycogen metabolism – Reactions and regulation of Glycogenolysis.	1
11.	Glycogen metabolism - Reactions and regulation of Glycogenesis.	1
12.	Metabolic disorders – Glycogen Storage Diseases (GSD)	1
13.	Lipid transport and storage – Metabolism of Plasma Lipoproteins	1
14.	Role of liver and adipose tissue in fat metabolism	1
15.	Role of brown adipose tissue in thermogenesis	1
16.	Catabolism of Triacylglycerols and its regulation	1
17.	Beta oxidation of Fatty acids and its regulation	1
18.	Ketogenesis and utilization of ketone bodies	1
19.	Biosynthesis of Fatty acids and its regulation	1
20.	Biosynthesis of Triacylglycerols and Phopholipids and their regulation	1
21.	Biosynthesis of Cholesterol and its regulation – Production of Bile acids	1
22.	Metabolism of Eicosanoids	1
23.	Lipid Storage Diseases	1
24.	Introduction to protein turnover and amino acid pools – Meister cycle	1
25.	Catabolism of amino acids - Deamination, transamination reactions and Ammonia carriers/ transport	1
26.	Excretion of nitrogen - Urea cycle and its regulation	1
27.	Catabolism of carbon skeletons of amino acids and its regulation	2
28.	Conversion of amino acids to specialized products - Heme Biosynthesis	1
29.	Conversion of amino acids to specialized products - Physiologically active amines	1
30.	Biosynthesis of non-essential amino acids and its regulation	1
31.	Metabolic disorders – phenylketonuria, methyl malonic aciduria, alkaptonuria, maple syrup urine disease, parkinson's disease, homocystinuria, hartnup's disease.	1
32.	Catabolism and regulation of Purine nucleotides	1
33.	Catabolism and regulation of Pyrimidine nucleotides	1
34.	Biosynthesis and regulation of Purine nucleotides	1
35.	Biosynthesis and regulation of Pyrimidine nucleotides	1
36.	Biosynthesis of nucleotide coenzymes and regulation	1
37.	Inhibitors of purine and pyrimidine metabolism – Role in Cancer therapy	1
38.	Metabolic disorders-hyperuricemia and gout.	1
39.	Structural and functional relationships of specialized tissues and organs, viz., Brain, muscle, adipose tissue, liver and kidney	2
40.	Organ specialization in fuel metabolism of brain, muscle, adipose tissue, liver and kidney	2

S. No.	Topics	No. of Lectures
41.	Inter-organ metabolic pathways	1
42.	Hormonal control of fuel metabolism	1
43.	Tracing metabolic fates - perturbing the system.	1
44.	Metabolic interrelationships in obesity, diabetes, cancer, aerobic and anaerobic exercise in horses, pregnancy, lactation and stress injury	2
	Total	**48**

I. Course Title : Molecular Biochemistry

II. Course Code : BCT 607

III. Credit Hours : 2 + 1

IV. Aim of the course

To provide knowledge regarding genes, their functions, expression, regulation and transfer in heterologous systems.

V. Theory

Unit I

Historical development of molecular biology, nucleic acids as genetic material, chemistry and structure of DNA and RNA, Genome organization in prokaryotes and eukaryotes, repetitive and non-repetitive DNA, satellite DNA; chromatin structure and function.

Unit II

DNA replication mechanisms in prokaryotes and Eukaryotes, DNA polymerases, Topoisomerases, DNA ligase, Reverse transcriptase, Transcription mechanisms in Prokaryotes and Eukaryotes, RNA polymerases, RNA editing, post transcriptional RNA processing. Recombination mechanisms, DNA repair mechanisms, Telomeres, Telomerase, Role of Telomeres in Cancer.

Unit III

Ribosomes - structure and function, organization of ribosomal proteins, genetic code, aminoacyl tRNA synthases, Inhibitors of replication, transcription and translation; Translation mechanisms in Eukaryotes and Prokaryotes and Post - translational modification; Nucleases and restriction enzymes, regulation of gene expression in prokaryotes and eukaryotes.

Unit IV

DNA sequencing techniques, Recombinant DNA technology, Plasmid biology, Cloning Vectors, Expression vectors, selection of recombinants, Heterologous protein expression systems, Recombinant protein purification, Polymerase Chain Reaction and its variants; Site Directed Mutagenesis, *In-vitro* transcription, Gene Silencing. Transgenic Animals, Introduction to Systems Biology.

VI. Practical

Isolation and purification of DNA - Plasmid isolation- Isolation and purification of RNA – Determination of concentration of DNA and RNA by spectrophotometry - Determination of Tm of DNA by Spectrophotometry - Restriction Digestion of DNA, Agarose gel electrophoresis - RAPD analysis of DNA - cDNA synthesis using PCR

VII. Suggested Reading

- Jocelyn E Krebs *et al*. 2017. *Lewin's Genes XII*. Jones and Bartlett Publishers Inc.
- Watson JD *et al*. 2017. *Molecular Biology of the Gene.* 7th Ed. Pearson Education.
- Eberhard. O. Voit. 2017. *A First Course in Systems Biology*, 2nd Edition. Garland Science Publishers.
- *Genome Editing and Engineering*: From TALENs, ZFNs and CRISPRs to Molecular Surgery, Ed. Krishnarao Appasani, Cambridge University Press, 2018
- *Molecular Cell Biology*, 8th Ed, Lodish *et al*. WH Freeman and Co., 2016
- *Molecular Biology of the Cell*, 6th Ed. Bruce Alberts *et al*, WW Norton and Company, 2014
- *Transgenic Animal Technology: A laboratory handbook*, 3rd Edition, Ed. Carl. A. Pinkert, Academic Press, 2014.
- *Molecular Biology*, 4th Ed, Robert F. Weaver, McGraw Hill Higher Education, 2007.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Historical Development of Molecular Biology	1
2.	Nucleic acids as genetic material, Chemistry and Structure of DNA and RNA	1
3.	Genome organization in prokaryotes and eukaryotes	1
4.	Repetitive and non-repetitive DNA, Satellite DNA	1
5.	Chromatin structure and function	1
6.	DNA replication mechanisms in prokaryotes and Eukaryotes, DNA polymerases, DNA ligase	1
7.	Topoisomerases	1
8.	Transcription mechanisms in Prokaryotes and Eukaryotes, RNA Pol.	1
9.	RNA editing	1
10.	Post-transcriptional RNA processing	1
11.	Recombination mechanisms	1
12.	DNA repair mechanisms	1
13.	Reverse transcriptase	1
14.	Telomeres, Telomerase, Role of Telomeres in Cancer	1
15.	Translation mechanisms in Eukaryotes and Prokaryotes	1
16.	Post - translational modification	1
17.	Ribosomes - structure and function, organization of ribosomal proteins,	1
18.	Genetic code	1
19.	Aminoacyl tRNA synthases	1
20.	Inhibitors of replication, transcription and translation	1
21.	Regulation of gene expression in prokaryotes and eukaryotes	1
22.	Recombinant DNA technology - Introduction	1
23.	Plasmid biology, Cloning Vectors, selection of recombinants	1
24.	Nucleases and restriction enzymes	1
25.	Polymerase Chain Reaction and its variants	1
26.	Expression vectors	1
27.	Heterologous protein expression systems	1
28.	Recombinant protein purification	1
29.	Site Directed Mutagenesis, *In-vitro* transcription,	1
30.	Gene Silencing	1
31.	Transgenic Animals	1
32.	Introduction to Systems Biology	1
	Total	**32**

S. No.	Topic	No. of Lectures/ Practicals
Practical		
1.	Isolation and purification of DNA	2
2.	Plasmid isolation	2
3.	Isolation and purification of RNA	2
4.	Determination of concentration of DNA and RNA by spectrophotometry	1
5.	Determination of TM of DNA by Spectrophotometry	1
6.	Polymerse chain reaction	2
7.	Restriction Digestion of DNA	2
8.	Agarose gel electrophoresis	1
9.	RAPD analysis of DNA	2
10.	cDNA synthesis using PCR	2
	Total	**17**

I. Course Title : Nutritional and Industrial Biochemistry

II. Course Code : BCT 608

III. Credit Hours : 2 + 0

IV. Aim of the course

To give exposure about biochemical principle as applicable to nutrition in animals and industry.

V. Theory

Unit I

Introduction - Nutrients and their importance in ruminants, non-ruminants and poultry - Energy value of various nutrients their importance and calorimetry - Nutrient absorption and biochemical changes involved - Introduction to BMR, SDA, PER and Biological value for protein - Requirements of different nutrients in animals - Role of nutrients in growth and production of animals – Bio-availability of nutrients in different food sources.

Unit II

Metabolic role of Nutrients - Overview of metabolism of different nutrients and regulation of nutrient absorption and utilization - Alterations that occur in nutritional requirement s during diseases and biochemical reactions due to Toxic factors in feed - Biochemical role of Macro and micro minerals in animal production - Vitamins and their role as co enzymes in metabolism – Nutrient deficiencies and metabolic disorders in animals - Biochemical alterations occurring due to phyto-toxins in ruminants - Biochemical importance of different feed additives - Agonists and antagonists of minerals and vitamins - Nutrient control of gene expression - Clinical issues of micro mineral metabolism - Nutrients (minerals) that resist digestion process in animals - Energy releasing and hematopoietic water soluble vitamins.

Unit III

Industrial biochemistry - applications of biological molecules for medical, industrial, environmental, agricultural or analytical purposes - Generation of gene-mediated industrial/ medical products - Introduction and application of fermentation technology for ethanol and biogas production - conversion of sunlight into biomass (bioreactors and biophotolysis) - Significance of pharmaceuticals products of animal origin (sex hormones- oestrogens, progesterone; corticosteroids) - Significance of pharmaceuticals of plant origin (alkaloids, atropine, morphine, cocaine, ergot alkaloids, flavonoids, xanthenes and terpenoids) - Physical, chemical and biological treatment of waste water, bioremediation of contaminated soils.

VI. Suggested Reading

- *Nutritional Biochemistry*, 2nd Edition, Tom Brody, Elsevier pub.2009
- *Text book of Biochemistry with clinical correlations*. 6th edition, Thomas M Devlin, Wileys-liss. Press.
- *A textbook of industrial microbiology* 2nd edition, Crueger W and Crueger A. 2000, Panima Publishing Corp.
- *Principle of fermentation technology*, 1997, Stanbury PF, Ethitaker H, Hall S, Aditya Books (P) Ltd.
- *Bioprocess Engineering: Basic Concepts*. Shuler M and Kargi F. Second Edition. Pearson Education. 2002
- *Nutritional Biochemistry of the vitamins*, by David a Bender, 2nd Edition, Cambridge University Press.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Nutrients and their importance in ruminants.	1
2.	Nutrients and their importance in Non ruminants and poultry	1
3.	Energy value of various nutrients their importance and calorimetry.	1
4.	Nutrient absorption and biochemical changes involved.	1
5.	Introduction to BMR, SDA, PER and Biological value for protein.	1
6.	Requirements of different nutrients in animals	1
7.	Role of nutrients in growth and production of animals	1
8.	Bio-availability of nutrients in different food sources	1
9.	An overview of metabolism of different nutrients.	1
10.	An overview of regulation of nutrient absorption and utilization.	1
11.	Alterations that occur in nutritional requirement s during diseases.	1
12.	Alterations in biochemical reactions due to Toxic factors in feed.	1
13.	Biochemical role of Macro minerals in animal production	1
14.	Biochemical role of Micro minerals in animal production.	1
15.	Vitamins and their role as co enzymes in metabolism	1
16.	Deficiencies of nutrients that cause metabolic disorders in animals	1
17.	Biochemical alterations occurring due to phyto toxins in ruminants	1
18.	Biochemical importance of different feed additives	1
19.	Agonists and antagonists of minerals.	1
20.	Agonists and antagonists of vitamins.	1
21.	Nutrient control of gene expression	1
22.	Clinical issues of micro mineral metabolism.	1
23.	Nutrients (minerals) that resist digestion process in animals.	1
24.	Energy releasing and hematopoietic water soluble vitamins.	1
25.	Industrial biochemistry- applications of biological molecules for medical, industrial, environmental, agricultural or analytical purposes.	1
26.	Generation of gene-mediated industrial/ medical products.	1
27.	Introduction and application of fermentation technology for ethanol and biogas production.	1

S. No.	Topic	No. of Lectures/ Practicals
28.	Introduction to industrial microorganisms and products, growth and product formation in biocatalysis.	1
29.	Conversion of sunlight into biomass (bioreactors and bio-photolysis)	1
30.	Significance of pharmaceuticals products of animal origin, sex hormones, oestrogens, progesterone, corticosteroids.	1
31.	Significance of pharmaceuticals of plant origin, Alkaloids, atropine, morphine, cocaine, ergot alkaloids, flavonoids, xanthenes and terpenoids;	1
32.	Physical, chemical and biological treatment of waste water, bioremediation of contaminated soils.	1
	Total	**32**

I. Course Title : Endocrinology and Reproductive Biochemistry

II. Course Code : BCT 609

III. Credit Hours : 2 + 0

IV. Aim of the course

To impart knowledge on the role of hormones in signalling and their biochemical role in reproduction of animals.

V. Theory

Unit I

Endocrinology - Classification, secretion, transport and regulation of hormones - Mechanism of hormone action and intracellular signalling after receptor activation - Releasing factors from hypothalamus and their effects on pituitary gland and metabolism - Synthesis, secretion, regulation, metabolic functions and physio-pathology of Hormones from Pituitary, Thyroid, Parathyroid, Pancreas, Adrenal and Pineal Glands.

Unit II

Endocrinology of Gonads and Reproductive Biochemistry - Female hormonal system - Synthesis, secretion, regulation, functions, and physio-pathology of ovarian hormones and male sex hormones - Prostaglandins: chemistry, functions and clinical importance - Endocrine aspects of reproduction status in domestic animals - Endocrine aspects of reproduction in poultry - Hormones involved in the development of ductal and lobule-alveolar system of mammary gland - Endocrine control of biosynthesis of milk.

VI. Suggested Reading

- *Dukes' Physiology of Domestic Animals*, 13th edition/ editor, William O Reece, Wiley Blackwell.
- Guyton and Hall *Textbook of Medical Physiology*, 13th edition/ editor, John E Hall, Elsevier.
- *Applied Animal Endocrinology*, E. James Squires, CABI
- *Endocrinology: An Integrated Approach*, by SS Nussey, SA Whitehead, 1st edition, CRC Press.
- *Biochemistry of Lactation*, TB Mepham, Elsevier

Course Outline

S. No.	Topics	No. ofLectures
Theory		
1.	Classification, secretion, transport and regulation of hormones.	2
2.	Mechanism of hormone action and intracellular signalling after receptor activation.	2
3.	Releasing factors from hypothalamus and their effects on pituitary gland and metabolism.	2
4.	Hormones from Pituitary, secretion, regulation, metabolic functions and physio-pathology.	2
5.	Synthesis, secretion, regulation, metabolic functions and physio-pathology of Thyroid hormones.	1
6.	Parathyroid gland, its hormone and effect on calcium and phosphate concentrations in the extracellular fluid	2
7.	Endocrine Pancreas: Hormone synthesis, secretion, regulation, metabolic functions and physio-pathology.	2
8.	Endocrine Adrenal: Hormone synthesis, secretion, regulation, metabolic functions and physio-pathology.	2
9.	The Pineal Gland and Melatonin secretion, regulation and function.	1
10.	Female hormonal system - Effect on ovaries - Synthesis, secretion, regulation, functions, and physio-pathology of ovarian hormones.	2
11.	Synthesis, secretion, regulation, metabolic functions and physio-pathology of male sex hormones.	2
12.	Prostaglandins: Chemistry, Functions and Clinical Importance	2
13.	Hormones concerned with animal production.	2
14.	Endocrine aspects in reproduction status in domestic animals	2
15.	Hormones concerned with poultry production.	2
16.	Endocrine aspects of reproduction in poultry	2
17.	Hormones involved in development of Ductal and Lobule-Alveolar System of mammary gland - Endocrine control of milk secretion and its biosynthesis	2
	Total	**32**

I. Course Title : Biochemistry of Ruminants and Wild Animals

II. Course Code : BCT 610

III. Credit Hours : 1 + 1

IV. Aim of the course

To acquaint the students about comparative metabolism in ruminant species and the common metabolic disorders in ruminants; to impart a basic knowledge about biochemistry of wild animals.

V. Theory

Unit I

Biochemistry of Ruminants - An overview of metabolism of carbohydrates, proteins and lipids in ruminants - Metabolism of nutrients by rumen microflora - Blood biochemistry of ruminants - Disorders associated with carbohydrates, proteins and lipid metabolism in ruminants - Liver and Kidney function tests - Diseases associated with major and trace elements in ruminants.

Unit II

Biochemistry of Wild Animals - Blood biochemistry and blood typing of wild animals - Fluid balance and electrolyte maintenance in wild animals - Biomarkers for assessment of diseases in wild animals - Diabetes mellitus in primates - Neurological diseases in cheetah

VI. Suggested reading

- Dvorak AM and Harris W. 1991. *Blood Cell Biochemistry*. 2nd Ed. Plenum.
- *Clinical Biochemistry of Domestic Animals*, 6th Edition/ Editors: Jiro Kaneko John Harvey Michael Bruss, Elsevier.
- *Lipid Metabolism in Ruminant Animals*, 1st Edition/ Editors: William W Christie, Elsevier.
- *Digestive Physiology and Metabolism in Ruminants*, Editors: Ruckebusch Y, Thivend.
- *Energy Nutrition in Ruminants*, Editors: Orskov ER.
- *Zoo and Wild Animal Medicine* (Current Therapy 3) by Murray E Fowler, 5th edition.
- *Textbook of Veterinary Biochemistry*, by RS Dhanotiya, JAYPEE.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Comparative metabolism of carbohydrates, proteins and lipids in ruminants	2
2.	Metabolism of nutrients by rumen microflora	1
3.	Blood biochemistry of ruminants	1
4.	Disorders associated with carbohydrate, protein and lipid metabolism	2
5.	Liver dysfunction and tests	1
6.	Kidney dysfunction and tests	1
7.	Diseases associated with major and trace elements	2
8.	Blood biochemistry and blood typing of wild animals	1
9.	Fluid balance and electrolyte maintenance in wild animals	2
10.	Biomarkers for assessment of diseases in wild animals	1
11.	Diabetes in primates	1
12.	Neurological diseases in cheetah	1
	Total	16
Practical		
1.	Methods of examining fluids and tissue in wild animals	1
2.	Pancreatic function test	1
3.	Estimation of Serum amylase	1
4.	Estimation of Serum Bilirubin	1
5.	Estimation of serum Inorganic Phosphate	1
6.	Estimation of serum Calcium	1
7.	Estimation of serum Magnesium	1
8.	Estimation of Vitamin A	1
9.	Estimation of serum LDH	1
10.	Estimation of rumen volatile fatty acid	1
11.	Estimation of rumen lactic acid	1
12.	Estimation of Cellulolytic activity	1
13.	Estimation of milk ketone bodies (acetone) by microdiffusion method	1
14.	Estimation of milk lactose	1
	Total	**14**

I. Course Title : Introduction to Bioinformatics and Computational Biology

II. Course Code : BCT 611

III. Credit Hours : 1 + 1

IV. Aim of the course

To impart an introductory knowledge of Bioinformatics and Computational biology to postgraduate students studying any discipline of veterinary/ agricultural science.

V. Theory

Unit I

Introduction to bioinformatics, scope and applications of bioinformatics; biological databases: primary, secondary and structural; basic concept of Protein and Gene Information Resources-PIR, SWISS-PROT, PDB, GenBank, DDBJ; Basic concept of computational biology, applications in different subfield of biology, software tools.

Unit II

Basic concept of sequence search algorithm and alignment tools: BLAST and FASTA; DNA and protein sequence analysis, local and global alignment; Algorithms: Dot Matrix method, dynamic programming methods; Pairwise and multiple sequence alignment and its application; Tools of Multiple sequence alignment: ClustalW.

Unit III

Basic concept of Phylogeny study; cDNA libraries and EST, EST analysis; database search engines: introduction and application; Commercial databases and software packages, GPL software for Bioinformatics.

Unit IV

Computer aided drug design: basic principles, docking; QSAR, 2DQSAR, 3DQSAR, their basic concept and applications, machine learning tools for QSAR.

VI. Practical

- Basic computing: Introduction to LINUX and Windows
- Nucleotide information resource: EMBL, GenBank, DDBJ
- Protein information resource: SwissProt, TrEMBL, Uniprot
- Structure databases: PDB, MMDB
- Search Engines: Entrez, ARSA, SRS
- Usage of NCBI resources
- Retrieval of sequence/ structure from databases
- Database searching
- Visualization of structures of DNA and Proteins using Rasmol
- Sequence similarity search using BLAST
- Multiple sequence alignment
- Primer designing

VII. Suggested Reading

- *Introduction to Bioinformatics* 2003. Attwood TK and Parry-Smith DJ, Pearson Education.
- *Essential bioinformatics* 2006. Xin Xiong. Cambridge University Press.
- *Bioinformatics: Concepts, Skills and Applications* 2004. Rastogi SC, Mendiratta N and Rastogi P. CBS.
- *Principles of Genome Analysis and Genomics* 2003. SB Primrose and RM Twyman, Blackwell Publishing.

- *Molecular Analysis and Genome Discovery* 2004. Ralph Rapley and Stuart Harbron (Eds.), John Wiley and Sons.
- *BioInformatics* 2001. Andreas D Baxevanis and BF Francis Ouellette (Eds.)
- *Wiley Interscience Proteins and Proteomics* 2003. Richard J. Simpson, Cold Spring Harbor Laboratory.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to bioinformatics - Scope and applications of bioinformatics	1
2.	Introduction to biological databases: primary, secondary and structural databases	1
3.	Basic concept of Protein and Gene Information Resources-PIR, SWISS-PROT, PDB, GenBank, DDBJ	1
4.	Basic concept of computational biology, applications in different subfields of biology	1
5.	Basic concept of sequence search algorithm and alignment tools: BLAST and FASTA; DNA and protein sequence analysis, local and global alignment	1
6.	Dot Matrix method, dynamic programming methods	1
7.	Pairwise and multiple sequence alignment and its application	1
8.	Tools of Multiple sequence alignment: ClustalW	1
9.	Basic concept of Phylogeny study	1
10.	cDNA libraries and EST, EST analysis	1
11.	Database search engines-introduction and application	1
12.	Commercial databases and software packages, GPL software for Bioinformatics	1
13.	Computer aided drug design-basic principles	1
14.	Introduction of Molecular docking and QSAR	1
15.	2DQSAR, 3DQSAR, their basic concept and applications	1
16.	Machine learning tools for QSAR	1
	Total	**16**
Practical		
1.	Basic concept of computer hardware and software, computer operating systems: Linux and windows	2
2.	Nucleotide information resource: EMBL, GenBank, DDBJ	1
3.	Protein information resource: SwissProt, TrEMBL, Uniprot	1
4.	Structure databases: PDB, MMDB	1
5.	Basic concept of molecular search Engines: Entrez, ARSA, SRS	1
6.	Usage of NCBI resources	2
7.	Retrieval of sequence/ structure from databases	1
8.	Database searching	1
9.	Visualization of structures of DNA and Proteins using Rasmol	1
10.	Sequence similarity search using BLAST	1
11.	Multiple sequence alignment tools: ClustalW, Bioedit, etc.	2
12.	Phylogeny study using different software tools	1
13.	Primer designing using different software tools	1
	Total	**16**

Course Title with Credit Load
Ph.D. in Veterinary Biochemistry

Course Code	Course Title	Credit Hours
RPE700*	Research and Publications Ethics	1 + 1
BCT 701	Applied Molecular Biochemistry and Systems Biology	2 + 1
BCT 702	Membrane Biochemistry	2 + 0
BCT 703	Recent trends in Enzymology	2 + 1
BCT 704	Diagnostic Techniques in Clinical Biochemistry	0 + 2
BCT 705	Recent Trends in Biochemical Techniques and Instrumentation	2 + 1
BCT 706	Developmental Biochemistry	2 + 0
BCT 707	Bioinformatics Tools in Biochemistry	1 + 1
BCT 708	Environmental and Toxicological Biochemistry	2 + 0
BCT 709	Biochemistry of Diseases and Disorders	2 + 0
BCT 710	Immuno-Biochemistry	2 + 0
BCT 711	Special Problem	0 + 2
BCT 712	Doctoral Seminar-I	1 + 0
BCT 713	Doctoral Seminar-II	1 + 0
BCT 714	Doctoral Research	0+75

*compulsory Major course for Doctorate programme. The other 10 credits can be registered from remaining 700 Series courses listed above

Course Contents
Ph.D. in Veterinary Biochemistry

I. Course Title : Applied Molecular Biochemistry and Systems Biology

II. Course Code : BCT 701

III. Credit Hours : 2 + 1

IV. Pre-requisite

Should have studied BCT-607: Molecular Biochemistry (2+1) or other equivalent courses with similar syllabi/ content at Master's level.

V. Aim of the course

To impart latest information on the molecular biochemistry of isolation, transfer and expression of genes and biochemical approaches employed in gene therapy and computational approaches to biology/ synthetic biology.

VI. Theory

Unit I

Organization of prokaryotic genome, nuclear and organelle genes, concept of genome mapping and Organization, Molecular evolution, Prokaryotic and Eukaryotic gene regulation, RNA editing.

Unit II

Comparative genomics, functional genomics, transcriptomics and transcriptional network, Application of genomics, Livestock genomics, Buffalo Genome Inititative, Dog genome projects, Role of genomics in Wild life conservation and Reconstruction of species, Bioethics and biosafety guidelines and IPR in recombinant DNA research.

Unit III

Transgenics, Gene Knock – out technology, Site specific nucleases, Zinc – Fingers, TALENS and CRISPR – Cas 9, Applications of Gene knock out, Development of Knock - out Animal models, Gene silencing, Antisense oligos, Ribozymes, RNAi, 3'UTR and miRNA, Applications of gene silencing, Site directed mutagenesis, gene targeting and gene therapy.

Unit IV

Nucleic acid sequencing: Various methods of sequencing including automated sequencing and Microarrays, Whole Genome Sequencing, epigenetic regulation, Protein sequencing, Peptide synthesis, Peptide arrays, protein engineering, Directed evolution of proteins.

Unit V

Mathematical modelling, Static Network models, Mathematics of Biological systems, Parameter estimation, Gene systems, Gene regulation models, Protein systems, Metabolic systems, Signalling systems, Population systems, Physiological modelling, Systems biology in Medicine and Drug development, Basic design of biological systems, Introduction to nutrigenomics and pharmacogenomics, Applications in Veterinary Science.

VII. Practical

DNA methylation protocols, Genome Editing protocols, *in-vitro* Site Directed Mutagenesis, Gene silencing protocols, Next Generation sequencing platforms, Quantitative PCR, SAGE, Massively Parallel Signature Sequencing (MPSS), Oligonucleotide synthesis and quality control, Cap Analysis of Gene Expression (CAGE)/ deep CAGE, Chip-Chip assay Proteomics - 2D-PAGE, MSMS, MALDI-TOF, and Protein-protein interaction (Hybrid assay, DNA-Protein interaction and gene regulation (EMSA and Chip assay), DNA Microarrays, Protein sequencing protocols.

VIII. Suggested Reading

- *Molecular Biology of the Gene*, 7th Ed. JD Watson *et al*., Pearson Education, 2017
- *Lewin's Genes XII*, Jocelyn E Krebs *et al*., Jones and Bartlett Publishers Inc., 2017
- *A First Course in Systems Biology*, 2nd Edition, Eberhard. OVoit, Garland Science publishers 2017
- *Directed Enzyme Evolution: Advances and Applications*, Ed. Miguel Alcalde, Springer International Publishing, 2017
- *Genome Editing in Animals: Methods and Protocols*, Ed. Izuho Hatada, Springer Protocols, 2017
- *Genome Editing and Engineering*: From TALENs, ZFNs and CRISPRs to Molecular Surgery, Ed. Krishnarao Appasani, Cambridge University Press, 2018
- *Molecular Cell Biology*, 8th Ed, Lodish *et al*., WH Freeman and Co., 2016
- *Nutrigenomics*, Eds. Carsten Carlberg, Stine Marie Ulven and Ferdinand Molnar, Springer Intl. Pub, 2016
- *CRISPR: Methods and Protocols*, Eds. Magnus Lundgren, Emmanuelle Charpentier, Peter C Fineran, Humana Press, 2015
- *Genome Analysis: Current Procedures and Applications*, Ed Maria S Poptsava, Caister Academic Press, 2014
- *Transgenic Animal Technology: A laboratory handbook*, 3rd Edition, Ed. Carl A Pinkert, Academic Press, 2014
- *Molecular Biology of the Cell*, 6th Ed. Bruce Alberts *et al*, WW Norton and Company, 2014
- *Bovine Genomics*, Ed. James E Womack, Wiley Blackwell, 2012
- *The Genetics of the Dog*, Eds. Elaine A Ostrander and Anatoly Ruvinsky, CABI press, 2012
- *An Introduction to Systems Biology*. Ed. Sangdun Choi, Humana Press, 2010
- *Genome Mapping and Genomics in Domestic Animals*, Eds. Noelle E Cockett, Chittaranjan Kole, Springer Verlag, 2009.
- *Gene Knockout protocols*, Eds. Ralf Kuhn, Wolfgang Wurst, 2009, Springer
- *Molecular Biology*, 4th Ed, Robert F. Weaver, McGraw Hill Higher Education, 2007
- *Comparative Genomics*, Ed. Nicholas H Bergman, Humana press, 2007
- *Molecular Biology and Genomics*, Cornel Mulhardt, Academic Press, 2007
- *The Dog and Its Genome*, Eds. Elaine A. Ostrander, Urs Giger, Kerstin Lindblad-Toh, CSHL press, 2006
- *Life: An Introduction to Complex Systems Biology*, Springer, 2006
- *An Introduction to Systems Biology: Design principles of Biological circuits*, Uri Alon, 2006, Chapman and Hall/ CRC
- *Directed molecular Evolution of Proteins: or How to improve Enzymes for Biocatalysis*, Eds. Susanne Brakmann, Kai Johnsson, Wiley VCH Verlag GmbH, 2003
- *Directed Evolution Library Creation*, Eds. Frances H Arnold, George Georgiou, Humana Press, 2003.
- Selected articles from journals.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Organization of prokaryotic genome	1
2.	Nuclear and organelle genes.	1
3.	Concept of genome mapping and Organization	1
4.	Molecular evolution	1
5.	Prokaryotic and Eukaryotic gene regulation	1
6.	RNA editing	1
7.	Comparative genomics	1
8.	Functional genomics	1
9.	Transcriptomics and transcriptional network	1
10.	Application of genomics, Livestock genomics, Buffalo Genome Initiative, Dog genome projects, Role of genomics in Wild life conservation and Reconstruction of species	1
11.	Bioethics and biosafety guidelines and IPR in recombinant DNA research	1
12.	Transgenics, Gene Knock-out technology.	1
13.	Site specific nucleases, Zinc-Fingers, TALENS and CRISPR – Cas 9,	1
14.	Applications of Gene knock out, Development of Knock-out Animal models	1
15.	Gene silencing, Applications of gene silencing	1
16.	Antisense oligos, Ribozymes	1
17.	RNAi, 3'UTR and miRNA, Site directed mutagenesis	1
18.	gene targeting and gene therapy	1
19.	Nucleic acid sequencing: Various methods of sequencing including automated sequencing and Microarrays	1
20.	Whole Genome Sequencing, epigenetic regulation	1
21.	Protein sequencing, Peptide synthesis	1
22.	Peptide arrays	1
23.	Protein engineering	1
24.	Directed evolution of proteins	1
25.	Mathematical modelling, Static Network models	1
26.	Mathematics of Biological systems, Parameter estimation	1
27.	Gene systems, Gene regulation models	1
28.	Protein systems, Metabolic systems	1
29.	Signalling systems, Population systems	1
30.	Physiological modelling	1
31.	Systems biology in Medicine and Drug development	1
32.	Basic design of biological systems	1
33.	Introduction to Nutrigenomics - Applications in Veterinary Science	1
34.	Pharmacogenomics - Applications in Veterinary Science	1
	Total	**34**
Practical		
1.	DNA methylation protocols	2
2.	Genome Editing protocols, *In-vitro* Site Directed Mutagenesis	2
3.	Gene silencing protocols	2
4.	Next Generation sequencing platforms	1
5.	Quantitative PCR, SAGE, Massively Parallel Signature Sequencing (MPSS)	1
6.	Oligonucleotide synthesis and quality control	2
7.	Cap Analysis of Gene Expression (CAGE)/ deep CAGE	2
8.	Chip-Chip assay Proteomics	1

S. No.	Topic	No. of Lectures/ Practicals
9.	2D-PAGE, MSMS, MALDI-TOF	2
10.	Protein-protein interaction (Hybrid assay, DNA-Protein interaction and gene regulation (EMSA and Chip assay), DNA Microarrays, Protein sequencing protocols	2
	Total	**17**

I. Course Title : Membrane Biochemistry

II. Course Code : BCT 702

III. Credit Hours : 2 + 0

IV. Pre-requisite

Should have studied BCT -602: Biochemistry of Biomolecules (3+0) or other equivalent courses with similar syllabi/ content at Master's level.

V. Aim of the course

To teach structure and functions of biomembranes, structure-function relationships, membrane biogenesis.

VI. Theory

Unit I

Concept of biomembranes and their classification based on cellular organelles; physico-chemical properties of different biological and artificial membranes, Membrane biogenesis and differentiation, Trafficking of Membrane Components - lipids, carbohydrates and proteins, cell surface receptors and antigen.

Unit II

Distribution and organization of membrane components-lipids; proteins- intrinsic and extrinsic: their arrangement; carbohydrates in membranes and their function. Cell membrane structure and the Fluid-mosaic model. Restoration and maintenance of cell membrane integrity and permeability. Methods for analysis of plasma membrane integrity. Separation of different membrane components.

Unit III

Molecular basis of biochemical behaviours of membranes, Various membrane movements; transport across membrane-Active transport, passive transport, diffusion, osmosis, exocytosis and endocytosis, Fick's law of diffusion and its physiological importance, energy transduction.

Unit IV

Role of membrane in cellular metabolism, cell recognition and cell –to –cell interaction; signal transduction, Molecular mechanisms, ion translocating antibiotics, valinomycin, gramicidin, ouabain, group translocation, ionophores, electrical gradient, energy coupling mechanism, recent trends and tools in membrane research.

VII. Suggested Reading

- Alberts B, Johnson A, Lewis J, Raff M, Roberts HK and Walter P. *Molecular Biology of the Cell. Garland Science*, Taylor and Fransis Group.
- Cooper GM and Hausam RE. 2015. *The Cell: A Molecular Approach*. Oxford University Press. ISBN: 9781605352909

- Lodish H, Berk A, Zipursky SA, Matsudaira P, Baltimore D and Darnel J. 1999. *Molecular Cell Biology*. WH Freeman.
- Nelson DL and Cox MM. 2000. *Lehninger Principles of Biochemistry*. 3rd Ed. Replika Press Pvt. Ltd., New Delhi for Worth Publ., New York.
- Selected articles from journals.

Course Outline

S. No.	Topics	No. of Lectures
Theory		
1.	Concepts of bio membranes and their classification based on cellular organelles	2
2.	Physico-chemical properties of different biological and artificial membranes	1
3.	Membrane biogenesis and differentiation	2
4.	Trafficking of Membrane Components - lipids, carbohydrates and proteins	2
5.	Cell surface receptors and antigen	1
6.	Distribution and organization of membrane components-lipids; proteins, intrinsic and extrinsic: their arrangement	2
7.	Cell membrane structure and the Fluid-mosaic model	1
8.	Restoration and maintenance of cell membrane integrity and permeability	1
9.	Methods for analysis of plasma membrane integrity.	2
10.	Separation of different membrane components.	1
11.	Molecular basis of biochemical behaviours of membranes	2
12.	Various membrane movements	1
13.	Transport across membrane-Active transport, passive transport, diffusion, osmosis, exocytosis and endocytosis	2
14.	Fick's law of diffusion and its physiological importance	1
15.	Energy transduction	1
16.	Role of membrane in cellular metabolism	1
17.	Role of membrane in cell recognition	1
18.	Cell to cell interaction	2
19.	Signal transduction	2
20.	Molecular mechanisms, ion translocating antibiotics, valinomycin, gramicidin, ouabain, group translocation, ionophores, electrical gradient, energy coupling mechanism.	2
21.	Recent trends and tools in membrane research	3
	Total	**33**

I. Course Title : Recent Trends in Enzymology

II. Course Code : BCT 703

III. Credit Hours : 2 + 1

IV. Pre-requisite

Should have studied BCT-603: Enzymology (2+1) or other equivalent courses with similar syllabi/ content at Master's level.

V. Aim of the course

To teach current developments in actions of enzymes and their applications.

VI. Theory

Unit I

Enzyme: Structure, mechanism, and Regulation. Three dimensional structure of enzyme, flexibility and conformational mobility of enzymes, enzyme families, dehydrogenase and dinucleotide fold, Multienzyme complexes, features and mapping of active site of enzymes, methods of examining enzyme-substrate complexes, reaction mechanism of lysozyme, chymotrypsin, carboxypeptidase A and ribonuclease A. Regulation of enzyme activity by zymogen activation, covalent modification and feed back inhibition. Allosteric enzyme with special reference to aspartate trans carbomylase. Concerted and sequential models of allosteric enzymes.

Unit II

Enzyme catalysis: general acid-base, covalent electrostatic and metal ion catalysis, orbital steering, principles of kinetic equivalence and kinetic isotopic effects, transition state theory-application and significance of enzyme catalysis. Hammond postulate

Enzyme kinetics and inhibition: factors influencing enzyme reaction velocity, steady-state kinetic of enzyme catalyzed reaction, significance of Michacelis-Menten parameters, Extension and modification of the Michacelis-Menten mechanism. Kcat/Km and kinetic perfection in enzyme catalysis, kinetics of multi-substrate system-random, sequential, ordered, Theorell-chance and the ping-pong mechanisms. Competitive, non-compititive enzyme inhibition, suicide substrates and anti-metabolites.

Unit III

Recent developments: Industrial application of Enzymes, Enzyme immobilization methods and application. Restriction endonucleases, enzyme engineering, use of site-directed mutagenesis for detection of enzyme mechanisms, Abzymes and ribozymes, Enzyme linkering. Biosensors.

Unit IV

Diagnostic enzymology: Assay of enzymes in clinical cases, Enzymes in Pathogenesis, Enzyme histochemistry and cytochemistry, Application of microscopy in enzymology, Enzyme immuno diagnostics, Cholinesterase, lipase, amylase, GGT, GPx, arginase, AST, ALT and SDH in diagnosis of diseases of animals. Therapeutic Enzymes.

VII. Practical

- Estimation of Antioxidant Enzymes (Superoxide dismutase, Glutathione Peroxidase, Catalase, Glutathione S-transferase) from tissue samples.
- Isolation, purification and characterization of enzymes from biological samples.
- Application of enzymes in competitive bioassays (ELISA, RIA)
- Determination of Enzyme activity in Native Gel Electrophoresis.
- Estimation of Diagnostic enzymes from Clinical samples.
- Application of Restriction enzymes in cloning experiments.

VIII. Suggested Reading

- David L Nelson and Cox Michael M. 2008. *Lehninger's Principles of Biochemistry*. 5th Ed. Freeman.
- Kaneko JJ, Harvey JH and Bruss ML. 2008. *Clinical Biochemistry of Domestic Animals*. 6th Ed. Academic Press.
- Maragoni AG. 2003. *Enzyme Kinetics - A Modern Approach*. John Wiley.

- Palmer T. 2001. *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry*. 5th Ed. Horwood Publ.
- Price NC and Stevens L. 2003. *Fundamentals of Enzymology*. Oxford Univ. Press.
- Voet D, Voet JG and Pratt CW. 2006. *Fundamentals of Biochemistry of Life at the Molecular Level*. 2nd Ed. John Wiley and Sons.
- Wilson K and Walker J. (Eds.). 2000. *Principles and Techniques of Practical Biochemistry*. 5th Ed. Cambridge Univ. Press.
- Selected articles from standard journals.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Enzyme: Structure, mechanism, and regulation.	3
2.	Three dimensional structure of enzyme, flexibility and conformational mobility of enzymes	2
3.	enzyme families, dehydrogenase and dinucleotide fold, Multienzyme complexes	1
4.	Features and mapping of active site of enzymes, methods of examining enzyme-substrate complexes	2
5.	reaction mechanism of lysozyme, chymotrypsin, carboxypeptidase A and ribonuclease A.	1
6.	Regulation of enzyme activity by zymogen activation, covalent modification and feedback inhibition.	1
7.	Allosteric enzyme with special reference to aspartate trans carbomylase. Concerted and sequential models of allosteric enzymes.	2
8.	Enzyme catalysis: general acid-base, covalent electrostatic and metal ion catalysis, orbital steering	2
9.	Principles of kinetic equivalence and kinetic isotopic effects, transition state theory-application and significance of enzyme catalysis. Hammond postulate	2
10.	Enzyme kinetics and inhibition: factors influencing enzyme reaction velocity, steady-state kinetic of enzyme catalyzed reaction, significance of Michacelis-Menten parameters	2
11.	Extension and modification of the Michacelis-Menten mechanism. Kcat/ Km and kinetic perfection in enzyme catalysis	2
12.	Kinetics of multi-substrate system-random, sequential, ordered Theorell-chance and the ping-pong mechanisms.	2
13.	Competitive, non-compititive enzyme inhibition, suicide substrates and anti-metabolites.	1
14.	Recent developments: Industrial application of Enzymes	1
15.	Enzyme immobilization methods and application.	1
16.	Restriction endonucleases	1
17.	Enzyme engineering, use of site-directed mutagenesis for detection of enzyme mechanisms	1
18.	Abzymes and ribozymes, Enzyme linkering. Biosensors.	1
19.	Diagnostic enzymology: Assay of enzymes in clinical cases	1
20.	Enzymes in Pathogenesis, Enzyme histochemistry and cytochemistry	1
21.	Application of microscopy in enzymology	1
22.	Enzyme immuno diagnostics, Cholinesterase, lipase, amylase, GGT, GPx, arginase, AST, ALT and SDH in diagnosis of diseases of animals. Therapeutic Enzymes.	2
	Total	33

S. No.	Topic	No. of Lectures/ Practicals
Practical		
1.	Estimation of Antioxidant Enzymes (Superoxide dismutase, Glutathione Peroxidase, Catalase, Glutathione S-transferase) from tissue samples	3
2.	Isolation, purification and characterization of enzymes from biological samples.	4
3.	Application of enzymes in competitive bioassays (ELISA, RIA)	2
4.	Determination of Enzyme activity in Native Gel Electrophoresis.	2
5.	Estimation of Diagnostic enzymes from Clinical samples.	2
6.	Application of Restriction enzymes in cloning experiments.	3
	Total	**16**

I. Course Title : Diagnostic Techniques in Clinical Biochemistry

II. Course Code : BCT 704

III. Credit Hours : 0 + 2

IV. Pre-requisite

Should have studied BCT-605: Clinical Biochemistry of Animals (2+1) or other equivalent courses with similar syllabi/ content at Master's level.

V. Aim of the course

To give exposure about biochemical changes in diseases of animals and current developments of diagnostic techniques in clinical biochemistry.

VI. Theory

Unit I

Scope of diagnostic techniques in disease diagnosis. Fractionation of cell organelles. Molecular basis of cell injury and diseases; Molecular basis of autoimmunity, immunodeficiency, Immunochemical techniques: Immunochemical protein analysis: immunoelectrophoresis, immunofixation and immunoassays. Oncogenesis and tumour markers.

Unit II

Comparative ruminant metabolism, metabolism of various nutrients by micro flora. Postruminal digestion of dietary and microbial biomolecules. Metabolic disorders of rumen and recent development in disorders of ruminants associated with protein, carbohydrate, fat (LDL, HDL, VLDL, apoproteins, etc. and triglycerides), mineral and electrolyte metabolism.

Unit III

Photometric methods: spectrophotometry (UV, visible) atomic reflectometry, turbidimetry, nephelometry, spectrofluorometry, atomic emission, etc. Spectrometric methods: AAS, mass spectrometry, nuclear magnetic resonance (NMR), infra-red (IR) spectroscopy.

Unit IV

Functional tests: Nucleic acid extraction, DNA finger printing, micro and mini satellites, PCR, RT-PCR, RFLP, Fluorescent In-situ hybridization (FISH), genome mapping, DNA microarrays, biomolecular prospecting and molecular designing in clinical biochemistry.

Unit V

Tests for cardiovascular diseases: Involvement of enzymes in diagnostics of heart disease including aspartate transaminase, isoenzymes of creatine kinase and lactate dehydrogenase and troponin. Myocardial infarction and shock; enzyme patterns and marker proteins.

Unit VI

Diagnostic use of serum enzyme assays and radioactive isotopes. LFT, KFT and tests for drugs of abuse.

Unit VII

Case Based Learning and selected articles from journals pertaining to disease diagnosis.

VII. Suggested Reading

- Bishop ML, Fody EP and Schoeff LE. 2004. *Clinical Chemistry: Principles, Procedures, Correlations* 5th edition, Lippincott Williams and Wilkins Press
- Nelson DL and Cox MM. 2007. *Lehninger's Principles of Biochemistry*. 4th Ed. Freeman.
- Kaneko JJ, Harvey JH and Bruss ML. 2008. *Clinical Biochemistry of Domestic Animals*. 6th Ed. Academic Press.
- Voet D, Voet JG and Pratt CW. 2006. *Fundamentals of Biochemistry of Life at the Molecular Level*. 2nd Ed. John Wiley and Sons.
- Racek J and Rajdl D. 2016. *Clinical Biochemistry*. 1st Ed. Karolinum Press.

Course Outline

Sl. No.	Topics	No. of Practical
Practical		
1.	Scope of diagnostic techniques in disease diagnosis. Fractionation of cell organelles	2
2.	Molecular basis of cell injury and diseases	1
3.	Molecular basis of autoimmunity, immunodeficiency, Immunochemical techniques -Immunochemical protein analysis-immunoelectrophoresis, immunofixation and immunoassays	3
4.	Oncogenesis and tumour markers	2
5.	Comparative ruminant metabolism, metabolism of various nutrients by micro flora	1
6.	Postruminal digestion of dietary and microbial biomolecules.	1
7.	Metabolic disorders of rumen and recent development in disorders of ruminants associated with protein	1
8.	Metabolic disorders of rumen and recent development in disorders of ruminants associated with carbohydrates	2
9.	Metabolic disorders of rumen and recent development in disorders of ruminants associated with fat, mineral and electrolyte metabolism.	2
10.	Photometric methods: spectrophotometry (UV, visible) atomic reflectometry, turbidimetry, nephelometry, spectrofluorimetry, atomic emission, etc.	1
11.	Spectrometric methods: AAS, mass spectrometry, nuclear magnetic resonance (NMR), infra-red (IR) spectroscopy.	1

S. No.	Topics	No. of Practical
12.	Functional tests: Nucleic acid extraction, DNA finger printing, micro and mini satellites	1
13.	PCR, RT-PCR, RFLP, Fluorescent In-situ hybridization (FISH)	1
14.	Genome mapping, DNA microarrays	1
15.	Biomolecular prospecting and molecular designing in clinical biochemistry	1
16.	Tests for cardiovascular diseases: Involvement of enzymes in diagnostics of heart disease including aspartate transaminase, isoenzymes of creatine kinase and lactate dehydrogenase and troponin	2
17.	Myocardial infarction and shock; enzyme patterns and marker proteins.	1
18.	Diagnostic use of serum enzyme assays	1
19.	Radioactive isotopes in radiodiagnosis	1
20.	Liver function tests (LFT)	1
21.	Liver function tests (KFT)	1
22.	Tests for drugs of abuse	1
23.	Case Based Learning and selected articles from journals pertaining to disease diagnosis	1
	Total	**30**

I. Course Title : Recent Trends In Biochemical Techniques And Instrumentation

II. Course Code : BCT 705

III. Credit Hours : 2 + 1

IV. Pre-requisite

Should have studied VBC-604: Analytical Techniques and Instrumentation in Biochemistry (2+1) or other equivalent courses with similar syllabi/ content at Master's level.

V. Aim of the course

To expose students about current developments in techniques used in animal biochemistry.

VI. Theory

Basic components of the Instrument, principle and applications of the following analytical techniques:

Unit I

Separation, purification and quantification of biomolecules:
Gas Chromatography (GC) and High performance liquid chromatography (HPLC) - Types of pumping systems and their essential features; Column packing; Normal and modified stationary phases; Detection systems;
Blotting techniques (Western), 2-D gel electrophoresis – IPG-DALT, IEF-SDS PAGE

Unit II

Structural elucidation of biomolecules and quantification:
NMR spectrometry, X-ray crystallography, ESR Spectroscopy, CD Spectroscopy and Mass Spectrometry (LC/ MS, GC/ MS, MALDI-TOF, SELDI-TOF).
Microscopy – Electron microscopy – SEM/ TEM/ STEM; Atomic force microscopy (AFM) or scanning force microscopy (SFM); Scanning Tunnelling Microscope (STM).

Unit III

Other Analytical techniques: Radiotracer techniques: Radiotracers in study of biological processes.

Tissue Culture: Setting up a cell culture laboratory; Principles of aseptic handling;, Cell line derivation; Cell freezing and quantitation; Contamination control; Cell freezing and thawing; Cell culture media constituents and their functions; Designing serum-free medium. Techniques for short-term and long-term culture of organs. Any other current technique with relevance to biochemistry.

VII. Practical

Demonstration of feasible techniques available at the department/ institute/ other institutes.

VIII. Suggested Reading

- Burtis CA, Ashwood ER and Burns DE. 2014. *Tietz Textbook of clinical Biochemistry and Molecular Diagnostics*. 5th Edition. Elsevier
- Nelson DL and Cox MM. 2017. *Lehninger's Principles of Biochemistry*. 7th Ed. Freeman.
- Garrity S. 1999. *Experimental Biochemistry*. 3rd Ed. Academic Press.
- Gowenlock AH. 2002. *Varley's Practical Clinical Biochemistry*. 6th Ed. CBS.
- George W Latimer Jr. 2016. *Official Methods of Analysis of AOAC International*, 20th Ed. AOAC International.
- Holme DJ and Hazel P. 1998. *Analytical Biochemistry*. 3rd Ed. Longman.
- Wilson K and Walker J. (Eds.). 2010. *Principles and Techniques of Biochemistry and Molecular Biology*. 7th Ed. Cambridge Univ. Press.
- Willard *et al*. 1988. *Instrumental Methods of Analysis*. 7th Ed. Wadsworth Pub Co.
- Selected articles from standard journals.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Gas Chromatography (GC) - Types of pumping systems and their essential features;S Column packing; Normal and modified stationary phases; Detection systems	4
2.	High performance liquid chromatography (HPLC) - Types of pumping systems and their essential features; Column packing; Normal and modified stationary phases; Detection systems	4
3.	Western blotting of proteins	1
4.	2-D gel electrophoresis of proteins – IPG-DALT, IEF-SDS PAGE	1
5.	NMR spectrometry	2
6.	X-ray crystallography	2
7.	ESR Spectroscopy	2
8.	CD Spectroscopy	2
9.	Mass Spectrometry (LC/ MS, GC/ MS, MALDI-TOF, SELDI-TOF)	3
10.	Electron microscopy – SEM/ TEM/ STEM	3
11.	Atomic force microscopy (AFM)	1
12.	Scanning Tunneling Microscopy (STM)	1
13.	Radiotracers in study of biological processes	2
14.	Tissue Culture: Setting up a cell culture laboratory; Principles of aseptic handling;, Cell line derivation; Cell freezing and quantitation; Contamination control; Cell freezing and thawing; Cell culture media	

S. No.	Topic	No. of Lectures/ Practicals
	constituents and their functions; Designing serum-free medium. Techniques for short-term and long-term culture of organs, etc.	3
15.	Any other current technique	1
	Total	32
Practical		
1.	Gas Chromatography (GC)	1
2.	High performance liquid chromatography (HPLC)	1
3.	Western blotting of proteins	1
4.	2-D gel electrophoresis of proteins	1
5.	NMR spectrometry	1
6.	X-ray crystallography	1
7.	ESR Spectroscopy	1
8.	CD Spectroscopy	1
9.	Mass Spectrometry (LC/ MS, GC/ MS, MALDI-TOF, SELDI-TOF).	1
10.	Electron microscopy – SEM/ TEM/ STEM	1
11.	Atomic force microscopy (AFM)	1
12.	Scanning Tunneling Microscopy (STM)	1
13.	Radiotracers	1
14-16.	Tissue Culture	3
	Total	**16**

I. Course Title : Developmental Biochemistry

II. Course Code : BCT 706

III. Credit Hours : 2 + 0

IV. Pre-requisite

Should have studied VBC-609: Endocrinology and Reproductive Biochemistry or other equivalent courses with similar syllabi/ content at Master's level.

V. Aim of the course

To understand the developmental processes in embryogenesis and its gene expression.

VI. Theory

Unit I

Biochemistry of fertilization - Sperm-egg structure - Acrosome reaction and capacitation, Sperm-egg interaction –receptors involved; sperm entry into egg; zygote formation. Formation of multicellular and multi-layered embryo: factors affecting cleavage of zygote; Types of cleavage; blastula formation; gastrulation; neurulation; somite formation and cell migration; factors affecting cell migration; cell-cell interactions and their expression; involvement of extracellular matrix during development(cell movement and regulation of shape); growth factors and their role; organogenesis-biochemistry and molecular biology. Application of "OMICS" techniques in developmental biology.

Unit II

Development and differentiation: Genes involved in the development of Drosophilla and C. elegans and their regulation. Expression of genes during differentiation of anterior and posterior and dorsal and ventral halves, head; thorax and abdomen. Pattern formation and positional information: Inductive interaction in the development of epithelia and body parts.

VII. Suggested Reading

- Scott F Gilbert. 2010. *Developmental Biology*, 9th edition. Sunderland (MA): Sinauer Associates.
- Scott Freeman 2014. *Biological Science*, 5th edition. Publisher: Benjamin-Cummings Publishing Co.
- Selected articles from standard journals.

Course Outline

S. No.	Title	No. of Lectures
Theory		
1.	Biochemistry of fertilization.	1
2.	Sperm-egg structure. Acrosome reaction and capacitation	3
3.	Sperm-egg interaction –receptors involved; sperm entry into egg; zygote formation.	3
4.	Formation of multicellular and multi-layered embryo: factors affecting cleavage of zygote; Types of cleavage	3
5.	Blastula formation; gasrulation; neurulation; somite formation and cell migration; factors affecting cell migration; cell-cell interactions and their expression; involvement of extracellular matrix during development(cell movement and regulation of shape); growth factors and their role;	5
6.	Organogenesis-biochemistry and molecular biology.	3
7.	Application of “OMICS” techniques in developmental biology.	3
8.	Development and differentiation: Genes involved in the development of Drosophilla and C. elegans and their regulation	4
9.	Expression of genes during differentiation of anterior and posterior and dorsal and ventral halves, head; thorax and abdomen.	4
10.	Pattern formation and positional information: Inductive interaction in the development of epithelia and body parts.	3
	Total	**32**

I. Course Title : Bioinformatics Tools in Biochemistry

II. Course Code : BCT 707

III. Credit Hours : 1 + 1

IV. Pre-requisite

Should have studied VBC-611: Introduction to Bioinformatics and Computational Biology or other equivalent courses with similar syllabi/ content at Master’s level.

V. Aim of the course

To impart knowledge of Bioinformatics applicable to biochemistry

VI. Theory

Unit I

Biological databases, nucleic acid and protein sequence databases; Pair wise sequence alignment; global and local alignments, matrices, gap penalties; Multiple sequence alignment and phylogenetic analysis-methods and programs

Unit II

Genome sequencing using next generation sequencing (NGS) technologies, sequence assembly and comparison, human genome, livestock, bacterial and viral genomes, Computational gene discovery; Gene and promoter prediction; Microarray technology: basic concept and application

Unit III

Protein structure- secondary and tertiary structure prediction; Homology and ab-initio based tertiary structure prediction; Structure validation tools, Ramachandran Map; protein motifs and domain prediction; RNA folding and secondary structure predictions

Unit IV

Metabolomics: concepts and principles; Nutrigenomics: bioinformatics in nutrition and health; Pharmacogenomics: introduction, applications, current and future perspectives

VII. Practical

- Practical application of NCBI resources
- Web based tools: Expasy, SwissProt, EBI
- Perform local alignment using different BLAST variants
- Multiple sequence alignment using ClustalW, T Coffee
- Analysis packages-commercial databases and packages, GPL software for Bioinformatics
- Database searching
- Phylogenetic analysis by PHYLIP and MEGA tools
- Protein structure visualization tools: RASMOL, SWISSPDB viewer,
- Homology modelling and structure validation of protein structures
- Tools for protein secondary and tertiary structure prediction- SANJIVNI, BHAGIRATH, SWISS Model, MODELLER, ROSETTA, I-TASSER, etc.
- Biomolecule chemical structure creation and modification using ChemSketch

VIII. Suggested Reading

- *Essential bioinformatics* 2006. Xin Xiong. Cambridge University Press
- *Discovering Genomics, Proteomics and Bioinformatics* 2007. A. Malcolm Campbell and Laurie J Heyer. Benjamin Cummings.
- *Proteins: Structures and Molecular Properties* 1993. Creighton TE. W.H. Freeman.
- *Bioinformatics: Sequence and Genome Analysis* 2001. Mount DW. Cold Spring Harbor.
- *Introduction to Computational Molecular Biology* 1997. Setubal Joao and Meidanis Joao. PWS Publishing Company.
- *Bioinformatics: Concepts, Skills and Applications* 2004. Rastogi SC, Mendiratta N and Rastogi P. CBS.
- *Principles of Genome Analysis and Genomics* 2003. SB. Primrose and R.M. Twyman, Blackwell Publishing.
- *Molecular Analysis and Genome Discovery* 2004. Ralph Rapley and Stuart Harbron (Eds.), John Wiley and Sons.
- *BioInformatics* 2001. Andreas D. Baxevanis and B. F. Francis Ouellette (Eds.).
- Online Resources available on Internet and Selected articles from standard journals.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Biological databases: nucleic acid and protein sequence databases	1
2.	Pair wise sequence alignment, global and local alignments, matrices, gap penalties	1
3.	Multiple sequence alignment: methods and programs	1
4.	Phylogenetic analysis: methods and applications	1
5.	Genome sequencing technologies-traditional and next generation sequencing (NGS)	1
6.	Assembly and comparison of genome: Human genome, livestock and bacterial genomes	1
7.	Computational gene discovery, Gene and promoter prediction	1
8.	Microarray technology: basic concept and application	1
9.	Protein structure- secondary and tertiary structure prediction	1
10.	Homology and ab-initio based tertiary structure prediction	1
11.	Protein structure validation tools, Ramachandran Map	1
12.	Protein motifs and domain prediction	1
13.	RNA folding and secondary structure predictions	1
14.	Metabolomics: concepts and principles	1
15.	Nutrigenomics: bioinformatics in nutrition and health	1
16.	Pharmacogenomics: introduction, applications, current and future perspectives	1
	Total	16
Practical		
1.	Practical application of NCBI resources	3
2.	Web based tools: Expasy, SwissProt, EBI	1
3.	Local alignment using different BLAST variants	2
4.	Multiple sequence alignment using ClustalW, T Coffee	1
5.	Commercial bioinformatics databases and packages, GPL software for Bioinformatics	2
6.	Database searching	1
7.	Phylogenetic analysis by PHYLIP and MEGA tools	1
8.	Protein structure visualization tools: RASMOL, SWISSPDB viewer, UCSF ChimeraX	1
9.	Homology modelling and structure validation of protein structures	1
10.	Practice on tools for protein secondary and tertiary structure prediction: SANJIVNI, BHAGIRATH, SWISS Model, MODELLER, ROSETTA, I-TASSER, etc.	2
11.	Biomolecule chemical structure creation and modification using ChemSketch	1
	Total	**16**

I. Course Title : Environmental and Toxicological Biochemistry

II. Course Code : BCT 708

III. Credit Hours : 2 + 0

IV. Aim of the course

To impart awareness on environmental pollutants and toxicants affecting livestock and poultry; Clinical Biochemistry in Toxicology.

V. Theory

Unit I

Introduction to environmental pollutants and toxicants, their classification, sources and impact on animal health including poultry. Effect of various pollutants on animal and microbial metabolism; their detoxification mechanism in animals and birds, Biochemical basis of pollutant tolerance. Soil enzymes, their source and role in environment, methods for measurement of pollution, Pesticide residues and its effect on animal health. environmental chemo-dynamics. Heavy metals and metalloids, industrial chemicals and biotoxins on animal health and productivity.

Unit II

Water pollution, biochemical basis for measuring water pollution, chemical properties of water-physical, chemical and biological treatment process. Biochemical oxygen demand and water quality assessment. Biochemical aspects of water quality.

Unit III

Global environmental issues in the light of biochemistry, methanogenesis and role of ruminants, global warming, green house gases, acid rain and their effects on animal health and productivity.

Unit IV

Distribution and storage of toxicants in animal body, target organ toxicity, biotransformation and elimination of toxicants, methods for measurement of toxin level in animals.

Unit V

Clinical Biochemistry in Toxicology- Hepatotoxicity and biochemical changes due to hepatotoxicity, Nephrotoxicity and its effect, Effects of toxins on lungs, respiratory tract, endocrine system, nervous system, erythrocyte and haematopoietic system. Toxins affecting haemoglobin and oxidative metabolism.

VI. Suggested Reading

- Casarett, Louis J.; Doull, John. *Casarett and Doull's Toxicology: The Basic Science of Poisons* 8th ed.: New York: McGraw-Hill, 2013. ISBN:9780071769235
- Hayes AW, Kruger CL. *Hayes' principles and methods of toxicology* 6th ed. ISBN:9781842145364
- Kaneko JJ, Harvey JW and Bruss ML. *Clinical Biochemistry of Domestic Animals, Academic* press, ISBN 13:978-0-12-370491-7.
- Selected articles from journals.

Course Outline

S. No.	Topic	No. of Lectures
Theory		
1	Introduction to environmental pollutants and toxicants, their classification	2
2	Sources and impact of pollutants and toxicants on animal health including poultry	2
3	Effect of various pollutants on animal and microbial metabolism	2

S. No.	Topic	No. of Lectures
4	Detoxification mechanism in animals and birds	2
5	Biochemical basis of pollutant tolerance	1
6	Soil enzymes, their source and role in environment	1
7	Methods for measurement of pollution	1
8	Pesticide residues and its effect on animal health	1
9	Environmental chemo-dynamics	1
11	Heavy metals and metalloids, industrial chemicals and biotoxins on animal health and productivity.	2
12	Water pollution, biochemical basis for measuring water pollution	1
13	Chemical properties of water-physical, chemical and biological treatment process	1
14	Biochemical oxygen demand and water quality assessment	1
15	Biochemical aspects of water quality	1
16	Distribution and storage of toxicants in animal body	1
17	Target organ toxicity	1
18	Introduction to environmental pollutants and toxicology	1
19	Biotransformation and elimination of toxicants	2
20	Methods for measurement of toxin level in animals	1
21	Clinical Biochemistry in Toxicology	1
22	Hepatotoxicity and biochemical changes due to hepatotoxicity	1
23	Nephrotoxicity and its effect	1
24	Effects of toxins on lungs, respiratory tract, endocrine system, nervous system, erythrocyte and haematopoietic system	2
25	Toxins affecting haemoglobin and oxidative metabolism.	2
	Total	**32**

I. Course Title : Biochemistry of Diseases and Disorders

II. Course Code : BCT 709

III. Credit Hours : 2 + 0

IV. Pre-requisite

Should have studied BCT-605:Clinical Biochemistry of Animals (2+1) or other equivalent courses with similar syllabi/ content at Master's level.

V. Aim of the course

To update general biochemical concepts for an understanding of biological and chemical principles underlying health, disease and disorders of animals and poultry.

VI. Theory

Unit I

Scope of biochemistry and its applications in understanding the development of diseases and their control.

Biochemical basis of Immunological diseases: Equine immuno- deficiency, neutrophil function defects and its testing, Autoimmune Diseases, Primary Immune Deficiency Diseases, Secondary Immunodeficiency, Hypersensitivity Diseases.

Endocrine diseases arising from over or under production of hormones or from resistance to a particular hormone; Thyroid disorders; Pancreatic disorders; Cushings disease. Hemostatic diseases: Role of Vascular Endothelium, Platelets, Coagulation Proteins, Complexes, and Thrombin Activation; Fibrinolysis, Hereditary and Acquired disorders of hemostasis.

Unit II

Nutritional diseases arising from over or under-nutrition of fat and water soluble vitamins and minerals: Night blindness, pernicious anaemia, iron overload, metabolic disorders of iron metabolism, rickets, osteomalacia, milk fever, swayback, anaemia of Inflammatory disease.

Toxic diseases: Hepatotoxicity, Nephrotoxicity; Toxins affecting: Skeletal and Cardiac muscle; Lung and Respiratory tract; Gastrointestinal tract; Erythrocytes, Haematopoietic system, Hemoglobin and oxidative metabolism; Endocrine system, Nervous system and neuromuscular disorders.

Unit III

Neoplastic diseases: Biochemical changes in development of various neoplasms, Deranged glucose metabolism in cancerous tissue, oncogenesis.

Degenerative diseases: *Neurodegenerative diseases* – including amyotrophic lateral sclerosis, Parkinson's *disease*, Alzheimer's *disease*, and Huntington's *disease*. Molecular basis of cell injury and diseases by Free Radicals.

Unit IV

Biochemical basis of cardiomyopathies in dogs and birds, Prions disease (Scrapie), Bovine spongiform encephalopathy, Reticuloendotheliosis in poultry, Avian Influenza; Retinitis pigmentosa, retinal degeneration and Lysosomal storage diseases in animals.

Comparative medical genetics: Genome sequences, Disease Gene Mapping, Genetic diseases, Gene therapy

VII. Suggested Reading

- Charles A Janeway Jr, Paul Travers, Mark Walport and Mark J Shlomchik. 2001. *Immunobiology, The Immune System in Health and Disease*, 5th edition, New York.
- David L Nelson and Cox Michael M. 2017. *Lehninger's Principles of Biochemistry*. 7th Ed. Freeman.
- Kaneko JJ, Harvey JW and Bruss ML. *Clinical Biochemistry of Domestic Animals*, Academic press, ISBN 13:978-0-12-370491-7.
- Kenneth M Murphy and Casey Weaver 2016. *Janeway's Immunobiology*, 9th Edition ISBN: 978-0-815-34505-3.
- Thomas M. Devlin (Ed) 2011. *Textbook of Biochemistry with Clinical Correlations*, John Wiley and Sons.
- Voet D, Voet JG and Pratt CW. 2016. *Fundamentals of Biochemistry of Life at the Molecular Level*. 5th Ed. John Wiley and Sons.
- Selected articles from standard journals.

Course Outline

S. No.	Topic	No. of Lectures
Theory		
1.	Scope of biochemistry and its applications in understanding the development of diseases and their control	1
2.	Biochemical basis of Immunological diseases: Equine immuno-deficiency, neutrophil function defects and its testing, Autoimmune Diseases, Primary Immune Deficiency Diseases, Secondary Immuno deficiency, Hypersensitivity Diseases	3
3.	Endocrine diseases arising from over or underproduction of hormones or from resistance to a particular hormone; Thyroid disorders; Pancreatic disorders; Cushings disease.	2

S. No.	Title	No. of Lectures
4.	Hemostatic diseases: Role of Vascular Endothelium, Platelets, Coagulation Proteins, Complexes, and Thrombin Activation; Fibrinolysis, Hereditary and Acquired disorders of hemostasis.	2
5.	Nutritional diseases arising from over or under-nutrition of fat and water soluble vitamins and minerals: Night blindness, pernicious anaemia, iron overload, metabolic disorders of iron metabolism, rickets, osteomalacia, milk fever, swayback, anaemia of Inflammatory disease.	4
6.	Toxic diseases: Hepatotoxicity, Nephrotoxicity; Toxins affecting: Skeletal and Cardiac muscle; Lung and Respiratory tract; Gastrointestinal tract; Erythrocytes, Haematopoietic system, Hemoglobin and oxidative metabolism; Endocrine system, Nervous system and neuromuscular disorders.	4
7.	Neoplastic diseases: Biochemical changes in development of various neoplasms, Deranged glucose metabolism in cancerous tissue, oncogenesis.	4
8.	Degenerative diseases: *Neurodegenerative diseases* – including amyotrophic lateral sclerosis, Parkinson's *disease*, Alzheimer's *disease*, and Huntington's *disease*; Molecular basis of cell injury and diseases by Free Radicals.	4
9	Biochemical basis of cardiomyopathies in dogs and birds, Prions disease (Scrapie), Bovine spongiform encephalopathy, Reticuloendotheliosis in poultry, Avian Influenza; Retinitis pigmentosa, retinal degeneration and Lysosomal storage diseases in animals.	5
10	Comparative medical genetics: Genome sequences, Disease Gene Mapping, Genetic diseases, Gene therapy.	3
	Total	**32**

I. Course Title : Immuno-biochemistry

II. Course Code : BCT 710

III. Credit Hours : 2 + 0

IV. Aim of the course

To impart knowledge about fundamental principles and applications of immunology and immunochemical research techniques.

V. Theory

Unit I

History and scope of immunology, Cellular basis of immunity-adaptive and non-adaptive immunity, Memory, Specificity and Diversity, Self and non self discrimination, Immune system, Organs, tissues and cells, Cell mediated vs Humoral immunity, Immunoglobulins, Concept of antigen, Immunogen, Adjuvant, Hapten

Unit II

Classes of antibodies, Antibody diversity, Theories of generation of antibody diversity, Monoclonal antibodies, Polyclonal antibodies, Hybridoma, Recombinant antibodies, Single chain and single domain antibodies in immunodiagnostics and immunotherapy, Phage display library, complement system- classical and alternate.

Unit III

Cellular interactions in the immune response, affinity, avidity, B-cell and T-cell response, major histocompatibility complex, cell mediated immune response, cytokines, Vaccine. Nanoparticles in vaccine development and delivery, Nanomedicine in immunodiagnostics and immunotherapy, Immunoregulation, immunological tolerance, hypersensitivity, innate resistance and specific immunity.

Unit IV

Current immunological techniques: Raising of antisera and antibody purification, Immunodiffusion, Immunoelectrophoresis, immunofluoresence, rocket electrophoresis, Immunological markers and fluorescence-activated cell sorting, Radioimmuno assay (RIA) and different types of ELISA, Immunohistochemistry, Immunoinformatics techniques.

VI. Suggested Reading

- Abbas AK and Lichtman AH. 2003. *Cellular and Molecular Immunology*. 5th Ed. WB Saunders.
- David J Dabbs. 2018. *Diagnostic Immunohistochemistry*. 5th Ed. Elsevier.
- Goldsby RA, Kindt TJ and Osborne BA. 2003. *Immunology*. 4th Ed. WH Freeman.
- Harlow and Lane D. (Eds.). 1988. *Antibodies: A Laboratory Manual*. Cold Spring Harbor Laboratory.
- *Immunochemistry*: Edited by CJ van Oss and MHV van Reganmortel. pp 1069. Marcel Dekker, New York. 1994. ISBN 0 8247 9123 1; TR O'Brien.
- Ivan Roitt (Eds.). 1997. *Essential Immunology* Publisher -Blackwell Scientific Publication, Oxford.
- Kuby J. 1996. *Immunology*. 3rd edition WH Freeman.
- Male D, Brostoff J, Roth DB and Roitt I. 2006. *Immunology*. 7th Ed. Elsevier.
- Manson MM. (Eds.). 1992. *Immunochemical Protocols: Methods in Molecular Biology* Vol. 10- Humana Press Totowa NJ.
- Mariusz Skwarczynski, Istvan Toth. 2017. *Micro and Nanotechnology in Vaccine Development*. 1st ed. Elsevier.
- Mathew Sebastian, Neethu Ninan AK. Haghi. 2012. *Nanomedicine and Drug Delivery*. 1st Ed. Apple Academic Press.
- Selected articles from standard journals.

Course Outline

S. No.	Title	No. of Lectures
Theory		
1.	History and scope of immunology, cellular basis of immunity-adaptive and non-adaptive immunity, memory, specificity and diversity, self and non self-discrimination,	2
2.	Immune system, organs, tissues and cells, cell mediated vs humoral immunity, immunoglobulins	3
3.	Concept of antigen, immunogen, adjuvant, hapten	1
4.	Classes of antibodies, Antibody diversity, theories of generation of antibody diversity,	3
5.	Monoclonal antibodies, polyclonal antibodies, Hybridoma, Recombinant antibodies, Single chain and single domain antibodies in immunodiagnostics and immunotherapy, Phage display library	4
6.	Complement system- classical and alternate.	2
7.	Cellular interactions in the immune response, affinity, avidity, B-cell and T-cell response, major histocompatibility complex, cell mediated immune response, cytokines.	4
8.	Vaccine Nanoparticles in vaccine development and delivery, Nanomedicine in immunodiagnostics and immunotherapy,	3

S. No.	Topics	No. of Lectures
9.	Immunoregulation, immunological tolerance, hypersensitivity, innate resistance and specific immunity.	2
10.	Current immunological techniques: Raising of antisera and antibody purification,	1
11.	Immunodiffusion, Immunoelectrophoresis, immunofluoresence, rocket electrophoresis	2
12.	Immunological markers and fluorescence-activated cell sorting.	1
13.	Radioimmuno assay (RIA) and different types of ELISA.	2
14.	Immunohistochemistry.	1
15.	Immunoinformatics techniques.	1
	Total	**32**

I. Course Title : Special Problem

II. Course Code : BCT 711

III. Credit Hours : 0+2

IV. Aim of the course

To provide expertise in handling practical research problem(s).

V. Practical

Short research problem(s) involving contemporary issues and research techniques.

VI. List of Journals

- *Indian Journal of Chemical Technology*
- *Indian Journal of Biochemistry and Biophysics*
- *Indian Journal of Chemistry - Section B*
- *Indian Veterinary Journal*
- *Journal of Chemical Sciences*
- *Journal of Indian Chemical Society*
- *Meat Science - An International Journal*
- *The EMBO Journal*
- *Theriogenology*
- *Trends in Biochemical Sciences*

e-Resources

- www.niscair.res.in/ScienceCommunication (Indian Journal of Biochemistry)
- www.medind.nic.in/iaf/iafm.shtml (Indian Journal of Clinical Biochemistry)
- www.ijcb.co.in (Indian Journal of Clinical Biochemistry)
- www.mcponline.org (Molecular and Cellular Proteomics)
- www.elsevier.com/vj/proteomics (Proteomics Virtual Journal)
- www.elsevier.com (Journal of Proteomics)
- www.elsevier.com (Clinical Biochemistry)
- www.sciencedirect.com/science/journal (Science Direct – Clinical Biochemistry)
- www.jbc.org (Journal of Biological Chemistry)

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Basic Veterinary Sciences
– Veterinary Biotechnology

Preamble

Considering latest trends in Veterinary Biotechnology four new courses at Doctorate level, i.e. Recent Trends in Cell and Molecular Biology, Diagnostic Platform, Gene Manipulation and Genome Editing and Recent trends in Bioinformatics have been introduced and some courses are reorganized

Course Title with Credit Load
M.V.Sc. in Veterinary Biotechnology

Course Code	Course Title	Credit Hours
BTY 601	Basic and Applied Biotechnology	2+0
BTY 602	Fundamentals of Cell Biology	2+0
BTY 603	Molecular Biology and Genetic Engineering	2+0
BTY 604	Animal Cell Culture–Principles and Applications	2+1
BTY 605	Molecular Diagnostics	2+1
BTY 606	Immunology Applied to Biotechnology	2+1
BTY 607	Introduction to Bioinformatics	2+1
BTY 608	Animal Genomics	2+1
BTY 609	Techniques in Molecular Biology and Genetic Engineering	0+2
BTY 610	Reproductive Biotechnology	2+1
BTY 611	Masters Seminar	1+0
BTY 612	Masters Research	0+30

Course Contents
M.V.Sc. in Veterinary Biotechnology

I. Course Title : Basic and Applied Biotechnology
II. Course Code : BTY 601
III. Credit Hours : 2+0
IV. Theory

Unit I

History and scope of Biotechnology, Application of Biotechnology in Agriculture, Veterinary Sciences, diagnostics and therapeutics, pharmaceutical industry, food industry, chemical industry and environment, plant tissue culture and its applications

Unit II

Biofermentation, Fermentation technology, aerobic and anaerobic fermentation, Different types of fermentations, Basic design and construction of fermenter, Media sterilization, Upstream and Downstream processing, Microbes and enzymes of industrial importance, Microbial growth kinetics, Immobilized enzymes and cells and immobilization process.

Unit III

Vaccines and their immune response, Types of vaccines: Conventional and new generation vaccine, Subunit vaccine, recombinant vaccines, Vectored vaccines, DNA vaccine, edible vaccine, DIVA strategy and reverse vaccinology

Unit IV

Biodiversity, genetic diversity, molecular taxonomy, species and population biodiversity, quantifying biodiversity, maintenance of ecological diversity, conservation of biodiversity and conservation of animal genetic resources.

V. Suggested Readings

- Becker JM, Cold Well GA and Zachgo EA. 2007. *Biotechnology a Laboratory Course*. Academic Press.
- Brown CM, Campbell I and Priest FG. 2005. *Introduction to Biotechnology*. Panima.
- Singh BD. 2006. *Biotechnology Expanding Horiozon*. Kalyani

S No.	Topics	Lecture No.
1.	History and scope of Biotechnology, Application of Biotechnology in agriculture, veterinary sciences, diagnostics and therapeutics, pharmaceutical industry, food industry, chemical industry and environment, plant tissue culture and its applications	1-3
2.	Biofermentation	4
3.	Fermentation technology, aerobic and anaerobic fermentation	5
4.	Different types of fermentations	6
5.	Basic design and construction of fermenter	7

S No.	Topics	Lecture No.
6.	Upstream processing- Media sterilization, inoculum preparation and and Downstream processing	8
7.	Microbes and enzymes of industrial importance, Microbial growth kinetics and products.	9
8.	Immobilized enzymes and cells and immobilization process	10
9.	Vaccines and their immune response	11
10.	Types of vaccines -Conventional and new generation vaccine	12-14
11.	Subunit vaccine, recombinant vaccines	15
12.	Vectored vaccines and DNA vaccine and their immune response	16
13.	Edible vaccine, DIVA strategy and reverse vaccinology	17-20
14.	Biodiversity, genetic diversity, molecular taxonomy, species and population biodiversity	21-22
15.	Quantifying biodiversity, maintenance of ecological diversity	23-25
16.	Conservation of biodiversity and conservation of animal genetic resources	26-28

I. Course Title : Fundamentals of Cell Biology

II. Course Code : BTY602

III. Credit Hours : 2 + 0

IV. Aim of the course

Understanding the functions of cell components and cell signal pathways

V. Theory

Unit I

Origin and evolution of cells – from molecules to first cell – from prokaryotes to eukaryotes – from single to multi cellular organisms – Chemical components of a cell – catalysis and use of energy by cells – techniques used to study cells – microscopy – light microscopy – fluorescent microscopy – electron microscopy – confocal microscopy – cell and cell parts separation techniques – ultracentrifugation – flow cytometry – detection of cell parts - antibodies

Unit II

Structure of cell – Plasma membrane – cytoskeleton – Nucleus – Chromosome-Chromosomal DNA packaging and its implications - endoplasmic reticulum – ribosome - mitochondria –Mitochondrial DNA organization - golgi complex – peroxisome - lysosome

Unit III

Cell Membrane transport – transport of small molecules - macromolecules and particles- exocytosis and endocytosis – Nuclear transport –protein synthesis and sorting – endoplasmic reticulum – golgi complex – peroxisomes – lysomes – lipid synthesis and sorting – Electron transport chain – chemiosmotic coupling - Transport of metabolites across the inner mitochondrial membrane – Mechanism of muscle contraction – cell crawling – functions of keratin and neurofilaments – organelle transport and separation of mitotic chromosome

Unit IV

Cell signaling – modes of cell-cell signaling- steroid hormones and the steroid receptor super family – Neurotransmitters - Peptide Hormones and Growth Factors - G Protein-Coupled Receptors - Receptor Protein-Tyrosine Kinases - Cytokine Receptors and Non receptor Protein-Tyrosine Kinases - The cAMP Pathway: Second Messengers and Protein Phosphorylation - Cyclic GMP - Phospholipids and Ca^{2+} - Ras, Raf, and the MAP Kinase Pathway - The JAK/ STAT Pathway - Integrins and Signal Transduction - Regulation of the Actin Cytoskeleton - Hedgehog and Wingless - Notch Signaling – Cell signal network - Feedback and crosstalk and networks of cellular signal transduction – cell cycle – regulators of cell cycle – events of M phase

VI. Suggested Readings

- Lewin B. 2008. *Gene IX*. Jones and Bartlett.
- Primrose SB. 2001. *Molecular Biotechnology*. Panima.
- Twyman RM. 2003. *Advanced Molecular Biology*. Bios Scientific

S. No.	Topic	No. of Lectures
1.	Origin and evolution of cells from molecules to first cell from prokaryotes to eukaryotes from single to multicellular organisms	1
2.	Chemical components of a cell Catalysis and use of energy by cells	2
3.	Techniques used to study cells Principles and applications of microscopy, light microscopy, fluorescent microscopy, electron microscopy and confocal microscopy, Cell and cell parts separation techniques Principles and applications of ultracentrifugation and flow cytometry Detection of cell parts Primary and secondary antibodies used to detect cell parts	3-4
4.	Structure of cell, Plasma membrane, Cytoskeleton	5
5.	Structure of cell, Nucleus, Chromosome Chromosomal DNA packaging and its implications	6
6.	Structure of cell, Endoplasmic reticulum, Ribosome Mitochondria	7
7.	Structure of cell, Mitochondrial organization, Golgi complex Peroxisome, Lysosome	8
8.	Cell Membrane transport, Transport of small molecules, Macromolecules and particles	9
9.	Cell Membrane transport, Exocytosis and endocytosis Nuclear transport	10
10.	Cell Membrane transport, Protein synthesis and sorting into Endoplasmic reticulum Golgi complex	11
11.	Cell Membrane transport, Protein synthesis and sorting into Peroxisomes, Lysomes Lipid synthesis and sorting	12-13
12.	Cell Membrane transport, Electron transport chain Chemiosmotic coupling	14
13.	Transport of metabolites across the inner mitochondrial membrane	15
14.	Mechanism of muscle contraction, cell crawling functions of keratin and neurofilaments	16
15.	Cell Membrane transport, organelle transport separation of mitotic chromosome	17
16.	Cell signaling, Modes of cell-cell signaling Steroid hormones and the steroid receptor super family	18
17.	Cell signaling, Neurotransmitters, Peptide Hormones and Growth Factors	19
18.	Cell signaling, G Protein-Coupled Receptors Receptor Protein-Tyrosine Kinases	20

S. No.	Topic	No. of Lectures
19.	Cell signaling, Cytokine Receptors Non receptor Protein-Tyrosine Kinases	21
20.	Cell signaling, The cAMP Pathway Second Messengers and Protein Phosphorylation	22
21.	Cell signaling, Cyclic GMP Phospholipids and Ca^{2+}	23
22.	Cell signaling Ras, Raf, and the MAP Kinase Pathway The JAK/ STAT Pathway Integrins and Signal Transduction	24
23.	Cell signaling, Regulation of the Actin Cytoskeleton Hedgehog and Wingless Notch Signaling	25-26
24.	Cell signaling, Cell signal network, Feedback and crosstalk Networks of cellular signal transduction	27
25.	Cell cycle, Regulators of cell cycle Events of M phase	28

I. Course Title : Molecular Biology and Genetic Engineering

II. Course Code : BTY 603

III. Credit Hours : 2+0

IV. Aim of the course

Understanding the principles of molecular biology and genetic engineering.

Unit I

History and scope of molecular biology – Discovery of DNA and evidence for DNA as the genetic material - structure of DNA, RNA and proteins – Organization of prokaryotic and eukaryotic genome – Gene transfer in micro organisms like conjugation, transformation, transduction and protoplastic fusion – DNA replication - genetic code - transcription, RNA processing and alternative splicing - Translation in prokaryotes and eukaryotes - Regulation of gene expression.

Unit II

Enzymes used in molecular biology and recombinant DNA research - Cloning vectors – plasmids, phages, phagemids, cosmids, BAC, YAC - Expression vector – bacterial, viral, baculo and yeast vectors, shuttle vectors - Polymerase chain reaction and different types of PCR - Probes – Synthesis and types, Nucleic acid hybridization and blotting - Construction of gene libraries and cDNA library - Gene mapping and DNA structure analysis.

Unit III

Cloning in bacteria, yeast, plant and animal cells – identification of gene of interest and synthesis of double stranded DNA and complementary DNA - Restriction enzyme digestion – ligation - methods for transfer of cloned DNA - identification and enrichment of recombinant clones - expression of recombinant DNA in prokaryotic and eukaryotic vectors - strategies for purification of expressed protein.

Unit IV

Molecular mechanism of mutation – DNA repair - site directed DNA alterations and gene manipulations - Gene editing techniques - Methods of DNA sequencing - Genetics of tumorigenic region of agrobacteria - Applications of genetic engineering in veterinary science- Ethics, legal issues and safety aspects of genetic manipulation.

V. Suggested Readings

- Kun LY. 2006. *Microbial Biotechnology*. World Scientific.
- Sambrook J and Russel DW. 2001. *Molecular Cloning: a Laboratory Manual*. Cold Spring Harbour Lab. Press.
- Twyman RM. 2003. *Advanced Molecular Biology*. Bios Scientific.

S. No.	Topic	No. of Lectures
1	History and scope of molecular biology – Discovery of DNA and evidence for DNA as the genetic material	1
2	Structure of DNA, RNA and proteins – Organization of prokaryotic and eukaryotic genome	2
3	Gene transfer in micro organisms like conjugation, transformation, transduction and protoplastic fusion	3
4	DNA replication - genetic code - transcription, RNA processing and alternative splicing	4-5
5	Translation in prokaryotes and eukaryotes - Regulation of gene expression	6-7
6	Enzymes used in molecular biology and recombinant DNA research	8-9
7	Cloning vectors – plasmids, phages, phagemids, cosmids, BAC, YAC	10-11
8	Expression vector – bacterial, viral, baculo and yeast vectors, shuttle vectors	12-13
9	Polymerase chain reaction and different types of PCR	14-15
10	Probes – Synthesis and types, Nucleic acid hybridization and blotting	16-17
11	Construction of gene libraries and cDNA library - Gene mapping and DNA structure analysis	18
12	Cloning in bacteria, yeast, plant and animal cells – identification of gene of interest and synthesis of double stranded DNA and complementary DNA	19-21
13	Restriction enzyme digestion – ligation - methods for transfer of cloned DNA - identification and enrichment of recombinant clones	22-24
14	Expression of recombinant DNA in prokaryotic and eukaryotic vectors - strategies for purification of expressed protein	25
15	Molecular mechanism of mutation – DNA repair - site directed DNA alterations and gene manipulations	26
16	Gene editing techniques and Methods of DNA sequencing	27-28
17	Genetics of tumorigenic region of agrobacteria	29
18	Applications of genetic engineering in veterinary sciences	30
19	Ethics, legal issues and safety aspects of genetic manipulation	31

I. Course Title : Animal Cell Culture–Principles and Applications

II. Course Code : BTY 604

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the principles and applications of animal cell culture

V. Theory

Unit I

Introduction, History of cell culture development, Methods of sterilization, Different tissue culture techniques including primary culture, Continuous cell lines- anchorage dependent and independent cell lines, Organ culture, Cell bank.

Unit II

Different types of cell culture media, Serum, growth supplements, Balanced salt solution, Serum free media, Enzymes used in cell culture, Factors that affecting the growth of cells.

Unit III

Cell culture contaminants, Cryopreservation of primary culture and cell line, Cell cloning, Types of cell culture bioreactor, Cell counting and cytotoxic assays.

Unit IV

Applications of animal cell culture, Hybridoma technology and monoclonal antibody production, Applications of monoclonal antibodies in diagnostic and cancer research, Isolation and culturing of adult and embryonic stem cells, Therapeutic applications of adult stem cells.

VII. Practicals

- Packaging and sterilization of glass and plastic ware for cell culture
- Preparation of reagents and media for cell culture
- Primary chicken embryo fibroblast
- Primary sheep/ goat kidney culture
- Cultivation of continuous cell lines
- Quantification of cells by trypan blue exclusion dye
- Isolation of lymphocytes and cultivation
- Study of effect of toxic chemicals on cultured mammalian cells
- Study of cytopathic effect of virus on mammalian cells
- Cryopreservation of primary cultures and cell lines
- Isolation and culture of stem cells from bone marrow

VIII. Suggested Readings

- Freshney: *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications*, 6th Edition.
- Portner R. 2007. *Animal Cell Biotechnology*. Humana Press.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction, History of cell culture development	1-2
2.	Methods of sterilization	3
3.	Tissue culture techniques- primary culture using various methods	4-5
4.	Continuous cell lines- anchorage dependent and independent cell lines	6
5.	Organ culture	7
6.	Cell bank and role of cell bank.	8
7.	Different types of cell culture media, Serum, growth supplements, balanced salt solution, Serum free media	9-12
8.	Enzymes used in cell culture, Factors that affecting the growth of cells	13
9.	Cell culture contaminants	14
10.	Cryopreservation of primary culture and cell line	15
11.	Cell cloning	16
12.	Types of cell culture bioreactor	17-18
13.	Cell counting and cytotoxic assays	19-21
14.	Applications of animal cell culture	22-24
15.	Hybridoma technology and monoclonal antibody production,	25-26

S. No.	Topic	No. of Lectures
16.	Applications of monoclonal antibodies in diagnostic and cancer research	27
17.	Isolation and culturing of adult and embryonic stem cells and therapeutic applications of adult stem cells	28
Practical		
1.	Packaging and sterilization of glass and plastic ware for cell culture	1
2.	Preparation of reagents and media for cell culture	2
3.	Primary chicken embryo fibroblast	3
4.	Primary sheep/ goat kidney culture	4
5.	Cultivation of continuous cell lines	5
6.	Quantification of cells by trypan blue exclusion dye	6
7.	Isolation of lymphocytes and cultivation	7
8.	Study of effect of toxic chemicals on cultured mammalian cells	8
9.	Study of cytopathic effect of virus on mammalian cells	9
10.	Cryopreservation of primary cultures and cell lines	10
11.	Isolation and culture of stem cells from bone marrow	11

I. Course Title : Molecular Diagnostics

II. Course Code : BTY 605

III. Credit Hours : 2+1

IV. Aim of the courses

Understanding the various diagnostics methods using molecular techniques.

V. Theory

Unit I

Introduction, Importance and historical perspective of development of molecular diagnostic technology, Development and optimisation of Nucleic acid detection assays: OIE guidelines, Concept of development of group specific and strain specific nucleic acid-based diagnostics, Basis for selection of gene/ nucleotide sequence of pathogenic organism to target for detection.

Unit II

Types and application of different molecular diagnostic assays. Restriction endonuclease analysis for identification of pathogens, Principle of development of pathogen specific DNA probes, Blotting techniques e.g. Southern and Northern hybridization.

Unit III

Signal, target and probe based amplification techniques, Transcription based amplification (TBA)/ Nucleic Acid Sequence Based Amplification (NASBA)/ Self-Sustaining Sequence Replication (SSSR/ 3SR), Strand Displacement Amplification (SDA), LAMP, Ligase Chain Reaction (LCR)-Prospects and Applications, History of PCR, principle, Cyclic and thermal parameters in PCR, Real time PCR, Variations in PCR, Applications of PCR for diagnosis of infectious diseases of animals and poultry.

Unit IV

Advancements in diagnostic technology platforms including DNA array technology, biosensors, Nanodiagnostics, Mass spectrometry, Molecular cloning, DNA sequencing including Next generation sequencing, Bead based assays and lateral-flow device technology.

VI. Practicals

- Preparations of buffers and reagents.
- Collection of clinical and environmental samples from animal and poultry farms for molecular detection of pathogens.
- Extraction of nucleic acids from clinical specimens.
- Qualitative and quantitative analysis of extracted nucleic acid.
- Agarose gel electrophoresis of extracted nucleic acids.
- Restriction endonuclease digestion and analysis in agarose electrophoresis.
- Polymerase chain reaction for detection of pathogens in blood and other animal tissues.
- RT-PCR for detection of RNA viruses
- PCR-RFLP for detection and typing of pathogens
- Real time PCR for detection of pathogens in semen and other animal tissues
- DNA fingerprinting for identification of genetic diseases
- PCR based detection of potential pathogens in milk, eggs and meat
- Sanger sequencing using capillary electrophoresis

Suggested Readings

- Elles R and Mountford R. 2004. *Molecular Diagnosis of Genetic Disease*. Humana Press.
- Rao JR, Fleming CC and Moore JE. 2006. *Molecular Diagnostics. Horizon Bioscience in seed lot systems*.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction, importance and historical perspective of development of molecular diagnostic technology	1-2
2.	Development and optimization of nucleic acid detection assays: OIE guidelines	3-4
3.	Concept of development of group specific and strain specific nucleic acid based diagnostics, basis for selection of gene/ nucleotide sequence of pathogenic organism to target for detection	5-6
4.	Types and application of different molecular diagnostic assays	7-8
5.	Restriction endonuclease analysis for identification of pathogens	9-10
6.	Principle of development of pathogen specific DNA probes Blotting techniques e.g. Southern and Northern hybridization	11
7.	Nucleic Acid Sequence Based Amplification (NASBA)-Prospects and Applications	12-13
8.	Historical background of development of PCR and other diagnostic assays, Signal, target and probe based amplification techniques, Transcription based amplification (TBA)/ Nucleic Acid Sequence Based amplification (NASBA)/ Self-Sustaining Sequence Replication (SSSR/ 3SR), Strand Displacement Amplification (SDA), LAMP, Ligase chain reaction (LCR) - Prospects And ApplicationsPCR principle, cyclic and thermal parameters in PCR, Real time PCR, Variations in PCR, application of PCR for diagnosis of infectious diseases of animals and poultry	14-17
9.	Real-time PCR and its application in diagnosis	18-19
10.	Advancements in diagnostic technology platforms	20
11.	DNA array technology	21

S. No.	Topic	No. of Lectures/ Practicals
12.	Nano-diagnostics	22-23
13.	Biosensors	24
14.	Mass spectrometry in disease diagnosis.	25
15.	Molecular cloning	26
16.	Bead based assays	27
17.	DNA sequencing including Next generation sequencing	28-29
18.	Lateral-flow devices and its applications in diagnosis	30
Practical		
1.	Preparation of buffers and reagents	1
2.	Extraction of nucleic acids and qualitative and quantitative analysis of Nucleic acid	2-3
3.	Agarose gel electrophoresis of Nucleic acids.	4
4.	Amplification of pathogen specific gene using PCR.	5-6
5.	Different types of PCR including RT-PCR, nested PCR, etc.	7-9
6.	Real-time PCR	10
7.	PCR-RFLP	11-12
8.	DNA fingerprinting for identification of genetic diseases	13
9.	Sanger sequencing using capillary electrophoresis	14-16

I. Course Title : Immunology Applied to Biotechnology

II. Course Code : BTY 606

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the basic immunology and various immunoassays

V. Theory

Unit I

Introduction, Principles of immunology, Immune system, Immune response, Major histocompatibility complex: Structure, Functions and gene organization and its association with disease and resistance; Immunity against infectious agents of animals; Immunological tolerance; Autoimmunity; Techniques used in biotechnology.

Unit II

Immunoglobulins: Isotype, Allotype and Idiotype; Antibody production and purification; Application of antibodies in purification, Immunoblotting; Expression of immunoglobulin genes in plants and production of antibodies; Cytokines: classification, Structure, Functions; Industrial production of cytokines and interferon.

Unit III

Application of antibodies in chemiluminescence and florescence assay used for identification of recombinant genes; Antibody based nucleic acid probes and their applications; Immunoinformatics; Transgenic animals and cellular chimeras; Immunodiagnostic tests: Agar gel precipitation, Agglutination reaction based tests, various types of immunoassays, immunofiltration tests, flow cytometry in disease diagnosis.

Unit IV

Chimeric and humanized monoclonal antibodies, Recombinant antibodies; Modern uses of antibody: Biosensors, Catalysis, *in vivo* imaging, Microarrays, Proteomics; Cancer immunity and its immunotherapy.

VI. Practicals

- Agar gel immunodiffusion test; latex agglutination test
- Immunofiltration assay
- Immunodiffusion assays
- Flow cytometry
- Immunoelectrophoresis.
- Fluorescent antibody test.
- Enzyme immunoassays including various types of ELISA & Immunoblotting.
- Affinity chromatography
- Lymphocyte proliferation assay
- Cultivation of normal lymphocytes and myeloma cell line.
- Somatic cell hybridization and production of hybridoma.
- Screening of hybrids for production of monoclonal antibodies
- Bioinformatics tools for immunological research

VII. Suggested Readings

- Kindt TJ, Goldsby RA and Osbrne BA. 2007. *Kuby Immunology*. WH Freeman.
- Male D, Brostoff J, Roth DB and Roitt I. 2006. *Immunology*. Elsevier.
- Spinger TA. 1985. *Hybridoma Technology in Biosciences and Medicine*. Plenum Press.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to principles of immunology, immune system and immune response	1
2.	Major histocompatibility complex: its structure, functions and gene organization	2
3.	MHC and its association with disease and resistance	3
4.	Immunity against infectious agents of animals	4
5.	Immunological tolerance	5
6.	Autoimmunity: mechanism and control	6
7.	Techniques used in biotechnology	7
8.	Immunoglobulins and its type: Isotype, Allotype and Idiotype	8
9.	Antibody production and purification	9
10.	Application of antibodies in purification	10
11.	Immunoblotting: principle and applications	11
12.	Expression of immunoglobulin genes in plants and production of antibodies	12
13.	Cytokines: classification, structure, functions	13
14.	Industrial production of cytokines and interferon	14
15.	Application of antibodies in chemiluminescence and florescence assay for identification of recombinant genes	15
16.	Antibody based nucleic acid probes and their applications	16
17.	Immunoinformatics: concept and application	17
18.	Transgenic animals and cellular chimeras	18
19.	Immunodiagnostic tests: agar gel precipitation, agglutination reaction based assays	19
20.	Various types of Immunoassays, immunofiltration tests, flow cytometry in disease diagnosis	20
21.	Chimeric and humanized monoclonal antibodies	21

S. No.	Topic	No. of Lectures/ Practicals
22.	Recombinant antibodies: production and application	22
23.	Modern uses of antibody: biosensors, catalysis, *in vivo* imaging, microarrays, proteomics	23
24.	Cancer immunity and its immunotherapy	24
Practical		
1.	Agar gel immunodiffusion test; latex agglutination	1
2.	Immunofiltration assay	2
3.	Flow cytometry	3
4.	Immunoelectrophoresis	4
5.	Fluorescent antibody test	5
6.	Enzyme immunoassays including various types of ELISA	6
7.	Immunoblotting	7
8.	Affinity chromatography	8
9.	Lymphocyte proliferation assay	9
10.	Cultivation of normal lymphocytes and myeloma cell line	10
11.	Somatic cell hybridization and production of Hybridoma	11
12.	Screening of hybrids for production of monoclonal antibodies	12
13.	Bioinformatics tools for immunological research	13

I. Course Title : Introduction to Bioinformatics

II. Course Code : BTY 607

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the various databases and packages used in Bioinformatics.

V. Theory

Unit I

Introduction, Database searching - Biological Data Acquisition, Retrieval methods for DNA sequence, protein sequence and protein structure information, General Introduction of Biological Databases;Nucleic acid databases (NCBI, DDBJ, and EMBL). Protein databases (Primary, Composite, and Secondary). Specialized Genome databases: (SGD, TIGR, and ACeDB). Structure databases (CATH, SCOP, and PDBsum) Format and Annotation: Conventions for database indexing and specification of search terms, Common sequence file formats. Data – Access, Retrieval and Submission: Standard search engines; Data retrieval tools – Entrez, DBGET and SRS; Submission of (new and revised) data; Sequence Similarity Searches.

Unit II

DNA sequence analysis, Progressive and hierarchical algorithms for MSA multiple sequence alignment, Local versus global. Distance metrics. Similarity and homology. Scoring matrices. Dynamic programming algorithms, Needleman-wunsch and Smith-waterman. Heuristic Methods of sequence alignment, FASTA, BLAST and PSI BLAST. Multiple Sequence Alignment and software tools for pairwise and multiple sequence alignment; Genome Analysis: Whole genome analysis, Viral vector resources, cDNA libraries and EST, EST analysis, EST contings resources, Phylogeny: Phylogenetic analysis, Definition and description of phylogenetic trees and various types of trees, Method of construction of Phylogenetic trees [distance based method (UPGMA, NJ), Maximum Parsimony and Maximum Likelihood method], Comparative genomics, orthologs, paralogs.

Unit III

Secondary database searching, Introduction to concept of secondary data bases and their applications, Genome databases at NCBI, SANGER, TIGR, EBI, AGD and T (Animal genome database and tool), Introduction to animal genome research, RNA databases, protein structural databases, Building search protocol, Introduction to concept chemoinformatics computer aided drug Design–basic principles, Docking, QSAR.

Unit IV

Analysis packages–commercial databases and packages, GPL software for Bioinformatics, web-based analysis tools.

VI. Practicals

- Usage of NCBI resources
- Retrieval of sequence/ structure from databases
- Visualization of protein structures
- Protein structure modeling/ predictions
- Protein antigenicity predictions
- Docking of ligand receptors
- BLAST exercises.
- Multiple sequence alignment and construction of phylogenetic tree

VII. Suggested Readings

- Attwood TK and Parry-Smith DJ. 2003. *Introduction to Bioinformatics*. Pearson Education.
- Rastogi SC, Mendiratta N and Rastogi P. 2004. *Bioinformatics: Concepts, Skills and Applications*. CBS.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to bioinformatics, concept and history of databases, various primary databases resources	1-4
2.	Nucleic acid databases and their variants	5
3.	Protein databases and its variants	6
4.	Specialized genomic resources	7
5.	DNA sequence analysis, introduction to concept indel, identity, mutations, gaps and penalties	8-9
6.	cDNA library, its applications, EST, gene contings, EST databases, EST analysis tools, sequence assembly tools and clustering EST libraries	10-12
7.	Gene cloning vectors, their databases, tools and resources	13
8.	Similarity vs homology, local and global alignments	14
9.	Introduction to the concept of pair wise sequence alignment and multiple sequence alignment, difference between pair wise sequence alignment and multiple sequence alignment, introduction to various algorithms used in pair wise sequence alignment and multiple sequence alignments	15-16
10.	Applications of phylogenetic analysis, type of phylogenetic trees	17-18

S. No.	Topic	No. of Lectures/ Practicals
11.	Introduction to methods/ matrixes used for construction of phylogenetic trees use of concept bootstrap value	19
12.	Introduction to concept secondary database, their applications	20
13.	Genome databases, animal genome databases	21
14.	RNA database and their variants with applications	22
15.	Building search protocols, use of search tools for homology/ similarity identification	23
16.	Secondary protein databases, their applications, protein sequence structure relationship and patterns protein folding	24-25
17.	Introduction to chemoinformatics and its applications, Applications of computer aided drug designing	26
18.	Basic concept of computer aided drug designing	27
19.	Structure based computer aided drug designing, ligand based computer aided drug designing, databases searching, de novo drug designing	28
20.	Commercial databases and packages	29
21.	GPL software for Bioinformatics	30
22.	Web based analysis tools	31
23.	Applications of bioinformatics in veterinary clinical research	32
Practical		
1.	Usage of NCBI resources, its variants and specialized databases	1-2
2.	Retrieval of sequence/ structure from databases, retrieval of nucleic acid sequences and retrieval of protein sequence and structure studies	3-4
3.	Proteins structure visualization, prediction using software and tools	5-6
4.	Protein modelling.	7
5.	Protein antigenicity prediction tools	8
6.	Using of ligand database tools and ligand docking	9-10
7.	RNA database searching	11
8.	BLAST searching tools generalized and specialized searches	12
9.	Pair wise sequence alignment, multiple sequence alignment, phylogenetic analysis	14-16

I. Course Title : Animal Genomics

II. Course Code : BTY 608

III. Credit Hours : 2 + 1

IV. Aim of the course

Understanding the gene mapping and DNA markers in livestock improvement

V. Theory

Unit I

Historical perspective, Genome organization in eukaryotes-Chromosome numbers in farm animals – Physical and molecular structure of chromosomes -Chromosome abnormalities– High order structures, Cohesions and condensins in chromosome structure. SMC proteins –Importance of repetitive DNA –Classical satellites, microsatellites and mini satellites- SINES and LINES- Minisatellite and microsatellite based fingerprinting techniques.

Unit II

Importance of gene mapping in livestock, Methods and techniques used for gene mapping, Physical mapping, Linkage analysis, Cytogenetic techniques, FISH technique in gene mapping, Somatic cell hybridization, Radiation hybrid maps, *in-situ* hybridization, Comparative gene mapping.

Unit III

DNA markers – Properties of DNA markers- RFLPs – Minisatellite and Microsatellite markers –PCR based markers- RAPD, PCR-RFLPs, Allele specific – PCR, SSCP, STMS markers, DAMD-PCR, ARMS PCR, AP-PCR, RAMPO, AFLP, SNP, EST, etc. Genetic characterization based on DNA markers, Genetic distance analysis, Quantitative Trait Loci (QTL), Applications of DNA markers in livestock improvement- Marker Assisted Selection (MAS) – Marker Assisted Introgression – Parentage determination – SNP chips - Genomic selection based on SNP typing – Methods of genome editing –ZFN, TALENS, Meganucleases and CRISPR –Cas. Role of genome editing in livestock improvement.

Unit IV

Genome sequencing- Next Generation Sequencing – Metagenomics –RNASeq analysis-Exome sequencing and ddRAD sequencing for genome wide SNP detection- Current status of whole genome sequencing and gene maps of livestock, Role of MHC in disease resistance, Genes influencing production traits, Mitochondrial DNA of farm animals, Evolutionary significance, Applications of genome analysis in animal breeding.

VI. Practicals

- Chromosome preparation (normal karyotyping, different types of banding) in farm animals
- Isolation and purification of animal genomic DNA from blood lymphocytes
- Analysis of DNA by agarose or polyacrylamide gel electrophoresis
- Checking the quality and quantity of genomic DNA
- Restriction digestion and analysis
- Southern hybridization
- DNA testing by microsatellite markers
- Techniques for revealing polymorphism- RFLP, SSCP, AFLP, Microsatellites, SNP chips
- Genomic DNA cloning or cDNA cloning
- Differentiation of tissues of different species by mitochondrial genome analysis.
- NGS data analysis- metagenome, RNASeq, exome and ddRAD sequence data by bioinformatics software

VII. Suggested Readings

- Gibson G and Muse SV. 2004. *A Primer of Genome Science*. Sinauer Associates.
- Primrose SB and Twyman RM. 2007. *Principles of Genome Analysis and Genomics*. Blackwell.
- Sensen CW. 2005. *Handbook of Genome Research*. Vols. I, II.Wiley- CVH.

S. No.	Topic	No. of Lectures/ Practicals
History		
1.	Historical perspective, Genome organization in eukaryotes- Chromosome numbers in farm animals – Physical and molecular structure of chromosomes -Chromosome abnormalities in farm animals	1-2

S. No.	Topic	No. of Lectures/ Practicals
2.	High order structures, Role of cohesions and condensins in chromosome structure- SMC proteins	3-4
3.	Importance of repetitive DNA –Classical satellites, microsatellites and mini satellites-SINES and LINES- Minisatellite and microsatellite based fingerprinting techniques	5-6
4.	Importance of gene mapping in livestock, methods and techniques used for gene mapping	7
5.	Physical mapping- cytogenetic techniques, FISH technique in gene mapping,	8
6.	Gene mapping by somatic cell hybridization.	9
7.	Radiation hybrid maps for gene mapping	10
8.	Linkage analysis -comparative gene mapping.	11
9.	DNA markers – Properties of DNA markers- RFLPs – Minisatellite and Microsatellite markers –PCR based markers- RAPD, PCR-RFLPs, Allele specific – PCR, SSCP, STMS markers, DAMD-PCR, ARMS PCR, AP-PCR, RAMPO, AFLP, SNP, EST, etc.	12-13
10.	Genetic characterization based on DNA markers, genetic distance analysis	14
11.	Quantitative Trait Loci (QTL)-Candidate gene approach-QTL mapping approach	15
12.	Applications of DNA markers in livestock improvement- Marker Assisted Selection (MAS)	16
13.	Marker Assisted Introgression –Parentage determination – SNP chips	17
14.	Genomic selection based on SNP typing	18
15.	Methods of genome editing –ZFN, TALENS, Meganucleases and CRISPR –Cas. Role of genome editing in livestock improvement.	19-20
16.	Genome sequencing-Sanger sequencing-Hierarchical shot gun approach	21
17.	Next Generation Sequencing-Pyrosequencing-Semiconductor sequencing-Illumina sequencing-Helicos and SMRT sequencing platforms	22-23
18.	Metagenomics –RNA Seq analysis	24-25
19.	Exome sequencing and ddRAD sequencing for genome wide SNP detection	26-27
20.	Current status of whole genome sequencing and gene maps of livestock	28
21.	Role of MHC in disease resistance	29
22.	Genes influencing production traits	30
23.	Mitochondrial DNA of farm animals, evolutionary significance	31
24.	Applications of genome analysis in animal breeding.	32
Practical		
1.	Chromosome preparation (normal karyotyping, different types of banding) in farm animals	1-2
2.	Isolation and purification of animal genomic DNA from blood lymphocytes	3
3.	Analysis of DNA by agarose gel electrophoresis	4
4.	Analysis of DNA by polyacrylamide gel electrophoresis	5
5.	Checking the quality and quantity of genomic DNA by Spectrophotometer	6
6.	Restriction digestion and analysis	7
7.	Southern hybridization	8
8.	DNA testing by microsatellite markers	9
9.	Techniques for revealing polymorphism- PCR-RFLP	10

S. No.	Topic	No. of Lectures/ Practicals
10.	Single Strand Conformational Polymorphism (SSCP) analysis	11
11.	AFLP, SNP chips	12
12.	Genomic DNA cloning or cDNA cloning	13
13.	Differentiation of tissues of different species by mitochondrial genome analysis	14
14.	NGS data analysis-metagenome, RNASeq, exome and ddRAD sequence data by bioinformatics software	15-16

I. Course Title : Techniques in Molecular Biology and Genetic Engineering

II. Course Code : BTY 609

III. Credit Hours : 0+2

IV. Aim of the course

To develop skill in various molecular biology and genetic engineering techniques

- Isolation of DNA from mammalian cells
- Isolation of bacterial plasmids
- Restriction endonuclease digestion of plasmid and chromosomal DNA
- Agarose gel electrophoresis of RE digested DNA
- PCR using random primers as well as specific primers
- Different types of PCR
- Isolation of mRNA/ RNA, Quantification of nucleic acids
- cDNA synthesis
- Real time polymerase chain reaction
- Synthesis of nucleic acid probes
- Nucleic acid hybridization
- Cloning of bacterial and viral genes into plasmid vectors
- DNA ligation and transformation and confirmation of recombinants
- Purification of recombinant protein
- Polyacrylamide gel electrophoresis (PAGE)
- Western blot analysis

Suggested Readings

- Kun LY. 2006. *Microbial Biotechnology*. World Scientific.
- Sambrook J and Russel DW. 2001. *Molecular Cloning: A Laboratory Manual*. Cold Spring Harbour Lab. Press.
- Twyman RM. 2003. *Advanced Molecular Biology*. Bios Scientific.

S. No.	Topic	No. of Lectures/ Practicals
1.	Isolation of DNA from blood and mammalian cells	1-2
2.	Isolation of bacterial plasmids	3-4
3.	Restriction endonuclease digestion of plasmid and chromosomal DNA	5-6
4.	Agarose gel electrophoresis of RE digested DNA	7
5.	Polymerase Chain Reaction using random primers as well as specific primers	8-9
6.	Different types of PCR	10-12
7.	Isolation of mRNA/ RNA, Quantization of nucleic acids	13-14

S. No.	Topic	No. of Lectures/ Practicals
8.	cDNA synthesis	15
9.	Real time polymerase chain reaction	16-17
10.	Synthesis of nucleic acid probes and hybridization	18
11.	Cloning of bacterial and viral genes into plasmid vectors	19-20
12.	DNA ligation and transformation and confirmation of recombinants	21-23
13.	Purification of recombinant proteins	24-25
14.	Polyacrylamide gel electrophoresis (PAGE)	26-27
15.	Western blot analysis	28-29

I. Course Title : Reproductive Biotechnology

II. Course Code : BTY 610

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the concept of assisted reproductive technology

V. Theory

Unit I

Assisted Reproductive Technology (ART), History, Role of biotechnology in ART, importance of assisted reproductive technology in human and animals

Unit II

Multiple Ovulation Embryo Transfer (MOET), *in-vitro* fertilization, Micro assisted fertilization, Embryo culture, Micromanipulation of gametes and embryos, preservation of embryos and oocytes

Unit III

Semen sexing technology, Embryo splitting, Different methods of embryo sexing, Transgenic animal production, Application, Limitation and regulatory issues

Unit IV

Somatic cell nuclear transfer of domestic animals and application. Isolation and characterization of embryonic stem cells. Different applications of embryonic stem cells

VI. Practicals

- MOET protocols for domestic animals
- Oocyte and embryo freezing protocol
- Oocyte collection and evaluation from live and slaughter house animals
- *In-vitro* embryo production
- Embryo quality analysis
- Embryo biopsy and embryo sexing

VII. Suggested Reading

- Ball PJH and Peter AR. 2004. *Reproduction in Cattle*. Blackwell.
- Gordon I. 2003. *Laboratory Production of Cattle Embryos*. CABI.
- Gordon I. 2005. *Reproductive Techniques in Farm Animals*. CABI.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	History, role of biotechnology in Assisted reproductive technology(ART)	1-2
2.	Application of ART in human and animals	3-4
3.	Multiple ovulation embryo transfer (MOET)- donor and recipient selection- synchronization-super ovulation-artificial insemination- embryo flushing- embryo evaluation- recipient management	5-6
4.	Oocyte recovery from slaughter house ovaries and live animals, oocytes evaluation and *in-vitro* maturation	7-8
5	*In-vitro* fertilization of oocytes, *In-vitro* culture and assessment of embryonic developmental stages	9-11
6.	Micro assisted fertilization	12-13
7.	Micromanipulation of gametes and embryos	14
8.	Preservation of embryos and oocytes	15
9.	Semen sexing technology and semen analysis	16
10.	Embryo splitting	17
11.	Different methods of embryo sexing	18-19
12.	Transgenic animal production, application, limitation and regulatory issues	20-22
13.	Somatic cell nuclear transfer of domestic animals and application	23-25
14.	Isolation and characterization of embryonic stem cells	26-27
15.	Different applications of embryonic stem cells	28
Practicals		
1.	MOET protocols for domestic animals	1-2
2.	Oocyte and embryo freezing protocol	3-4
3.	Oocyte collection and evaluation from live and slaughter house animals	5-6
4.	*In-vitro* embryo production	7-8
5.	Embryo quality analysis	9
6.	Embryo biopsy and embryo sexing	10

Course Title with Credit Load
Ph.D. in Veterinary Biotechnology

Course Code	Course Title	Credit
RPE 700	Research and Publication Ethics*	1+1
BTY 701	Genetic Engineering	1+2
BTY 702	Functional Genomics and Proteomics	3+0
BTY 703	Advances in Cell and Molecular Biology	2+0
BTY 704	Diagnostic Platform	1+1
BTY 705	Gene Manipulation and Genome Editing	2+0
BTY 706	Trends in Vaccinology	2+1
BTY 707	Advances in Bioinformatics	1+1
BTY 708	Advances in Reproductive Biotechnology	2+1
BTY 709	Advances in Animal Cell Culture	2+1
BTY710	Industrial Biotechnology	2+1
BTY 711	Rumen and Feed Biotechnology	2 +1
BTY 712	Doctorate Seminar-I	1+0
BTY 713	Doctorate Seminar-II	1+0
BTY 714	Doctorate Research	0+70

*compulsory Major course for Doctorate programme. The other 10 credits can be registered from remaining 700 Series courses listed above

Suggested list of specified Minor subjects (Departments)

Major Subject	Minor subjects (Departments)*
Veterinary Biotechnology	Biochemistry, Physiology, Microbiology, Animal Genetics and Breeding, LPT, Gynaecology and Obstetrics, Pathology, Animal Nutrition, Parasitology and Pharmacology and Toxicology, medicine, surgery, public health, wild life

*The Minor courses may be taken from any number of disciplines/ departments listed against major discipline limiting to credits prescribed as decided by the Chairman of Advisory Committee of the student.

Minor courses may also be taken from the other than those listed above on the recommendations of advisory committee, if essentially required as per the research problem with the concurrence of Head of the Department and Concerned Authorities.

Course Contents
Ph.D. in Veterinary Biotechnology

I. Course Title : Genetic Engineering
II. Course Code : BTY 701
III. Credit Hours : 1+2

IV. Aim of the course

Understanding the concept of gene cloning and expression.

V. Theory

Unit I

Cloning vectors- plasmids, Phages, Cosmids, BAC, YAC, Expression vectors-viral, baculo and yeast vectors, Shuttle vectors.

Unit II

Restriction, ligation, Transformation and recombinant selection methods, Construction of genomic and cDNA library, Construction of full length cDNA, Preparation of probe, Nick translation, Random hexamer and nick translation.

Unit III

Linkers, Adapters and cassettes, Screening the library.

Unit IV

Expression of genes, Prokaryotic and eukaryotic expression, Identification of recombinant proteins, Purification of expressed protein.

VI. Practicals

- Preparation of vector
- Restriction enzyme digestion of vector
- Preparation of target DNA and Purification of DNA
- DNA ligation
- Preparation of electro competent cells
- Transformation
- Calculation of transformation efficiency
- Screening by colony PCR
- Selection of recombinant by insert release
- Induction of expressed protein
- Purification of expressed protein
- SDS-PAGE
- Western blotting.

VII. Suggested Readings

- Ausubel FM, Brent R, Kingston RE, Moore DD, Seidman JG, Smith JA and Struhl K. 2002. *Short Protocols in Molecular Biology*. Wiley

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Cloning vectors- plasmids, phages, cosmids, BAC, YAC	1-2
2.	Expression vectors- viral, baculo and yeast vectors, shuttle vectors.	3-4
3.	Restriction, ligation, transformation	5-6
4.	Recombinant selection methods	7
5.	Construction of genomic and cDNA library	8
6.	Construction of full length cDNA	9
7.	Preparation of probe	10
8.	Nick translation random hexamer and nick translation	11
9.	Linkers, adapters, Cassettes,	12
10.	Screening the library	13
11.	Expressions of genes, prokaryotic and eukaryotic expression	14-15
12.	Identification of protein, Purification of expressed protein	16
Practical		
1.	Preparation of vector	1-2
2.	Restriction enzyme digestion of vector	3
3.	Preparation of target DNA and Purification of DNA	4-5
4.	DNA ligation	6
5.	Preparation of electro competent cell	7
6.	Transformation	8
7.	Calculation of transformation efficiency	9
8.	Screening by colony PCR	10
9.	Selection of recombinant by insert release	11-12
10.	Induction of expressed protein	13
11.	Purification of expressed protein	14-15
12.	SDS-PAGE	16-17
13.	Western blotting	18-19

I. Course Title : Functional Genomics and Proteomics

II. Course Code : BTY 702

III. Credit Hours : 3+0

IV. Aim of the course

Understanding the principles of functional genomics and proteomics

V. Theory

Unit I

Overview of Mammalian Genome: Mitochondrial genome, Protein coding genes, RNA genes and repeat sequences, Variations in the mammalian genome, Expression of mammalian genome.

Unit II

Overview of Mammalian Transcriptome: Different methods to study gene expression, Single gene analysis, Northern blots, Quantitative PCR, SAGE, MPSS and SSH, Introduction to basic microarray technology, Design of experiments, Types of microarray.

Unit III

Methods to study the mammalian Genome: Chromosome number evolution in mammalian species, Chromosome territory, Karyotyping, FISH and Spectral karyotyping, Next Generation sequencing platforms chemistries and their applications, Mutation detection methods for single gene and genome wide scale.

Unit IV

Databases such as NCBI, EBI, Nucleotide, Genome, SNP, Gene, Unigene, Homologene, Protein, etc. under NCBI. Service databases under EBI. Genome browsers, The concept of Comparative genomics, Genome BLAST and BLAT. Proteomics technology, Identification and analysis of proteins by 2D analysis, Mass spectrophotometery, Circular Dischorism, Fluorescence Spectroscopy, NMR and X-ray crystallography, MALDI-TOF, Differential display proteomics, Protein -protein interaction, Yeast two hybrid system and phage display.

VI. Suggested Reading

- Gibson G and Muse SV. 2004. *A Primer of Genome Science*. Sinauer Associates.
- Primrose SB and Twyman RM. 2007. *Principles of Genome Analysis and Genomics*. Blackwell.
- Sensen CW. 2005. *Handbook of Genome Research*. Vols. I, II Wiley- CVH.

S. No.	Topic	No. of Lectures
1.	Overview of Mammalian Genome: Mitochondrial genome	1
2.	Protein coding genes	2
3.	RNA genes and repeat sequences	3
4.	Variations in the mammalian genome	4
5.	Expression of mammalian genome	5
6.	Overview of Mammalian Transcriptome	6
7.	Different methods to study gene expression	7-8
8.	Single gene analysis, Northern blots, Quantitative PCR	9-10
9.	SAGE, MPSS and SSH	11-12
10.	Introduction to basic microarray technology, Design of experiments	13-14
11.	Types of microarray	15-16
12.	Mammalian Genome- Chromosome number, evolution in mammalian species	17
13.	Chromosome territory	18
14.	Karyotyping, FISH and Spectral karyotyping	19
15.	Next Generation sequencing platforms chemistries and their applications	20-21
16.	Mutation detection methods for single gene and genome wide scale	22-23
17.	Databases such as NCBI, EBI	24
18.	Nucleotide, Genome, SNP, Gene, Unigene, Homologene, Protein, etc. under NCBI. Service databases under EBI	25
19.	Genome browsers, The concept of Comparative genomics, Genome BLAST and BLAT	26
20.	Proteomics technology, identification and analysis of proteins by 2D analysis	27-29
21.	mass spectrophotometery,	30
22.	Circular Dischorism	31
23.	Fluorescence Spectroscopy	32-34
24.	NMR and X-ray crystallography	35-37
25.	MALDI-TOF	38-39
26.	Differential display proteomics	40-42
28.	Protein -protein interaction, yeast two hybrid system	43-45
29.	Phage display	46

I. Course Title : Advances in Cell and Molecular Biology

II. Course Code : BTY 703

III. Credit Hours : 2 + 0

IV. Aim of the course

Understanding the latest development in cell and molecular biology

V. Theory

Unit I

Cell chemistry and Biosynthesis pathways – Molecular motors of cell biology – Cell signalling – Signal Transduction – Chemotropic Energy Metabolism – Apoptosis pathways.

Unit II

Structure and functions of Prokaryotic and Eukaryotic Operons – Recombination and Genetic variability – Regulation of Gene Expression – Strategies of nuclear Transport – Carrier Proteins and active membrane transport methodologies.

Unit III

Protein Biosynthesis and Transportation – Protein sorting - Enzymes in Molecular Biology – Post transcriptional control strategies – Plasmids in recombinant DNA technology.

Unit IV

RNA interference technology – Insights into Nanobiology – Biosensors – DNA Microarray – Peptide Synthesis – Reverse Genetics.

VI. Suggested Readings

- Lewin B. 2008. *Gene IX*. Jones and Bartlett.
- Primrose SB. 2001. *Molecular Biotechnology*. Panima.
- Twyman RM. 2003. *Advanced Molecular Biology*. Bios Scientific

S. No.	Topic	No. of Lectures
1.	Cell chemistry and biosynthesis pathway	1
2.	Molecular motors of cell biology	2
3.	Cell signalling	3
4.	Signal transduction	4
5.	Chemotropic energy metabolism	5
6.	Apoptosis pathways	6
7.	Structure and functions of prokaryotic and eukaryotic operons	7-8
8.	Recombination and genetic variability	9
9.	Regulation of gene expression	10
10.	Strategies of nuclear transport	11
11.	Carrier proteins and active membrane transport methodologies	12
12.	Protein biosynthesis	13
13.	Protein transportation	14
14.	Protein sorting	15
15.	Enzymes in molecular biology	16
16.	Post transcriptional control strategies	17
17.	Plasmids in recombinant DNA technology	18
18.	RNA interference technology	19
19.	Insights into nanobiology	20

S. No.	Topic	No. of Lectures
20.	Biosensor	21
21.	DNA microarray	22-24
22.	Peptides synthesis	25-27
23.	Reverse genetics	28

I. Course Title : Diagnostic Platform

II. Course Code : BTY 704

III. Credit Hours : 1 + 1

IV. Aim of the course

Understanding the concept of various diagnostic platforms.

V. Theory

Unit I

History and evolution of diagnostic platforms- Methods for identifying agents for infection or disease- Point-of-care assays- Point-of-care assays based on proteins-point-of-care assays based on nucleic acids, Principles for specific identification of the analytes or clinical parameters - Various assays for different platform.

Unit II

Catridges- Polymer catridges- Catridge based *in-vitro* diagnostics- Microfluidics/ nanotechnology sensors- Complexity and diversity of samples- Sample preparation-extraction of DNA/ RNA- PCR for marker DNA sequence- POC based on microfluidic chips.

Unit III

Detection principles- Colorimetric- Optical, Electrochemical, Magnetic, Mechanical protein detection methods- Sensitive sensing principles- NASBA- RPA- LAMP with QUASR- Integrated microfluidic system.

Unit IV

Instrumentation for point of care diagnostic platform- Blood protein analyses, the Afinion platform from Axis-Shield- The Verigene ® System by Nanosphere- Cepheid's GeneXpert cassette- NorChip- use of smart phone apps for real time monitoring and analysis.

VI. Practicals

- DNA/ protein extraction
- RNA extraction
- Polymerase chain reaction
- NASBA
- RPA
- LAMP
- Microfluidic assay

VII. Suggested Readings

- *Diagnostic Devices with Microfluidics*. 1st Edition. Francesco Piraino, Šeila Selimoviæ. CRC Press
- *Point-of-Care Diagnostics on a Chip*. David Issadore Robert M. Westervelt

S.No.	Topic	No. of Lectures/ Practicals
Theory		
1.	History and evolution of diagnostic platforms	1
2.	Methods for identifying agents for infection or disease, point-of-care assays	2
3.	Point-of-care assays	3
4.	Principles for specific identification of the analytes or clinical parameters, various assays for different platform	4
5.	Catridges, polymer catridges- catridge based *in-vitro* diagnostics	5
6.	Microfluidics/ nanotechnology sensors, complexity and diversity of samples	6
7.	sample preparation, extraction of DNA/ RNA, PCR for marker DNA sequence	7
8.	POC based on microfluidic chips	8
9.	Detection principles- colorimetric- optical, electrochemical, magnetic	9
10.	Detection principles- colorimetric- optical, electrochemical, magnetic, mechanical protein detection methods	10
11.	Sensitive sensing principles- NASBA- RPA- LAMP with QUASR	11
12.	Integrated microfluidic system	12
13.	Instrumentation for point of care diagnostic platform	13
14.	Blood protein analyses, the Afinion platform from Axis-Shield	14
15.	The Verigene ® System by Nanosphere- Cepheid's GeneXpert cassette	15
16.	NorChip, use of smart phone apps for real time monitoring and analysis	16-17
Practical		
1.	DNA/ protein extraction	1-2
2.	RNA extraction	3
3.	Polymerase chain reaction	4-5
4.	NASBA	6
5.	RPA	7
6.	LAMP	8
7.	Microfluidic assay	9-10

I. Course Title : Gene Manipulation and Genome Editing

II. Course Code : BTY 705

III. Credit Hours : 2 + 0

IV. Aim of the course

Understanding the various method of gene manipulation and genome editing.

V. Theory

Unit I

Genome Overview: Genetic architectures of model organisms: yeast, *C. elegans*, Drosophila, Mouse, Human, Chromosomal and Genomic overviews of cattle, buffalo, sheep, goat, pigs and poultry.

Unit II

Tools to characterize transgene: Identification and characterization of suitable transgene. Vectors used to clone and expression of foreign gene in prokaryotic and eukaryotic systems. Different types of promoters for tissue specific expression of transgene. Detection of transgene in the new-born.

Unit III

Methods of gene transfer: Microinjection of recombinant DNA into fertilized eggs/ stem cells, Transfection of DNA totipotent kerato-carcinoma cells, Electroporation, gene transfer into cultured cells.

Unit IV

Genome editing tools: Zinc finger, TALEN and CRISPR: Their discovery, Types and their mechanism. Applications of these tools for *in vivo* genome engineering. Mono allelic and biallelic gene editing. Screening for genome editing process in cells/ animals. Applications of these tools in animal science for genetic studies, therapeutic potential and transgenic animal as bioreactors. Recent examples of genome edited animals and their applications in animal science.

VI. Suggested reading

- *Human genome editing science, ethics and governance*

S. No.	Topic	No. of Lectures
1.	Genetic architectures of model organisms: yeast, *C. elegans*, *Drosophila*, Mouse, human	1-2
2.	Chromosomal and Genomic overviews of cattle, buffalo, yak, Mithun, sheep and goat	3-4
3.	Chromosomal and Genomic overviews of pigs and poultry genome	5
4.	Identification and characterization of suitable transgene	6
5.	Vectors used to clone and expression of foreign gene in prokaryotic systems.	7-8
6.	Vectors used to clone and expression of foreign gene in eukaryotic systems.	9-10
7.	Different types of promoters in prokaryotes and eukaryaotes for tissue specific expression of transgene	11-12
8.	Detection of transgene in the new-born	13
9.	Microinjection of recombinant DNA into fertilized eggs/ stem cells	14-16
10.	Transfection of DNA totipotent/ ES cells and kerato-carcinoma cells,	17-18
11.	Electroporation, gene transfer into cultured mammalian cells.	19-21
12.	Zinc finger and TALEN types and their mechanism	22
13.	CRISPR types and their mechanism	23-24
14.	Applications of these tools for *in vivo* genome engineering.	25
15.	Mono allelic and biallelic gene editing	26
16.	Screening for genome editing process in cells/ animals.	27
17.	Applications of these tools in animal science for genetic studies, therapeutic potential and transgenic animal as bioreactors.	28
18.	Recent examples of genome edited animals and their applications in animal science	29-30

I. Course Title : Trends in Vaccinology

II. Course Code : BTY 706

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the current trends in vaccine production technologies.

V. Theory

Unit I

Immunity against veterinary infectious agents: Bacteria, Virus, fungi and parasites; Immunoinformatics and its application to epitope mapping of pathogens, etc.; Advancement in vaccinology: Vaccinomics, Adversomics, Systems Vaccinology, reverse vaccinology, Structural Vaccinology and computational vaccinology and its applications.

Unit II

Current trends in vaccine development against animal pathogens; Molecular approaches for vaccine development including: recombinant peptide vaccines, vectored vaccines, Marker vaccines, DNA vaccines, genetically manipulated live vaccines, etc.; Plant expression system based vaccines, idiotype and synthetic peptide based vaccines.

Unit III

Vaccines and Immunotherapeutic for Treating Non-Infectious Diseases: Cancer; obesity, neurodegenerative diseases, addictions, atherosclerosis, etc.; DIVA Vaccines for animal disease; Vaccines for emerging human and animal diseases; Novel immunomodulators and vaccine delivery systems: Immunomodulators including cytokines and new adjuvants; delivery of immunogens through liposomes, microspheres, ISCOMS, nanotechnology based vaccine delivery, etc.

Unit IV

Vaccine formulation: pharmacopeia requirements; Vaccine qualities and its control; Large scale vaccine production technology: cost effectiveness of preventive immunization programmes; Stages of development of vaccine; Clinical trials of vaccine and its regulation; Commercial vaccines available against animal pathogens, its characteristics and immunization schedule; Vaccine stability, Preservation and vaccination failure; Environmental concerns with the use of recombinant vaccines.

VI. Practicals

- Purification of immunoglobulins: gel filtration and ion exchange chromatography
- Hybridoma technique for monoclonal antibody production
- Preparation of gene construct for recombinant and nucleic acid vaccine
- Expression of gene encoding immunogenic protein in prokaryotic/ yeast/ animal cell culture system
- Study of immune response against recombinant vaccine
- Use of modern adjuvants in vaccines
- Isolation and characterization of antigens from viruses, bacteria
- Immunoassays: ELISA, FAT, RIA

VII. Suggested Reading

- Levine MM, Kaper JB, Rappuoli R, Liu MA, Good MF. 2004. *New Generation Vaccines*. 3rd Ed. Informa Healthc

S. No.	Topic	No. of Lectures/ Practicals
1	Immunity against veterinary infectious agents: bacteria, virus, fungi and parasites	1-3

S. No.	Topic	No. of Lectures/ Practicals
2	Immunoinformatics and its application to epitope mapping of pathogens, etc.	4
3	Advancement in vaccinology: Vaccinomics and Adversomics	5
4	Systems Vaccinology and Reverse vaccinology	6-7
5	Structural Vaccinology, computational vaccinology and its applications	8
6	Current trends in vaccine development against animal pathogens	9
7	Molecular approaches for vaccine development including: recombinant peptide vaccines, vectored vaccines, Marker vaccines, DNA vaccines, genetically manipulated live vaccines, etc.	10-12
8	Plant expression system based vaccines	13
9.	Idiotype and synthetic peptide based vaccines	14
10.	Vaccines and Immunotherapeutic for treating non-infectious Diseases: Cancer; obesity, neurodegenerative diseases, addictions, atherosclerosis, etc.	15-16
11.	DIVA Vaccines for animal disease	17
12.	Vaccines for emerging human and animal diseases	18
13.	Novel immunomodulators: Immunomodulators including cytokines and new adjuvants	19-20
14.	Novel vaccine delivery systems: delivery of immunogens through liposomes, microspheres, ISCOMS, nanotechnology based vaccine delivery, etc.	21-23
15.	Vaccine formulation: pharmacopeia requirements	24
16.	Vaccine qualities and its control	25
17.	Large scale vaccine production technology: cost effectiveness of preventive immunization programmes	26
18.	Stages of development of vaccine, clinical trials of vaccine and its regulation	27
19.	Commercial vaccines available against animal pathogens, its characteristics and immunization schedule	28-29
20.	Vaccine stability, preservation and vaccination failure	30-31
21.	Environmental concerns with the use of recombinant vaccines	32
Practical		
1.	Purification of immunoglobulins: gel filtration and ion exchange chromatography	1-2
2.	Hybridoma technique for monoclonal antibody production	3-4
3.	Preparation of gene construct for recombinant and nucleic acid vaccine.	5
4.	Expression of gene encoding immunogenic protein in prokaryotic/ yeast/ animal cell culture system.	6
5.	Study of immune response against recombinant vaccine.	7-8
6.	Use of modern adjuvants in vaccines	9
7.	Isolation and characterization of antigens from viruses, bacteria,	10
8.	Immunoassays: ELISA, FAT, RIA	11

I. Course Title : Advances in Bioinformatics

II. Course Code : BTY 707

III. Credit Hours : 1+1

IV. Aim of the course

To impart an introductory knowledge about the subject of Bioinformatics to the students studying any discipline of science.

V. Theory

Unit I

Introduction to Computational Gene Prediction and Genome annotation Basic concepts in Computational Phylogenetic Analysis, Super trees, consensus trees, tree compatibility. Algorithms for evaluating the tree space; Markov Chain Monte Carlo, genetic algorithms. Evaluation of results from phylogentic analyses, phylogenetic dating Genome annotation; Gene networks (basic concepts). Completed genomes and bioinformatics approaches to analyze the genomes of Viruses, Bacteria and animals.

Unit II

DNA microarray: understanding of microarray data and correlation of gene expression data to biological processes and computational analysis tools (especially clustering approaches). Methods of Genome sequencing, EST, STS, GSS database and their generation, Whole Genome comparison, RNA folding, RNA loops, conformational study, Whole genome analysis, Whole genome regression and prediction methods, Trasncriptome analysis and its applications, Animal QTL databases and SIGENAE analysis of breeding animals genome.

Unit III

Transcriptome and Proteome- General Account; Tools of proteome analysis, Motifs and Folds; Protein structure related databases, Protein Data Bank format, Concepts of B-factor and R-factor, Protein Structural Alignment and Superposition, Structure visualization of proteins. Protein Fold Classification, Protein structure comparison, CATH and SCOP Databases. Protein structure prediction methods. Homology modeling. Molecular Docking and Drug design (Basic concepts) Molecular dynamics and simulation study of protein, Force field concepts.

Unit IV

Protein identification and characterization:- AA CompIdent, TagIdent, PepIdent and MultiIdent, PROSEARCH, PepSea, PepMAPPER, FindPept, introduction to the concept of chemoinfromatics, metabolomics and immunoinfromatics.

VI. Practicals

- Gene annotation
- Phylogenetic tree construction
- RNA folding
- Genome database searching
- Protein folding and structure predictions
- Analysis of 3D structure of protein using RasMol through command line.
- Molecular Docking of protein and ligand by HEX.
- Analysis of 3D structure of protein and nucleic acid using Cn3D.
- QTL databases

VII. Suggested Readings

- Attwood TK and Parry-Smith DJ. 2003. *Introduction to Bioinformatics*. Pearson Education.
- Rastogi SC, Mendiratta N and Rastogi P. 2004. *Bioinformatics: Concepts, Skills and Applications*. CBS.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to Computational Gene Prediction and Genome annotation	1
2.	Basic concepts in Computational Phylogenetic Analysis, phylogenetic dating genome annotation; Gene networks	2
3.	Completed genomes and bioinformatics approaches to analyze the genomes of Viruses, Bacteria and Animals	3-4
4.	Understanding of microarray data and correlation of gene expression data to biological processes and computational analysis tools	5
5.	Methods of Genome sequencing, EST, STS, GSS database Whole Genome comparison	6-7
6.	RNA folding, RNA loops, conformational study and specialized RNA databases	8
7.	Whole genome analysis, whole genome regression and prediction methods	9
8.	Trasncriptome analysis and its applications, Animal QTL databases and SIGENAE analysis of breeding animals genome	10
9.	Tools of proteome analysis, Motifs and Folds; Protein structure related databases, Protein Data Bank format, Concepts of B-factor and R-factor,	11
10.	Protein Structural Alignment and Superposition, Structure visualization of proteins. Protein Fold Classification, Protein structure comparison, CATH and SCOP Databases. Protein structure prediction methods. Homology modeling	12-13
11.	Molecular Docking and Drug design (Basic concepts) Molecular dynamics and simulation study of protein, Force field concepts	14
12.	Protein identification and characterization	15
13.	Introduction to the concept of chemoinformatics, metabolomics and immunoinformatics	16
Practical		
1.	Gene annotation, sequence retrieval specialized searches	1-3
2.	Phylogenetic tree construction and phylogenetic dating	4-5
3.	RNA folding, RNA secondary structure prediction, DNA secondary structure prediction	5-6
4.	Genome database searching, conting preparation	7
5.	Protein folding and structure predictions	8
6.	Analysis of 3D structure of protein using RasMol through command line	9
7.	Molecular Docking of protein and ligand by HEX	10
8.	Analysis of 3D structure of protein and nucleic acid using Cn3D	11
9.	QTL databases	12

I. Course Title : Advances in Reproductive Biotechnology

II. Course Code : BTY 708

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the reproductive techniques in farm animals

V. Theory

Unit I

Micromanipulation of embryos and gametes, Somatic Cell Nuclear Transfer(SCNT), nuclear reprogramming, Transgenic animal production, Combining Transgenic and SCNT, Gene targeting, Genome editing and disease modeling.

Unit II

In vivo Vs *in-vitro* production of embryos, Embryos quality, Transcriptomics, Metabolomic approach, Sperm sexing technologies and their application, Preimplantation genetic diagnosis and screening, Epigenetic reprogramming, Large offspring syndrome.

Unit III

Sources of stem cells, Embryonic stem cells, Spermatogonial stem cells, Induced pluripotent stem cells, Stem cells application in regenerative medicine and disease therapeutics.

Unit IV

Social, Ethical, Religious and regulatory issues related to assisted reproductive technology, Transgenic and stem cells therapy.

VI. Practicals

- Micro assisted fertilization- ICSI
- Embryo biopsy for PGD and sexing
- Sperm quality analysis by flow cytometry
- Embryo quality analysis
- SCNT protocol
- Isolation and characterization of embryonic stem cells
- Gene expression in sperm and embryos

VII. Suggested Reading

- Gordon I. 2005. *Reproductive Techniques in Farm Animals*. CABI

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Micromanipulation of embryos and gametes, Somatic cell nuclear transfer (SCNT) and Nuclear reprogramming	1-3
2.	Transgenic animal production and SCNT	4-5
3.	Gene targeting	6
4.	Gene editing and disease modelling	7-8
5.	*In vivo vs in-vitro* embryos	9-10
6.	Embryos quality – Transcriptomics, Metabolomic approach	11-13
7.	Sperm sexing technologies and their applications	14-15
8.	Pre implantation genetic diagnosis and screening	16-17
9.	Epigenetic reprogramming	18
10.	Large offspring syndrome	19-20
11.	Source of stem cells, embryonic stem cells, spermatogonial stem cells	21-23
12.	Induced pluripotent stem cells	24-25
13.	Stem cells application in regenerative medicine and diseases therapeutics	26
14.	Social, ethical, religious and regulatory issues related to assisted reproductive technology	27
15.	Transgenic and stems cells therapy	28

S. No.	Topic	No. of Lectures/ Practicals
Practical		
1.	Micromanipulator, micro assisted fertilization, ICSI protocol	1-2
2.	Embryo biopsy- sexing	3-4
3.	Sperm preparation and sperm quality analysis by flow cytometry	5-6
4.	Embryo quality analysis- Morphological assessment and Staining technique	7-8
5.	SCNT protocol- enucleation, somatic cell injection, fusion activation and embryo culture	9-10
6.	Isolation of inner cell mass from blastocyst, culture and characterisation of embryonic stem cells	11
7.	Gene expression in sperm and embryos	12

I. Course Title : Advances in Animal Cell Culture

II. Course Code : BTY 709

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the latest development in animal cell culture

V. Theory

Unit I

Development of cell lines using various methods, Characterization of cell lines by morphology, Chromosome analysis, DNA content, Isoenzyme analysis and antigenic markers, DNA fingerprinting.

Unit II

Setting of new cell culture lab, Detection methods for cell culture contaminants, Three dimensional culture- classification of 3D culture methods and microfluidics, Tissue engineering- types of cells, Scaffold materials, Bioprinting, Bioartificial organs, Flow Cytometry and its applications in cell culture.

Unit III

DNA transfer by viral and non viral methods, Expression of recombinant proteins in mammalian and avian cell lines.

Unit IV

Monoclonal antibody production and characterization, Up-stream and downstream processing of cell culture based vaccines, Diagnostic antigens and other pharmaceutical agents, Cell culture fermentors.

VI. Practicals

- Primary and secondary mammalian cell culture
- Development of transformed cells
- Characterization of cell lines by karyotyping
- Transfection of cells with recombinant DNA
- Expression of recombinant proteins
- Scaling-up of cultures
- Flow Cytometry

- Immunization of mice
- Maintenance of myeloma cell lines
- Fusion
- Characterization of mAbs

VII. Suggested Readings

- Freshney RI. 2005. *Culture of Animal Cells*. Wiley Liss.
- Portner R. 2007. *Animal Cell Biotechnology*. Humana Press

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Development of cell lines using various methods	1
2.	Characterisation of cell lines by morphology	2
3.	Characterisation of cell lines by chromosome analysis	3
4.	Characterisation of cell lines by DNA content, isoenzyme analysis and antigenic markers	4
5.	Characterisation of cell lines DNA fingerprinting	5
6.	Setting of new culture lab	6
7.	Detection methods for cell culture contaminants	7
8.	Classification of 3D culture methods and micro fluidics	8
9.	Tissue engineering- types of cells, scaffold materials, bio printing, bio artificial organs,	9
10.	Flow Cytometry and its applications in cell culture	11
11.	DNA transfer by viral and non viral methods	11
12.	Expression of recombinant proteins in mammalian and avian cell lines	12
13.	Monoclonal antibody production and characterisation	13
14.	Upstream and downstream processing of cell culture based vaccines, diagnostic antigens and other pharmaceutical agents	14-15
15.	Cell culture fermentors	16
Practical		
1.	Primary and secondary mammalian cell culture	1
2.	Development of transformed cells	2
3.	Characterization of cell lines by karyotyping	3
4.	Transfection of cells with recombinant DNA	4
5.	Expression of recombinant proteins	5
6.	Scaling-up of cultures	6
7.	Flow Cytometry	7
8.	Immunization of mice	8
9.	Maintenance of myeloma cell lines	9
10.	Fusion	10
11.	Characterisation of Mabs	11

I. Course Title : Industrial Biotechnology
II. Course Code : BTY 710
III. Credit Hours : 2+1

IV. Aim of the course

Understanding the fermentation process and Bioenergy system.

V. Theory

Unit I

Introduction to fermentation process- Microbes and enzymes of industrial importance - screening and genetic improvement of industrially important microorganisms, Microbial metabolites- Microbial growth, Substrate degradation and product formation –Recombinant products.

Unit II

Fermentation systems -Batch culture, Continuous culture, Fed-batch culture, Kinetics of growth and product formation, Design of a fermenter, Basic functions of a fermenter for microbial or animal cell culture, Aseptic operation and containment, Construction and components, Types of fermenters, Fermenters for animal cell culture, Sterilization of reactor.

Unit III

Media for industrial fermentations: Typical media, Medium formulation, Precursors and metabolic regulators, Antifoams. Upstream and Downstream processing-Filtration, Centrifugation, Cell disruption, Liquid-liquid extraction, Chromatography, membrane processes, Drying, Crystallization, Whole broth processing.

Unit IV

Bioenergy- Gaseous fuels: Biohydrogen, Biomethane and Microbial fuel cell; Liquid fuels: Bioethanol, Biodiesel and Biobutanol, Aerobic and Anaerobic wastewater treatment processes—Single cell protein production -Metal leaching- Industrial chemicals- Food additives –Food supplements -Health care products.

VI. Practicals

- Isolation of Industrially important enzyme producing microorganisms
- Strain improvement
- Bioreactor operation
- Production of Industrial compounds, enzymes
- Downstream processing- Filtration, Centrifugation, Cell disruption,
- Liquid-liquid extraction, Chromatography- HPLC
- Microbial fuel cell design and operation for waste water treatment

VII. Suggested Readings

- Alberghina L. 2000. *Protein Engineering for Industrial Biotechnology*. Routledge.
- Kun LY. 2006. *Microbial Biotechnology*. World Scientific.
- Singh, R and Ghosh SK. 2004. *Industrial Biotechnology*. Global Vision Publ. House.
- Thomson J. 2006. *Your Guide to Industrial Biotechnology*. Abhishek Publ

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to fermentation process, history of fermentation process	1
2.	Enzymes of industrial importance, Microbes producing industrially important enzymes	2
3.	Screening of microbes for enzyme production	3
4.	Genetic improvement of microorganism for improved production	4-5
5.	Microbial growth studies and their metabolites-primary and secondary	6
6.	Product formation by substrate degradation	7

S. No.	Topic	No. of Lectures/ Practicals
7.	production of recombinant products	8
8.	Batch, continuous and fed batch fermentation	9-10
9.	Kinetics of growth and product formation	11-12
10.	Design of a fermenter, basic functions, types of fermenters	13
11.	Animal cell culture by using bioreactors, Fermenters for animal cell culture	14
12.	Aseptic operation, Containment, Sterilization	15-16
13.	Medium formulation, precursors, metabolic regulators, antifoams	17-18
14.	Upstream and down stream processing	19
15.	Filteration, Centrifugation	20
16.	Extraction, Chromatography, membrane process	21-22
17.	Drying crystallization, whole broth processing	23-24
18.	Bioenergy production	25
19.	Biohydrogen, biomethane, biodiesel and biobutanol production	26
20.	Microbial fuel cells	27
21.	Aerobic treatment of waste water	28
22.	Anaerobic waste water treatment	29
22.	Singel cell protein production, Metal leaching	30
23.	Food additives	31
24.	Food supplements and health care products	32
Practical		
1.	Isolation of industrially important enzyme producing microorganism	1
2.	Screening for enzyme production	2
3.	Extraction and characterization of enzymes	3
4.	Enzyme kinetics	4
5.	Strain improvement by different methods	5
6.	Bioreactor operation	6
7.	Optimiisation of enzyme and industrial compounds production using bioreactor	7
8.	Filteration	8
9.	Cell disruption	9
10.	Chromatography	10-12
11.	Microbial fuel cell design	13
12.	Optimisation of electrodes, catholyte	14
13.	Waste water treatment	15-16

I. Course Title : Rumen and Feed Biotechnology

II. Course Code : BTY 711

III. Credit Hours : 2 + 1

IV. Aim of the course

Understanding the rumen ecosystem and manipulation of rumen microbes.

V. Theory

Unit I

Rumen ecosystem – Classification of rumen microbes – Isolation – Cultural characters – Rumen fermentation – Techniques to increase production of rumen microbes – Metabolic inter-relationship between rumen microbes.

Unit II

Feed processing and preservation, Microbial bioconversion of lignin and cellulose rich feeds -Factors affecting delignification, Large scale bioconversion of substrates, Pretreatment of feeds, Chemical vs microbial treatment of feeds, Anti-nutritional factors present in feeds, Microbial detoxification of aflatoxins, Mimosine and other anti-metabolites present.

Unit III

Manipulation of rumen methane production – Addition of methane inhibitors.– Non-genetic manipulation of rumen microbes – Addition of antibiotics, Selective defaunation, Addition of fats, Addition of protein degradation protectans, Addition of buffer substances – Rumen escape proteins.

Unit IV

Genetic manipulation of rumen microflora to improve feed utilization -Manipulation of rumen microbes by recombinant DNA technology – Inter species H_2 transfer and its importance –Single cell protein (SCP) as animal feed-Rumen metagenomics-Methods of studying rumen metagenome-Conventional cloning and sequencing of metagenomic DNA-NGS based shot gun sequencing – Amplicon sequencing of 16 S/ 18S rRNA hyper variable regions –Bioinformatics analysis of metagenomic sequence data Use of probiotics-Microorganisms and proteins used as probiotics, Mechanism of action of probiotics, Immune response to probiotics, Anti-mutagenic and anti-tumour activities of probiotics.

VI. Practicals

- Introduction to feeds and fodders for ruminants
- Estimation of proximate principles, Fibre fractions in concentrates and roughages
- Methods for evaluating rumen fermentation parameters
- Sampling of rumen contents – Microbial and protozoal count – Fixing and staining of rumen protozoa and bacteria
- Estimation of rumen fermentation parameters-pH, Rumen NH3-N, Lactic acid
- *In-vitro* Gas Production Test -(IVGPT)
- Rumen liquor analysis – Total volatile fatty acids – Individual volatile fatty acids-Ammonia Nitrogen
- TCA precipitable Nitrogen-Methane production
- Rumen microbial enzyme assay
- Isolation of DNA from rumen samples
- Rumen metagenome and Bioinformatics analysis of metagenomic sequence data

VII. Suggested Readings

- Huffnagle GB and Wernick S. 2007. *The Probiotics Revolution: The Definitive Guide to Safe, Natural Health*. Bantam Books.
- Kalidas S, Paliyath G, Pometto A and Levin RE. 2004. *Functional Foods and Biotechnology*. CRC Press.
- Roger A. 1989. *Food Biotechnology*. Cambridge Univ. Press.
- Hobson PN and Stewart CS. 1997. *The Rumen Microbial Ecosystem*.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Rumen ecosystem – Classification of rumen microbes	1-2
2.	Isolation and Cultural characters of rumen microbes	3-4
3.	Rumen fermentation – Techniques to increase production of rumen microbes	5-6
4.	Metabolic inter-relationship between rumen microbes	7
5.	Feed processing and preservation, microbial bioconversion of lignin and cellulose rich feeds -Factors affecting delignification, large scale bioconversion of substrates	8-9
6.	Pretreatment of feeds, chemical vs microbial treatment of feeds, anti-nutritional factors present in feeds	10-11
7.	Microbial detoxification of aflatoxins, mimosine and other anti-metabolites present.	12-13
8.	Manipulation of rumen methane production – addition of methane inhibitors	14-15
9.	Non-genetic manipulation of rumen microbes – addition of antibiotics, selective defaunation, addition of fats, addition of protein degradation protectans, addition of buffer substances – Rumen escape proteins.	16-17
10.	Genetic manipulation of rumen microflora to improve feed utilization -Manipulation of rumen microbes by recombinant DNA technology	18-19
11.	Inter species H_2 transfer and its importance –Single cell protein (SCP) as animal feed	20
12.	Rumen metagenomics-Methods of studying rumen metagenome-conventional cloning and sequencing of metagenomic DNA	21-22
13.	NGS based shot gun sequencing – amplicon sequencing of 16S/ 18S rRNA hyper variable regions	23-24
14.	Bioinformatics analysis of metagenomic sequence data	25-26
15.	Use of probiotics-Microorganisms and proteins used as probiotics	27-28
16.	Mechanism of action of probiotics, immune response to probiotics.	29-30
17.	Anti-mutagenic and anti-tumour activities of probiotics.	31-32
Practical		
1.	Introduction to feeds and fodders for ruminants	1
2.	Estimation of proximate principles in concentrates and roughages	2
3.	Estimation of fibre fractions in concentrates and roughages	3
4.	Methods for evaluating rumen fermentation parameters	4
5.	Sampling of rumen contents – Microbial and protozoal count	5
6.	Fixing and staining of rumen protozoa and bacteria	6
7.	Estimation of rumen fermentation parameters-pH, Rumen NH3-N, Lactic acid	7
8.	*In-vitro* Gas Production Test (IVGPT)	8
9.	Rumen liquor analysis – Total volatile fatty acids – Individual volatile fatty acids – Ammonia Nitrogen	9
10.	TCA precipitable Nitrogen-Methane production	10
11.	Rumen microbial enzyme assay	11
12.	Collection,isolation and quality check of DNA from rumen samples	12
13.	Rumen metagenome and Bioinformatics analysis of metagenomic sequence data	13

List of Journals

- *Animal Biotechnology*
- *Animal Genetics*
- *Animal Reproduction*
- *Cellular and Molecular Probe*
- *Current Science*
- *Genome Research*
- *Indian journal of Microbiology*
- *Journal of Clinical Microbiology*
- *Journal of Dairy Science*
- *Journal of Reproduction and Fertility*
- *Methods in Virus Research*
- *Nature*
- *Nature Biotechnology*
- *Nature Genetics*
- *Nucleic Acid Research*
- *PNAS*
- *Reproduction in Domestic Animals Science*
- *Theriogenology*
- *Trends in Biotechnology*
- *Trends in Genetics*
- *Viral Research*

e-Resources

www.cls.casa.colostate.edu/TransgenicCrops/teacherlinks
www.hpc.unm.edu/~aroberts/main/top5%25.htm
www.isaaa.org
www.ciat.cgiar.org/biotechnology/cbn/gines_mera_fund.htm
www.scidev.net/en/agriculture-and-environment/agri-biotech/links/publications-andinformation-services
www.biotechinstitute.org/programs/t_leader_program.html
www.sci-ed-ga.org/modules/dna/analogies.html
www.accessexcellence.org/AE/AEPC/WWC/1993
www.atschool.eduweb.co.uk/trinity/bio2.html
www.pub.ac.za/resources/teach.html
www.bio-link.org/biomaterial.htm
www.biotechnology.gov.au/index.cfm?event=object.showContent and objectID=B35A914C-DE3D-1A59-79F89FAA26F54E44
www.monsanto.com/products/techandsafety/technicalpubs/eduwebsites.asp
www.ejbiotechnology.info/content/vol5/issue3/teaching/01/index.html
www.ncbiotech.org/resource_center/for_educators/online_teaching_resources.html
www.ias.ac.in/currsci/dec252006/1594
www.cccoe.k12.ca.us/stsvcs/newteacher/rop/curr_rop_links2.html
www.scielo.cl/scielo.php?pid=S0717-34582003000100004 and script=sci_arttext
www.sunysb.edu/ligase/Forstudents/BiotechTeachingCenter/biotechcenter.html
www.ca.uky.edu/agc/pubs/brei/brei3tg/brei3tg.htm
www.aggie-horticulture.tamu.edu/tisscult/biotech/biotechteach.html
www.ejbiotechnology.info/content/vol6/issue2/issues/2/index.html
http://science.nhmccd.edu/biol/bio1int.htm#dna

http://nhscience.lonestar.edu/biol/bio1int.htm
www.ingentaconnect.com/content/tandf/tsed/2000/00000022/00000009/art00007
www.buildingbiotechnology.com/free.php
www.biotechnologist2020.com/2008/04/teaching-jobs-in-bioinformatics.html
www.eric.ed.gov/ERICWebPortal/recordDetail?accno=EJ613711
www.uq.edu.au/teaching-learning/index.html?page=61920
www.nature.com/nbt/journal/v18/n9/full/nbt0900_913b.html
www.fotodyne.com/literature/datasheets/E10700
www.biotethics.org/conferences/maastricht/partecipants.html
www.brookes.ac.uk/studying/courses/postgraduate/2008/biotech
www.bioweb.usc.edu/courses/2003-spring/documents/bisc406-notes_011603
www.agen.ufl.edu/~chyn/age2062/lect/lect_09/lect_09.htm
www.bioinformaticscourses.com/BIOL358/lectures.html
www.isis.vt.edu/~nstone/LifeSci/lect5.html
www.nwo.nl/nwohome.nsf/pages/NWOA_6Y2LGH_Eng
www.soi.wide.ad.jp/class/20040016
www.sciencetech.technomuses.ca/english/schoolzone/biotech.cfm
www.freevideolectures.com/biotech.html
www.agen.ufl.edu/~chyn/age4660/lect/lect_07/lect_07.htm
www.web.mit.edu/cheme/news/frontiers_2005.html

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Basic Veterinary Sciences
– Veterinary Extension Education

Preamble
(Veterinary Extension Education)

To ensure that academic and scientific developments in all fields of veterinary sciences and Animal Husbandry get translated into adoption by the beneficiaries, framing of contemporary courses in Veterinary Extension became essential. Livestock entrepreneurship course has been introduced at masters level. New courses at doctorate level like theory constructions in social sciences, facilitation for development and Management Extension Organizations were introduced for the first time in view of the importance of the same. Farm journalism has been shifted to Masters level. SSS-600-Statistics for Social Sciences (2+1) is made core corse for M.V.Sc.

The national priorities/ international developments are given due importance and are aligned accordingly in the curriculum adequately to build required competencies of the students to meet challenges of current agricultural scenarios. The curriculum development emphasized on outcome-based approach, the social process of curriculum construction (involvement of stakeholders) and matching curriculum with job requirements for employability of students. A significant emphasis on the different developmental programmes and or initiatives of the Government of India are highlighted in the syllabi of the postgraduate and doctoral programmes. The following are the specific inclusions of topics/ units focusing on the recent national priorities/ international developments.

Course	Topic/ Unit Included
EXT 601: Development Perspectives of Extension Education (2 +1)	Extension approaches followed in current livestock development programmes, viz., Rashtriya Gokul Mission, National Livestock Mission, Rashtriya Krishi Vikas Yojana, Livestock Insurance Scheme, Livestock Health and Disease Control, Pashu Sanjivini, National Programme for Dairy Development, National Programme for Bovine Breeding, Aatmanirbhar Bharat Abhiyaan and digital initiatives such as E- Pashudhan Haat, National Animal Disease Reporting System for livestock development, etc.
EXT 607: Livestock Entrepreneurship (1+2)	Role of Government and Non-Government agencies in promoting entrepreneurship in India- eg. Atal Innovation Mission, Startup India, Mudra Bank Scheme, Dairy Entrepreneurship Development Scheme, Agri-Clinics & Agri-Business Centers (ACABC), Entrepreneurship Development and Employment Generation (EDEG)
EXT 609: Gender Empowerment and	Policies and programmes in empowering women

Course	Topic/ Unit Included
Livestock Development (1+0)	in general and livestock development in specific. eg. UJJAWALA, Pradhan Mantri Mahila Shakti Kendra, One Stop Centre Scheme, Mahila E-haat, STEP, etc.
EXT 704 Policies and Regulations in the Livestock Sector (1+0)	State, National and Global policies related to livestock sector WTO, IPR, HACCP, Sanitary and phyto-sanitary measures, Agriculture Produce and Livestock Marketing (APLM) Act, Animal Welfare, etc.
EXT 705 Educational Technology (2+1)	Digital Initiatives in Education, viz., SWAYAM (MOOCs platform) Swayam Prabha, National Digital Library, National Academic Depository, E-Shodh Sindhu, E Acharya, EVidhwaan, Agriculture Education Portal, e-KrishiShiksha, KrishiKosh, CeRA, National Educational Alliance for Technology (NEAT), etc.
EXT 707: Monitoring and Evaluation of Livestock Development Programmes (2+1)	Development of M&E plans and procedures for livestock developmental programmes using the participatory approach.

Course Title with Credit Load
M.V.Sc. in Veterinary Extension Education

Course Code	Course Title	Credit Hours
EXT 601	Development Perspectives of Extension Education	2+1
EXT 602	Communication for Livestock Development	1+1
EXT 603	Diffusion and Adoption of Innovations	2+1
EXT 604	Programme Planning and Evaluation	1+1
EXT 605	Research Methodology	2+1
EXT 606	Social Psychology and Group Dynamics	1+1
EXT 607	Livestock Entrepreneurship	1+2
EXT 608	Human Resource Management in Animal Husbandry Sector	1+1
EXT 609	Gender Empowerment and Livestock Development	1+0
EXT 610	Farm Journalism	1+1
SSS 600	Statistics for Social Sciences	2+1
EXT 611	Masters Seminar	1+0
EXT 612	Masters Research	0+30

Course Contents
M.V.Sc. in Veterinary Extension Education

I. Course Title : Development Perspectives of Extension Education
II. Course Code : EXT 601
III. Credit Hours : (2 +1)

IV. Aim of the courses

- To acquaint the students with different extension approaches and their implications in animal husbandry.
- To make students realise the importance of linkages among departments and various institutions.
- To acquaint the students with the recent development in extension.

V. Theory

Unit I

Important concepts in extension science; various schools of thought; Critical review and reflections on the philosophy and principles of extension.

Unit II

Implications of earlier extension efforts. Emerging issues, problems and challenges of animal husbandry extension education.

Unit III

Changing approaches – ToT approach, Education Approach, Farmer Participatory Approaches (PRA, RRA, PLA, PTD, PCD, etc.), Demand Driven approach, Market led extension, FSA, Commodity Specific Approach, Market led Extension; Classification of PRA, Differences between PRA and RRA; Global concepts of extension (SAARC, BRICS, US, Japan, UK, Philippines and Israel) and its application to Indian context. Privatization of extension. Public Private Partnership.

Unit IV

Extension approaches of State and Central Governments, ICAR, SVUs/ SAUs, NGOs, corporate and other organizations. Extension Advisory Services - Meaning, Concept - Challenges in Animal Husbandry Extension Advisory Services. Extension approaches followed in current livestock development programmes, viz., Rashtriya Gokul Mission, National Livestock Mission, Rashtriya Krishi Vikas Yojana, Livestock Insurance Scheme, Livestock Health and Disease Control, Pashu Sanjivini, National Programme for Dairy Development, National Programme for Bovine Breeding, Aatmanirbhar Bharat Abhiyaan and digital initiatives such as E-Pashudhan Haat, National Animal Disease Reporting System for livestock development, etc. Linkages between researcher-extension agent - livestock farmer-industry in the generation, Dissemination and commercialization of animal husbandry practices/ technologies.

VI. Practical

Study of the extension approaches, functions, roles, responsibilities, organizational set-up of State Animal Husbandry Department/ Livestock Development Agency/ Dairy Federation/ Rural Development agencies, Study of selected FPOs, CIGs, NGOs, SHGs, etc. Critical analysis of cases on linkage between different actors of animal husbandry sector.

VII. Suggested Reading

- Anandajayasekeram P, Puskur R, Sindu Workneh and Hoekstra D. 2008. *Concepts and practices in agricultural extension in developing countries:* A source book. IFPRI (International Food Policy Research Institute), Washington, DC, USA, and ILRI (International Livestock Research Institute), Nairobi, Kenya. 275 pp. https://cgspace.cgiar.org/bitstream/handle/10568/99/Source_book.pdf
- Ashok G, Sharma P, Anisha S and Prerna T. 2018. *Agriculture Extension System in India Review of Current Status, Trends and the Way Forward*, Indian Council for Research on International Economic Relations (ICRIER). http://icrier.org/pdf/Agriculture-Extension-System-in-India-2018.pdf
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- Burton ES, Robert PB and Andrew JS. 1997. *Improving agricultural extension A reference manual*, FAO Rome https://www.oerafrica.org/FTPFolder/Website%20Materials/Agriculture/haramaya/Perspective_Agricultural_Extension/Attachment/Improving%20AgEx.-FAO.pdf
- Dahama OP and Bhatnagar OP. 1987. *Education and Communication for Development*. Cambridge Univ. Press.
- Davis K and Sulaiman RV. 2016. *Extension Methods and Tools*. Module 2 NELK. GFRAS. https://www.g-fras.org/en/component/phocadownload/category/70-new-extensionist-learning-kit-nelk.html?download=560:nelk-module-2-extension-methods-and-tools-textbook
- Dharma OP. 2017. *Development Perspectives in Extension Education* Agro Tech Publishing Academy, Udiapur
- FAO. 2016. *New directions for inclusive Pluralistic Service Systems*. Report of FAO Expert Consultation. Food and Agriculture Organization of the United Nations and Royal Tropical Institute, Rome. http://www.fao.org/3/ai6103e.pdf
- GFRAS. 2016. *The New Extensionist Learning Kit*. http://g-fras.org/en/knowledge/new-extensionist-learningkit-nelk.html#module-1-introduction-to-the-new-extensionist
- Gwyn EJ and Garforth C. n.d. *The history, development, and future of agricultural extension*. FAO. Rome. http://www.fao.org/docrep/W5830E/w5830e03.htm
- Rivera WM and Schram SG. (Ed). 1987. *Agricultural Extension World wide – Issues, Practices and Emerging Priorities*. Croome Helm,
- Roling N. 1988. *Extension science, information systems in agricultural development*. Cambridge University Press
- S Adolph B. 2011. *Rural Advisory Services Worldwide: A Synthesis of Actors and Issues*. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/knowledge/gfras-publications.html?download =6:rural-advisory-services-worldwide and start=40
- Swanson BE. 2008. *Global Review of Good Agricultural Extension and Advisory Service Practices*. Food and Agriculture Organization of the United Nations. Rome. http://www.fao.org/docrep/pdf/011/i0261e/i0261e00.pdf

• Van den Ban AW and Hawkins HS. 1998. *Agricultural extension- Chapter* 10, BSL, CBS Publishers and Distributors.

Course outlines

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Important concepts in extension science	1
2.	Various schools of thought in extension	2
3.	Critical review and reflections on the philosophy of extension	2
4.	Critical review and reflections on the principles of extension	1
5.	Implications of earlier extension efforts.	1
6.	Emerging issues, problems and challenges of animal husbandry extension education	2
7.	Changing approaches – ToT approach, Education Approach, Demand Driven approach, Market led extension, FSA, Commodity Specific Approach, Market led Extension	3
8.	Farmer participatory approaches (PRA, RRA, PLA, PTD, PCD, etc Classification of PRA, Differences between PRA and RRA;	3
9.	Global concepts of extension (SAARC, BRICS, US, Japan, UK, Philippines and Israel) and its application to Indian context	3
10.	Systems Concepts - FSA, Commodity Specific Approach, Market led Extension, Privatization of extension. Public Private Partnership	3
11.	Extension approaches of State and Central Governments, ICAR, SVUs/ SAUs, NGOs, corporate and other organizations	4
12.	Extension Advisory Services - Meaning, Concept - Challenges in Animal Husbandry Extension Advisory Services	2
13.	Extension approaches followed in current livestock development programmes, viz., Rashtriya Gokul Mission, National Livestock Mission, Rashtriya Krishi Vikas Yojna, Livestock Insurance Scheme, Livestock Health and Disease Control, Pashu Sanjivini, National Programme for Dairy Development, National Programme for Bovine Breeding, Aatmanirbhar Bharat Abhiyaan and digital initiatives such as E-Pashudhan Haat, National Animal Disease Reporting System for livestock development, etc.	2
14.	Linkages between researcher-extension agent - livestock farmer-industry in the generation of animal husbandry practices/ technologies	1
15.	Linkages between researcher-extension agent - livestock farmer-industry in the dissemination and commercialization of animal husbandry practices/ technologies	1
	Total	**32**
Practicals		
1.	Study of the extension approaches, functions, roles, responsibilities	1
2.	Organizational set-up of State Animal Husbandry Department	1
3.	Organizational set-up dairy/ rural development agencies	2
4.	Organizational set-up of ICAR institutions	2
5.	Study on the formation of FPOs – principles, practices, requirements, procedures	2
6.	Study on the formation of CIGs - principles, practices, requirements, procedures	2
7.	Study on the formation of SHGs principles, practices, requirements, procedures	1

S. No.	Topic	No. of Lectures/ Practicals
8.	Role of NGOs in developmental perspectives	1
9.	Critical analysis of cases on linkage between different actors of animal husbandry sector.	2
10.	Critical analysis of livestock development programmes	2
	Total	**16**

I. Course Title : Communication for Livestock Development

II. Course Code : EXT 602

III. Credit Hours : (1+1)

IV. Aim of the course

To acquaint students with dynamics of communication and apply in development of livestock sector.

V. Theory

Unit I

Communication- meaning, concept, purpose and process of communication- Models and theories of communication: Aristotle, Berlo, Osgood Schramm, Shanon and Weaver, Johari window, New Comb, Westley and McLean, etc. Critical analysis of models and theories of communication. Recent developments in communication theories and models.

Unit II

Types of communication-intrapersonal, interpersonal, verbal and non-verbal; Criteria of effective communication, Determinants of communication- Empathy, credibility, fidelity, distortion, feedback and barriers to effective communication; Group and mass communication. Key communicators and their role in livestock development. Organizational Communication - formal- informal; downward-upward- horizontal; Problems in organizational communication.

Unit III

Business Communication: Relevance and importance in livestock business development. Features of business communication, Guidelines for business communication, formal and informal business communication, Various types of business communication (Letters, Reports, Proposals, Manuals, Outreach writing (Advertisements, Pamphlets, Signs, Press Release, etc.). Effective business communication.

Unit IV

ICT-concept, importance and types of tools and applications; Role and significance of ICT tools in Animal Husbandry Development - Use and importance of Social Media in livestock development. Overview of emerging technologies.

VI. Practical

Exercises in improving communication skills (Speaking skill – Public speaking, Persuasive speech, Informative speech, etc.) Exercises on Listening, Exercises on Reading, Exercises on Non-verbal communication, Writing of Business Communication, Identification of key communicators, Communication barriers, distortion and fidelity in livestock development. Identification of different social media tools used for livestock development; Comparative study of different tools and their areas of applications in animal husbandry sector; Hands on experience in writing blogs; ICT tools in Animal Husbandry Extension delivery system; Analysis of web portals – KVK portals, Knowledge portal, ICAR, SAUs, etc.

VII. Suggested Reading

- Bhagat Amit K. *Communication as a Management Tool: Principles and Practices*. Akhand Publishing House, New Delhi. 2012
- Cragan FJ and Wright WD. 1999. *Communication in Small Groups – Theory, Process, Skills*. Wadsworth Publ.
- Mcquail D and Windahl S. 1993. *Communication Models for the Study of Mass Communications*. Longman Publ.
- Ray GL. 2011. *Extension, Communication and Management*. Kalyani Publishers, Ludhiana.
- Rogers EM and Shoemaker FF. 1971. *Communication of Innovations: A Cross – Cultural Approach*. The Free Press.
- Roloft Michael F. 1981. *Interpersonal Communication*. Sage Publ.
- Ruben Brent D. *Communication and Human Behaviour*. McMillan Publishing Company. New York. 1984.
- Sehgal MK and Khetrapal V. 2008. *Business Communication*. Excel Books. New Delhi.
- Srinivasa Raju Melkote and H Leslie Steeves. 2001. *Communication for Development Theory and Practice for empowerment and social justice*. Sage Publications
- Andres D and Woodard J. 2013. *Social media handbook for agricultural development practitioners*. Publication by FHI360 of USAID. http://ictforag.org/toolkits/social/SocialMedia 4AgHandbook.pdf
- Barber J, Mangnus E and Bitzer V. 2016. *Harnessing ICT for agricultural extension*. KIT Working Paper 2016: 4. https://213ou636sh0ptphd141fqei1-wpengine.netdna-ssl.com/sed/wp-content/uploads/sites/2/2016/11/KIT_WP2016-4_Harnessing-ICT-for-agricultural-extension.pdf
- Bheenick K and Bionyi I. 2017. *Effective Tools for Knowledge Management and Learning in Agriculture and Rural Development*. CTA Working paper. https://publications.cta.int/media/publications/downloads/1986_PDF.pdf
- FAO 2011. *E-learning methodologies a guide for designing and developing e-learning courses*. Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/015/i2516e/i2516e.pdf
- George T, Bagazonzya H, BallantyneP, Belden C, Birner R, Del CR and Treinen S. 2017. *ICT in agriculture: connecting smallholders to knowledge, networks, and institutions*. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/12613 16
- Mayer RE. 2005. *The Cambridge handbook of multimedia learning*. New York: University of Cambridge.
- Mittal N, Surabhi, Gandhi, Sanjay and Gaurav T. 2010. *Socio-Economic Impact of Mobile Phones on Indian Agriculture*. ICRIER Working Paper No. 246, Indian Council for Research on International Economic Relations (ICRIER), New Delhi.
- Saravanan R and Suchiradipta B. 2016. *Social media policy guidelines for agricultural extension and advisory services*, *GFRAS interest group on ICT4RAS, GFRAS*: Lindau, Switzerland. www.g-fras.org/en/knowledge/gfras-publications.html?download=415:social-media-policy-guidelines-for-agricultural-extension-and-advisory-services
- Saravanan R. 2010. (Ed.) ICTs for Agricultural Extension: Global Experiments, Innovations and Experiences, New India Publishing Agency (NIPA), New Delhi.

http://www.saravananraj. net/wp-content/uploads/2014/12/32_India_ICTs-for-Agricultural-Extension_Saravanan.pdf

- World Bank. 2017. *ICT in Agriculture (Updated Edition): Connecting Smallholders to Knowledge, Networks, and Institutions*. Washington, DC: World Bank. https://openknowledge. worldbank.org/handle/10986/27526

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Communication – meaning, concept, purpose of communication	1
2.	Models and theories of communication: Aristotle, Berlo, Osgood Schramm, Shanon and Weaver, Johari window, New Comb, Westley and McLean, etc.	1
3.	Critical analysis of models and theories of communication.	1
4.	Recent developments in communication theories and models	1
5.	Types of communication-intrapersonal, interpersonal, verbal and non-verbal;	1
6.	Criteria of effective communication, Determinants of communication-Empathy, credibility, fidelity, distortion, feedback	1
7.	Barriers for effective communication	1
8.	Group and mass communication. Key communicators and their role in livestock development	1
9.	Organizational Communication - formal- informal; downward-upward-horizontal; Problems in organizational communication	
10.	Key communicators and their role in livestock development	1
11.	Business Communication: Relevance and importance in livestock business development	1
12.	Features and guidelines for business communication, Formal and informal business communication	1
13.	Various types of business communication (Letters, Reports, Proposals, Manuals, Outreach writing (Advertisements, Pamphlets, Signs, Press Release, etc.) Effective business communication	1
14.	ICT-concept, importance and types of tools and applications; Role and significance of ICT tools in Animal Husbandry Development	1
15.	Use and importance of Social Media in livestock development.	1
16.	Overview of emerging technologies	1
	Total	**16**
Practicals		
1.	Exercises in improving communication skills – Oral Communication	1
2.	Exercises in improving communication skills – Public speaking	1
3.	Exercises in improving communication skills – Persuasive speech	1
4.	Exercises in improving communication skills –Informative speech	1
5.	Exercises on Listening skills	1
6.	Exercise on Reading skills	1
7.	Exercise on Non-verbal communication	1
8.	Writing of Business Communications	1
9.	Identification of key communicators	1
10.	Role of key communicators	1
11.	Communication barriers	1
12.	Distortion and Fidelity of communication in livestock development.	1
13.	Importance of feedback in communication	1
14.	Identification of different social media tools used for livestock development	1
15.	Comparative study of different tools and their areas of applications in animal husbandry sector	1

S. No.	Topic	No. of Lectures/ Practicals
16.	ICT tools in Animal Husbandry Extension delivery system- analysis of web portals – KVK portals, Knowledge portal, ICAR, SAUs, etc.	1
	Total	**16**

I. Course Title : Diffusion and Adoption of Innovations

II. Course Code : EXT 603

III. Credit Hours : (2+1)

IV. Aim of the course

To sensitize the students to technology generation, dissemination and its adoption through effective communication

V. Theory

Unit I

Concept, meaning, importance of diffusion. Elements in diffusion process; Models and theories of diffusion.

Unit II

Concept, meaning, importance of adoption. Steps in adoption process. Adoption models; Stages in diffusion-adoption process; Innovation- Decision Process, Adopter categories and their characteristics. Factors influencing adoption. Attributes of innovations, Factors affecting the rate of adoption and sources of information. Consequences of innovations.

Unit III

Adopter categories and their characteristics. Identification and evaluation of innovations in livestock sector – Attributes, Reason for adoption, Non-adoption and Discontinuance, Consequences. Diffusion and adoption of livestock sectoral innovations.

Unit IV

Agricultural Innovation System – Origin of innovation system - Concepts and elements; Innovation vs Invention, Innovation and types of innovation; Innovations in livestock sector; Role of enabling environment; Methodologies for AIS Diagnosis; Capacity Development in AIS.

VI. Practical

Identification of adopter categories in the selected village, Study on attributes of innovation of selected dairy farming technologies/ sheep/ goat/ poultry farming technologies. Identification of sources of information at different stages of adoption on selected livestock technologies; Study of factors increasing or retarding the rate of adoption; Consequences of adoption of livestock technologies; Case studies in of Agricultural Innovation System, Presentation of reports on adoption and diffusion of innovations

VII. Suggested Reading

- Brown Lawrence A. 1981. *Innovation Diffusion: A New Perspective. Communication for Social Change*. Sage Publ.

- Cragan FJ and Wright WD. 1999. *Communication in Small Groups – Theory, Process, Skills*. Wadsworth Publ.
- Dasgupta. 1989. *Diffusion Agricultural Innovations in Village India*.
- Hall A, Sulaiman RV, Beshah T, Madzudzo E and Puskur R. 2009. *Agricultural innovation system capacity development: Tools, principles or policies*? Capacity.org (37): 16-17. http://www.capacity.org/en/journal/practice_reports/tools_principles_or_policies
- ILRI. 2014. *Innovation Platform practice briefs. International Livestock Research Institute*. https://clippings.ilri.org/2014/02/03/ipbrief1/
- Leeuwis C and van den Ban A W. 2004. *Communication for rural innovation: Rethinking agricultural extension*. John Wiley and Sons. Methuen.
- OECD. 2012. *Innovation for Development. A Discussion of the Issues and an Overview of Work of the OECD Directorate for Science, Technology and Industry*. https://www.oecd.org/innovation/inno/50586251.pdf
- Ray GL. 2005. *Extension Communication and Management*. Kalyani Publishers, AA. 1987.
- Rogers EM. 2003. *Diffusion of Innovations*. Free Press.
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- World Bank. 2006. *Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems*. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/7184
- World Bank. 2012. *Agricultural Innovation Systems: An Investment Source book*. Washington DC, World Bank. http://siteresources.worldbank.org/INTARD/Resources/335807-1330620492317/9780821386842.pdf

Course outlines

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Concept, Meaning, Importance of diffusion with special reference to Livestock Sector	1
2.	Elements in diffusion process	1
3.	Models and theories of diffusion	2
4.	Concept, meaning, importance of adoption	1
5.	Steps in adoption process. Adoption models	2
6.	Stages in diffusion-adoption process; Innovation- Decision Process	2
7.	Adopter categories and their characteristics.	1
8.	Factors influencing adoption	1
9.	Attributes of innovations	1
10.	Factors affecting the rate of adoption and sources of information.	1
11.	Consequences of innovations.	2
12.	Adopter categories and their characteristics	2
13.	Identification and evaluation of innovations in livestock sector – attributes, reason for adoption, non-adoption and discontinuance, Consequences.	3
14.	Diffusion and adoption of livestock sectoral innovations	2
15.	Agricultural Innovation System – origin of innovation system - concepts and elements	2
16.	Innovation vs Invention, Innovation and types of innovation	2
17.	Innovations in livestock sector	1
18.	Role of enabling environment; Methodologies for AIS Diagnosis	3
19.	Capacity Development in AIS	2
	Total	**32**

S. No.	Topic	No. of Lectures/ Practicals
Practicals		
1.	Identification of adopter categories in the selected village	2
2.	Study on the attributes of innovation of selected dairy farming technologies	2
3.	Attributes of innovation of selected sheep/ goat/ poultry farming technologies	2
4.	Identification of sources of information at different stages of adoption on a selected livestock technologies	2
5.	Study of factors increasing or retarding the rate of adoption	2
6.	Consequences of adoption of livestock technologies	2
7.	Case studies in of Agricultural Innovation System	2
8.	Presentation of reports on adoption and diffusion of innovations	2
	Total	**16**

I. Course Title : Programme Planning and Evaluation

II. Course Code : EXT 604

III. Credit Hours : 1+1

IV. Aim of the course

To expose the students to programme planning, Monitoring and evaluation of animal husbandry development programmes.

V. Theory

Unit I

Genesis and importance of programme planning. Objectives, principles and steps in programme planning process. Role of animal husbandry extension agencies and stakeholders in planning and implementation of Animal Husbandry Extension programmes.

Unit II

Participatory Programme planning: Meaning, Role and Benefits; Stakeholders Participation in Development - Identify Key Stakeholders, Examine Stakeholder's Interests and Impact of the Project, Assess Stakeholder Power and Interest, Outline a Stakeholder Participation Strategy.

Unit III

Meaning and Scope of Monitoring; Basic Concepts and Elements in Monitoring; Types of Monitoring; Techniques of Monitoring; What is Evaluation? Appraisal vs. Monitoring vs. Evaluation vs. Impact Assessment – Major differences; Types of Evaluation, Evaluation Designs.

Unit IV

Project Management Techniques- Gantt chart, Programme Evaluation and Review Technique (PERT). Critical Path Method (CPM). Project formulation. Project appraisal in terms of social benefit analysis, logical frame work. Various stakeholders in livestock development; stakeholder analysis, and report writing.

VI. Practical

Preparation of comprehensive livestock development programme for a village.

Developing instruments for monitoring and evaluation of on-going development programme at village level (Logical Frame Work). Participatory techniques (RRA, PRA, Case study, etc.). SWOT analysis of a livestock development programme.

VII. Suggested Reading

- Bagno lB. 2014. *Conducting participatory monitoring and evaluation*. Pages 81-85 in FAO, Decision tools for family poultry development.
- Baker H. 1984. *The program planning process*. Pages 50-64 in D. Blackburn (ed.), Extension handbook. Guelph, Ontario, Canada: University of Guelph.
- Baum WC and Tolbert SM. 1985. *Investing in Development: Lessons of the World Bank Experience*, Oxford University Press.
- Bennett CF. 1979. *Analyzing impacts of extension programs*. Washington, D.C., USA: U.S. Department of Agriculture.
- Choudhary S. 1988. *Project Management*, New Delhi: Tata McGraw Hill.
- Dale R. 2004. *Evaluating Development Programmes and Projects*, New Delhi, India: Sage Publications
- Fear FA. 1988. *Community needs assessment: A crucial tool for adult educators*. Paper presented at the MAACE Midwinter Conference, February 1988, Lansing, Michigan, USA.
- GFRAS. 2017. *The New Extensionist Learning Kit*. 13 Learning Modules for Extension Professionals. Lausanne, Switzerland, Global Forum for Rural Advisory Services GFRAS.
- Harold Kerzner. 2013. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*. Wiley
- Hoffman V, Christinck A and Lemma M. (eds.). 2009. *Rural Extension*. Margraf Publishers GmbH.
- Leagans JP. 1961. *Programme planning to meet people's needs. In: Extension education in community development, Directorate of Extension*, Ministry of Food and Agriculture, Government of India, New Delhi.
- Mukherjee N. 2002. *Participatory Learning and Action with 100 field Methods*. Concept Publishing Company, New Delhi.
- Rietbergen MJ and Narayan D. 1997. *Participatory tools and techniques: A resource kit for participation and social assessment*. Washington, D.C., USA: The World Bank. Accessed at: www.fao.org/ag/ againfo/ programmes/ en/ lead/ toolbox/ Refer/ STkHold.htm
- Roling N. 1988. *Extension science: information systems in agricultural development*, Cambridge University Press.
- Scott Bercun. 2008. *Making Things Happen – Mastering Project Management*. O'Reilly Publishers
- Somesh K. 2002. *Methods for Community Participation - A Complete Guide for Practitioners*. Vistar Publications New Delhi.
- Suvedi M and Kaplowitz MD. 2016. *Process Skills and Competency Tools – What Every Extension Worker Should Know – Core Competency Handbook*. Urbana, IL, USAID-MEAS.
- Van den Ban AW and Hawkins HS. 2002. *Agricultural extension*, CBS Publishers and Distributors, New Delhi.

Course outlines

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Genesis and importance of programme planning in Animal Husbandry Sector	1
2.	Objectives, principles and steps in programme planning process	1
3.	Role of animal husbandry extension agencies and stakeholders in planning and implementation of animal husbandry extension programmes	1
4.	Participatory Programme planning – Meaning, Role and Benefits	1

S. No.	Topic	No. of Lectures/ Practicals
5.	Stakeholders Participation in Development - Identify Key Stakeholders, Examine Stakeholder's Interests and Impact of the Project	1
6.	Assess Stakeholder Power and Interest, Outline a Stakeholder Participation Strategy;	1
7.	Meaning and Scope of Monitoring; Basic Concepts and Elements in Monitoring; Types of Monitoring;	2
8.	Techniques of Monitoring; What is Evaluation? Appraisal vs. Monitoring vs. Evaluation vs. Impact Assessment – Major differences;	1
9.	Types of Evaluation, Evaluation Designs;	1
10.	Project Management Techniques- Gantt chart, Programme Evaluation and Review Technique (PERT). Critical Path Method (CPM)	2
11.	Project formulation, Project appraisal in terms of social benefit analysis, logical frame work	1
12.	Various stakeholders in livestock development;	2
13.	Stakeholder analysis, and report writing.	1
	Total	**16**
Practicals		
1.	Preparation of comprehensive livestock development programme for a village	3
2.	Developing instruments for monitoring and evaluation	2
3.	Identification of key stakeholders in the livestock development	1
4.	Application of developed instruments for monitoring and evaluation of on-going development programme at village level (Logical Frame Work)	2
5.	Data collection and analysis of on-going development programme of a village	2
6.	Simulated exercises on Project Management Techniques - Gantt chart, PERT, CPM	3
7.	SWOT analysis of a livestock development programmes	1
8.	Report preparation and presentation	2
	Total	**16**

I. Course Title : Research Methodology

II. Course Code : EXT 605

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and skills in formulating and conducting an independent research in the field of Animal Husbandry Extension.

V. Theory

Unit I

Concept, nature and scope of research in social sciences. Types of research- fundamental, applied and action research, experimental and non-experimental research. Identification of concepts, constructs, variables. Hypothesis– importance, selection criteria (qualities of a workable hypothesis), formulation and testing of hypothesis. Selection and formulation of research problem.

Unit II

Measurement and levels of measurement; Research designs- exploratory, experimental, and ex-post-facto research design. Sampling -Sampling methods- probability and non-probability sampling. Sources of errors.

Unit III

Methods of data collection– survey method, observation method, interview/ questionnaire method, case study, content analysis, sociometry, focus group discussion, projective techniques, Online tools of data collection, Reliability and validity of measuring instruments.

Unit IV

Social statistics – designs in data analysis, Parametric and Non-Parametric statistical methods. Data analysis and interpretation and inference, Report writing. Review of studies in social research.

VI. Practical

Construction of data collection tools, GPS-enabled data collection, Development of online tools of data collection (Google Forms, Survey Monkeys, etc.) Application of statistical software for data analysis and interpretation. Creative scientific thinking, selecting a research problem and working it out with all the steps; report writing and presentation of the reports.

VII. Suggested Reading

- Arlene Fink (Ed). 2003. *The Survey Kit* (10 booklets). Sage Publ.
- Babbie E. 2008. *The basics of social research*. 4th ed. Belmont, CA, USA; Thompson Wordsworth.
- Creswell JW. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. Third edition. Thousand Oaks: Sage Publications.
- Creswell John W. 1994. *Research Design – Qualitative and Quantitative Approaches*. University of Nebraska, Lincoln.
- Creswell JW. 2012. *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Fourth edition. Boston, MA: Pearson.
- Edwards AL. 1969. *Techniques of Attitude Scale Construction*. Vakil, Feffer and Simons
- Garrett HE. 1966. *Statistics in Psychology and Education*. International Book Bureau, Hyderabad.
- Goode WJ and Hatt PK. 1952. *Methods in Social Research*. McGraw-Hill.
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- Henerson EM, Morris LL. and Gibbon CT. 1987. *How to Measure Attitudes*. Sage Publ.
- Kerlinger FN and Lee HB. 2000. *Foundations of Behavioral Research*. Orlando, FL: Harcourt College Publishers.
- Kumar R. 2014. *Research Methodology: A Step –by - Step Guide for Beginners*. Fourth Edition. Thousand Oaks, California: Sage Publications.
- Miller Delbert C. 1991. *Handbook of Research Design and Social Measurement*. Indiana University. Sage Publ.
- NeumanWL. 2006. *Social Research Methods: Qualitative and Quantitative Approaches*. Toronto: Pearson.
- Oppenheim AN. 1979. *Questionnaire Design and Attitude Measurement*. Heinemann Educational Books.
- Sekaran U and Bougie R. 2013. *Research Methods for Business A Skill-Building Approach*. 6th Edition, Wiley, New York.
- Sivakumar PS, Sontakki BS, Sulaiman RV, Saravanan R and Mittal N. (eds). 2017. *Good Practices in Agricultural Extension Research. Manual on Good Practices in Extension Research and Evaluation. Agricultural Extension in South Asia.* Centre for research on innovation and science and policy (CRISP), Hyderabad. India.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Concept, nature and scope of research in social sciences, scientific vs nonscientific approaches,	1
2.	Research - Characteristics of research, Approaches of Research	1
3.	Types of Research (Pure/ Basic; Evaluative, Fundamental, applied and action research)	1
4.	Experimental and non-experimental research	1
5.	Identification of concepts, constructs, variables	1
6.	Hypothesis and its importance, Characteristics and sources and Classification of hypothesis	1
7.	Selection criteria (qualities of a workable hypothesis)	1
8.	Formulation and testing of hypothesis	1
9.	Selection and formulation of research problem	1
10.	Measurement and levels of measurement	1
11.	Research Designs - Exploratory research design	1
12.	Research Designs Experimental research design	1
13.	Research Designs Ex-post-facto research design	1
14.	Sampling– concept, meaning importance in social sciences	1
15.	Sampling methods - Probability Sampling and Non-Probability sampling	1
16.	Sources of errors	2
17.	Methods of data collection: Over view of different tools of data collection, selection of appropriate method	1
18.	Survey method – Purpose, Types, Planning a survey, advantages and limitations	1
19.	Observation Method - Purpose, Types, Planning for observation, advantages and limitations	1
20.	Interview/ questionnaire method - Purpose, Types, Planning an Interview/ questionnaire, advantages and limitations	1
21.	Case study - Purpose, Planning a case study, advantages and limitations	1
22.	Content analysis	1
23.	Focus Group Discussion	1
24.	Sociometry and projective techniques	1
25.	Online tools of data collection – concept, meaning, importance and types in social research	1
26.	Reliability of measuring instruments – definition, importance in social sciences, Methods to test reliability	1
27.	Validity of measuring instruments - definition, importance in social sciences, Types of validity	1
28.	Social statistics – designs in data analysis – criteria for choosing a right a right design and analysis	1
29.	Parametric and Non-Parametric statistical methods – use and significance; types of tests used in social research with implications	1
30.	Data analysis and interpretation and inference	2
31.	Report writing	1
32.	Review of studies in social research	1
	Total	**32**
Practicals		
1.	Construction of different data collection tools relevant to livestock sector	2
2.	GPS-enabled data collection	3

S. No.	Topic	No. of Lectures/ Practicals
3.	Development of online tools of data collection (Google Forms, Survey Monkeys, etc.)	2
4.	Application of statistical software for data analysis and interpretation	3
5.	Creative scientific thinking	1
6.	Selecting a research problem and working it out with all the steps	3
7.	Report writing and presentation of the report.	2
	Total	**16**

I. Course Title : Social Psychology and Group Dynamics

II. Course Code : EXT 606

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with the structure and functioning of social groups and socio psychological aspects in interacting with livestock farmers.

V. Theory

Unit I

Concepts, scope and importance of psychology and social psychology in animal husbandry extension, Perception - nature, laws and selectivity in perception, factors in perception, importance of perception in extension work, Attitude - nature, theories, measurement and change of attitude towards livestock farming, Importance of attitude scales in livestock research and development.

Unit II

Motivation– nature, characteristics, theories, types and techniques of motivating farmers, Learning- principles, theories of learning and experiential learning and adult learning (andragogy).

Unit III

Intelligence- nature, theories and measurement, Personality- nature, traits, types, biological and socio-cultural determinants of personality, Group and individual behaviour.

Unit IV

Concept and types of groups; Group behaviour and dynamics: structures - attraction, coalition, communication and power; group mobilisation – social capital, group decision making, Factors affecting group performance; Conflict management in groups; Group belongingness, Community Mobilization, Importance of coordination among livestock development organisations.

VI. Practical

Study of groups and group dynamics (*eg*.: Self Help Groups (SHGs), Milk Cooperative Societies, Commodity groups and Farmer producer Company/ organization (FPO), Joint Liability Group (JLG), youth clubs, etc.). Exercises on measurement of motivation, perception and personality traits.

VII. Suggested Reading

- Cragan FJ and Wright WD. 1999. *Communication in Small Groups – Theory, Process, Skills*. Wadsworth Publ.
- Donelson R. Forsyth, *Group Dynamics* 2018 7th Edition, Cengage Learning
- Joseph Bohac and Stan Dekoven 2013. *Group Dynamics*. Vision Publishing (Ramona, CA)
- Kagan J and Havemann E. 1980. *Psychology – An Introduction*. Harcourt Brace Javanovich Inc.
- Morgan CT, King RA and Robinson NM. 1979. *Introduction to Psychology*. Tata McGraw-Hill.
- Napier RW and Gershenfeld MK. 2006. *Groups – Theory and Experience*. AITBS Publ.
- Robert A Baron. *Social Psychology*. 2016. 13th Edition Pearson Education
- Secord PF and Backman CW. 1964. *Social Psychology*. McGraw-Hill.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Concepts, scope and importance of psychology and social psychology in animal husbandry extension	1
2.	Perception - nature, laws and selectivity in perception	1
3.	Attitude - nature, theories, measurement and change of attitude towards livestock farming. Importance of attitude scales in livestock research and development.	1
4.	Motivation– nature, characteristics, theories, types and techniques of motivating farmers.	2
5.	Learning- principles, theories of learning and experiential learning and adult learning (andragogy).	2
6.	Intelligence- nature, theories and measurement.	1
7.	Personality- nature, traits, types, biological and socio-cultural determinants of personality.	1
8.	Group and individual behaviour.	1
9.	Concept and types of groups; Group behaviour and dynamics: structures - attraction, coalition, communication and power; group mobilisation – social capital, group decision making	2
10.	Factors affecting group performance;	1
11.	Conflict management in groups;	1
12.	Group belongingness, Community Mobilization,	1
	Total	**16**
Practicals		
1.	Study of Self Help Groups and their group dynamics	2
2.	Study of Milk Cooperative Societies and their group dynamics	2
3.	Study of Commodity Interest groups (CIGs)	2
4.	Study of Farmer Producer Company/ organization (FPO)	2
5.	Study of Joint Liability Group (JLG) and youth clubs, etc.	2
6.	Exercises on measurement of motivation	2
7.	Exercises on measurement of perception	2
8.	Exercises on measurement of personality traits	2
	Total	**16**

I. Course Title : Livestock Entrepreneurship

II. Course Code : EXT 607

III. Credit Hours : 1+2

IV. Aim of the courses

- To orient the students on basic concepts of entrepreneurship and the initiatives in promoting livestock as an enterprise.
- To impart knowledge in the various facets of entrepreneurial management and consumer behaviour for establishment of livestock ventures.

V. Theory

Unit I

Entrepreneurship - Role of Entrepreneurship in Economic Development of the country and current scenario and future prospects; Factors influencing Entrepreneurship (Internal factors, External factors, Political factors, Socio-Cultural Environment, Legal and Technological Environment); Role of Government and Non-Government agencies in promoting entrepreneurship in India- eg: Atal Innovation Mission, Startup India, Mudra Bank Scheme, Dairy Entrepreneurship Development Scheme, Agri-Clinics and Agri-Business Centers (ACABC), Entrepreneurship Development and Employment Generation (EDEG), etc.

Unit II

Livestock -Business Plan: Business Idea Generation, Brainstorming and evaluation of ideas, Competition, Scalability of the product, Price feasibility, Distribution and logistics, Ease of technology, Opportunities and threats, Internal strengths and weaknesses (SWOT analysis) Government regulations and statutory compliances, Sources of financial assistance.

Unit III

Livestock Business Evaluation: Evaluating financial feasibility, Cost of production and marketing, Project cost determination and fund requirement, Assessing working capital requirement, Non-fund based requirements (BG, LC), Cost of capital sources and cost of finance. Technical feasibility, Patents, Make or buy decision, Plant size and location, Machinery requirement, Outsourcing requirements, Project report and appraisal techniques- Net present value, Payback period, Break even analysis, CB Ratio.

Unit IV

Consumer Behaviour: Consumer behaviour- Definition, Consumer and customers, Buyers and users, Consumer behaviour and its applications in livestock marketing; Consumer behaviour models; Consumer motivation, Consumer perception, Consumer behaviour and marketing communications, Consumer decision-making process, Organizational buying behaviour, Modern marketing information system (marketing intelligence, communicating and acting on marketing intelligence).

VI. Practical

Exposure visits to commercial livestock enterprises- Dairy, Poultry, Meat/ Dairy/ Feed Processing Units. Analysis of successful cases of livestock entrepreneurship, Development of livestock business plans, Presentation of livestock business development plans, Study of consumer behavior, Critical analysis of livestock markets/ super markets/ malls.

VII. Suggested Reading

- Khanka SS. 1999. *Entrepreneurial Development*. S. Chand and Co.
- Gupta CB. 2001. *Management Theory and Practice*. Sultan Chand and Sons.
- Grover I. 2008. *Handbook on Empowerment and Entrepreneurship*. Agrotech Public
- Nandan H. 2013. *Fundamentals of Entrepreneurship*, PHI publishers
- Reading material of Course AEM-202 Agri-*Business and Entrepreneurship Development*. http://www.manage.gov.in/pgdaem/studymaterial/aem202.pdf
- Hisrich RD, Peters MP and Shepherd A. 2007. *Entrepreneurship*, 6th Edition, Tata McGraw Hill
- Singh D. 1995. *Effective Managerial Leadership*. Deep and Deep Publ.
- Tripathi PC and Reddy PN. 1991. *Principles of Management*. Tata McGraw Hill.
- Desai V. 1997. *Small Scale Industries and Entrepreneurship*. Himalaya Publ. House.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Entrepreneurship and its role in Economic Development of the country and current scenario and future prospects	1
2.	Factors influencing Entrepreneurship (Internal factors, External factors, Political factors, Socio - Cultural Environment, Legal and Technological Environment)	1
3.	Role of Government and Non-Government agencies in promoting entrepreneurship in India- eg: Atal Innovation Mission, Startup India, Mudra Bank Scheme, Dairy Entrepreneurship Development Scheme, Agri-Clinics and Agri-Business Centers (ACABC), Entrepreneurship Development and Employment Generation (EDEG), etc.	1
4.	**Livestock -Business Plan**: Business Idea Generation, Brainstorming and Evaluation of ideas, Competition, scalability of the product, Price feasibility, Distribution and Logistics Ease of Technology, Opportunities and Threats, Internal Strengths and Weaknesses (SWOT analysis)	2
5.	Government Regulations and statutory compliances, Sources of Financial Assistance	1
6.	**Livestock Business Evaluation**: Evaluating Financial Feasibility, Cost of Production and Marketing, Project Cost Determination and Fund requirement, assessing Working Capital Requirement, Non-fund based Requirements (BG, LC), Cost of Capital Sources and Cost of Finance	2
7.	Technical Feasibility, Patents, Make or Buy Decision, Plant Size and Location, Machinery Requirement, Outsourcing Requirements,	2
8.	Project Report and Appraisal Techniques- Net Present Value, Payback period, Break even analysis, CB Ratio	2
9.	**Consumer Behaviour:** Consumer Behaviour- Definition, Consumer and Customers, Buyers and Users, Consumer Behaviour and its Applications in Livestock Marketing;	1
10.	Consumer behaviour models; Consumer Motivation, Consumer Perception, Consumer Behaviour and Marketing Communications, Consumer Decision-making Process, Organizational Buying Behaviour,	2
11.	Modern marketing information system (marketing intelligence, communicating and acting on marketing intelligence).	1
	Total	**16**

S. No.	Topic	No. of Lectures/ Practicals
Practical		
1.	Visit to commercial livestock enterprises – Dairy, Poultry, any other economically important species of the region	5
2.	Visit to Meat/ Dairy/ Feed Processing Units	5
3.	Visit to any agri/ livestock start up	3
4.	Analysis of successful cases of livestock entrepreneurship	4
5.	Development of livestock business plans	4
6.	Presentation of livestock business development plans	3
7.	Study of consumer behavior	3
8.	Visit to livestock markets/ super markets/ malls and analysis	5
	Total	**32**

I. Course Title : Human Resource Management in Animal Husbandry Sector

II. Course Code : EXT 608

III. Credit Hours : 1+1

IV. Aim of the course

To make students understand human resource management techniques and deal organizational challenges effectively

V. Theory

Unit I

Concept, importance and functions of human resource management in animal husbandry sector. Process of management- planning, organizing, staffing, directing, coordination, reporting and budgeting. Principles, levels and types of organizations.

Unit II

Supervision- meaning, process and techniques. Work motivation. Job efficiency and job satisfaction.

Unit III

Organizational communication. Organizational climate. Conflict management.

Unit IV

Training– models, methods, Identification of training needs, Training evaluation and developing strategies for human resource development in animal husbandry sector. Capacity need assessment and personnel management in animal husbandry organizations.

VI. Practical

Training needs assessment farmers/ extension personnel, Development of training modules, Organization and evaluation of a training programme

VII. Suggested Reading

- Khanka SS. 1999. *Entrepreneurial Development*. S. Chand and Co.
- Gupta CB. 2001. *Management Theory and Practice*. Sultan Chand and Sons.
- BJ Lathi, Parag Narkhede and Vivek Yawalkar 2015. *Human Resource Management,* Prashant Publications.

- Noe RA, Hollenbeck JR, Gerhart B and Wright PM. 1997. *Human Resources Management: Gaining a competitive advantage.*
- Grover I. 2008. *Handbook on Empowerment and Entrepreneurship*. Agrotech Public.
- Nandan H. 2013. *Fundamentals of Entrepreneurship*, PHI publishers.
- Reading material of Course AEM-202 *Agri-Business and Entrepreneurship Development*. http://www.manage.gov.in/pgdaem/studymaterial/aem202.pdf
- Hisrich RD, Peters MP and Shepherd A. 2007. *Entrepreneurship*, 6th Edition, Tata McGraw Hill.
- Singh D. 1995. *Effective Managerial Leadership*. Deep and Deep Publ.
- Tripathi PC and Reddy PN. 1991. *Principles of Management*. Tata McGraw Hill.
- Vasanta Desai. 1997. *Small Scale Industries and Entrepreneurship*. Himalaya Publ. House.

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Concept, importance and functions of human resource management in animal husbandry sector	1
2.	Process of management- planning, organizing, staffing, directing, coordination, reporting and budgeting	1
3.	Principles, levels and types of organizations	1
4.	Supervision- meaning, process and techniques	1
5.	Work motivation	1
6.	Job efficiency and job satisfaction	1
7.	Organizational communication	1
8.	Organizational climate	1
9.	Conflict management	1
10.	Training– concept, meaning, importance of training in Animal Husbandry	1
11.	Training models and methods	2
12.	Identification of training needs	1
13.	Training evaluation	1
14.	Capacity need assessment and Personnel management in animal husbandry organizations	1
15.	Developing strategies for human resource development in animal husbandry sector	1
	Total	**16**
Practical		
1.	Training needs assessment of livestock farmers	2
2.	Training needs assessment of poultry farmers	2
3.	Training needs assessment of extension personnel	2
4.	Development of training module	2
5.	Planning for training programme	3
6.	Organization of training programme	3
7.	Evaluation of training programme	2
	Total	**16**

I. Course Title : Gender Empowerment and Livestock Development

II. Course Code : EXT 609

III. Credit Hours : 1+0

IV. Aim of the course

To acquaint students with gender perspectives, empowerment and its importance in livestock development, policies and programmes.

V. Theory

Unit I

Gender and empowerment: meaning and importance in livestock sector, Gender related concepts and importance of empowering women in livestock development; Need and focus on gender sensitization, Gender in community diversity and its implication for empowerment.

Unit II

Gender perspectives in development of women, Social characteristics, Roles, Responsibilities, Resources, Constraints, Legal issues and opportunities; Economical, educational and other parameters with special reference to livestock development.

Unit III

Gender tools and methodologies: Dimensions and methodologies for empowerment; Gender budgeting; Gender analysis framework- context, activities, Resources and programme action profile; Technologies and empowerment, Gender specific technologies, Household technology interface, Socio-cultural interface and women as consumers of technologies.

Unit IV

Policies and programmes in empowering women in general and livestock development in specific eg: UJJAWALA, Pradhan Mantri Mahila Shakti Kendra, One Stop Centre Scheme, Mahila E-haat, STEP, etc.

VI. Suggested Reading

- Grover I and Grover D. 2002. *Empowerment of Women*. Agrotech Publ. Academy.
- Porter F, Smyth I and Sweetman C. 1999. *Gender Works: Oxfarm Experience in Policy and Practice*. Oxfarm Publ.
- Raj MK. 1998. *Gender Population and Development*. Oxford Univ. Press.
- Sahoo RK and Tripathy SN. 2006. *SHG and Women Empowerment*. Anmol Publ.
- Sinha K. 2000. *Empowerment of Women in South Asia. Association of Management Development Institution in South Asia*, Hyderabad.
- Thakur Joshi S. 1999. *Women and Development*. Mittal Publ. Vishwanathan M. 1994. Women in Agriculture and RD. Rupa Books.
- Ramkumar S, Garforth C, Rao SVN and Waldie K. (Ed). 2001. *Landless Livestock Farming - Problems and Prospects*. RAGACOVAS, Pondicherry.
- Seth Mira 2001. *Women and Development – Indian Experience*. Sage Publ.
- Samanta RK. (Ed). *Women in Agriculture – Perspectives, Issues and Experiences*. MD Publ.
- Waldie K and Ramkumar S. 2002. *Landless Women and Dairying – Opportunities for Development within a Poverty Perspective*. RAGACOVAS, Pondicherry.
- *Gender and empowerment: Definitions, approaches, and implications for policy* http://genderandenvironment.org/resource/gender-and-empowerment-definitions-approaches-and-implications-for-policy/
- Njuki, J., Waithanji, E., Bagalwa, N. and Kariuki, J. 2013. *Guidelines on integrating gender* in livestock projects and programs. Nairobi, Kenya: ILRI.
- https://cgspace.cgiar.org/bitstream/handle/10568/33425/GenderInLivestock.pdf
- http://wcd.nic.in/womendevelopment/national-policy-women-empowerment

Course Outline

S. No.	Topic	No. of Lectures
Theory		
1.	Gender and empowerment: meaning, importance in livestock sector	1
2.	Gender related concepts	1
3.	Importance of empowering women in livestock development	1
4.	Need and focus on gender sensitization,	1
5.	Gender in community diversity and its implication for empowerment	1
6.	Gender perspectives in development of women	1
7.	Gender- Social characteristics, roles, responsibilities, resources, constraints, legal issues and opportunities; economical, educational and other parameters with special reference to livestock development	2
8.	Gender tools and methodologies: Dimensions and methodologies for empowerment	1
9.	Gender budgeting	1
10.	Gender analysis framework- context, activities, resources and programme action profile	1
11.	Technologies and empowerment - Gender specific technologies	1
12.	Household technology interface, Socio-cultural interface	1
13.	Women as consumers of technologies	1
14.	Policies and programmes in empowering women in general and livestock development in specific - Eg: UJJAWALA, Pradhan Mantri Mahila Shakti Kendra, One Stop Centre Scheme, Mahila E-haat, STEP etc	2
	Total	**16**

I. Course Title : Farm Journalism

II. Course Code : EXT 610

III. Credit Hours : 1+1

IV. Aim of the course

To sensitize students about the role of print, electronic, digital and internet media for promoting animal husbandry sector.

V. Theory

Unit I

Concept of farm journalism and communication. Journalism as a means of mass communication and its role in livestock development. Opportunities, strength and limitations. Ethics and principles of journalism for effective writing.

Unit II

Writing skills –Principles of writing - art of writing, News items, News stories, feature articles, Success stories, Magazines, bulletins, folders, etc. Fundamentals of lay-out in writing. Writing of research papers and popular articles in journals, Farm magazines and e-journals. Methods and techniques of broadcasting of farm programmes. Writing scripts for radio and televisions.

Unit III

Rapport building with different categories of clients involved in veterinary and animal husbandry extension programmes. Art of speaking. Importance of listening and reading. Writing for press news. Relations with press media. Event management, Organization of press meet. Qualities of a good public relations manager. Role and importance of art of speaking, listening and reading skills

Unit IV

Types of internet based media- Writing for web- concepts, Writing for social media (Blogs, etc.) – Ethics and values. Development of Multimedia Modules.

VI. Practical

Designing and preparation of news stories, feature articles, success stories related to animal husbandry. Designing and preparation of Magazines, Pamphlets, folders, popular research articles, radio, T.V. scripts. Visit to Agricultural Technology Information Centre (ATIC) centre to record the activities of preparation, editing and publication of news articles and research publications.

VII. Suggested Reading

- Bhaskaran C, Prakash R and Kishore Kumar N. 2008. *Farm Journalism in Media Management*. Agro-Tech Publ. Academy.
- Chattergee PC. 1991. *Broadcasting in India*. Sage Publ.
- Chiranjeev A. 1999. *Electronic Media Management*. Authors Press.
- D'Souza YK.1998. *Principles and Ethics of Journalism and Mass Communication*. Commonwealth Publ.
- Defleur ML and Dennis EE. 2001. *Understanding Mass Communications*. Goyalsaab Publ.
- Jaico Publ. Malhan PN. 2004. *Communication Media: Yesterday, Today and Tomorrow*. Directorate of Publication Division, New Delhi.
- Jain SC. 2006. *International Marketing Management*. CBS Publ.
- Keval J Kumar. 2004. *Mass Communication in India*.
- Mehta DS. 1992. *Mass Communication and Journalism in India*. Allied Publ.
- Panigrahy D. 1993. *Media Management in India*. P. K. Biswasroy (Ed.). Kanishka Publ.
- Singh AK 2014. *Agricultural Extension and Farm Journalism*, Agrobios Publications

Course Outline

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Concept of farm Journalism and communication	1
2.	Journalism as a means of mass communication and its role in livestock development.	1
3.	Role journalism in livestock development	1
4.	Opportunities, Strength and limitations in farm journalism in livestock sector	1
5.	Ethics and principles of journalism for effective writing	1
6.	Writing skills –Principles of writing, art of writing, news items, news stories, feature articles, success stories, magazines, bulletins, folders, etc.	1
7.	Fundamentals of lay-out in writing	1
8.	Writing of research papers and popular articles in journals, farm magazines and e-journals	1
9.	Methods and techniques of broadcasting of farm programmes.	1
10.	Writing scripts for radio and televisions	1
11.	Writing for press news; Organization of press meet and Event management	1
12.	Relations with press media Qualities of a good public relations manager	1
13.	Types of internet based media- Writing for web- concepts, Writing for social media (Blogs, etc.) – Ethics and values.	1

S. No.	Topic	No. of Lectures/ Practicals
14.	Development of Multimedia Modules	1
15.	Rapport building with different categories of clients involved in veterinary and animal husbandry extension programmes	1
16.	Role and importance of art of speaking, listening and reading skills	1
	Total	**16**

Practicals

1.	Designing and preparation of news stories related to animal husbandry.	1
2.	Designing and preparation of feature articles related to animal husbandry	1
3.	Designing and preparation of success stories related to animal husbandry	1
4.	Designing and preparation of Magazines	1
5.	Designing and preparation of Pamphlet	1
6.	Designing and preparation of Folders	1
7.	Designing and preparation of Popular research articles	1
8.	Writing of Radio script	1
9.	Preparation of TV script	2
10.	Development of Short film and feature film;	2
11.	Visit to editor office of farm journals of State Veterinary University	1
12.	Field visit to Successful Livestock farmer and documenting success story	1
13.	Visit to ATIC to record the activities of preparation, editing and publication of news articles and research publications	2
	Total	**16**

I. Course Title : Statistics for Social Sciences

II. Course Code : SSS 600

III. Credit Hours : 2+1

IV. Aim of the course

To equip the students with knowledge and skills in the applications of statistics in the field of veterinary and Animal Husbandry Extension.

V. Theory

Unit 1

Descriptive statistics- measures of central tendency, Measures of dispersion, Coefficient of variance, Standard error, Skewness and kurtosis, Contingency tables, Normal distribution, Test of significance – One sample t test, Independent t test, paired t test, ANOVA and z - one tailed and two tailed tests.

Unit 2

Population versus sample, Sampling errors, Sample size determination, Survey instruments, Open ended and closed ended questions, and online survey tools.

Unit 3

Dependency among the variables, correlation- Pearson, Spearman and Kendall, point biserial correlation, Regression analysis, Assumptions, Multiple linear Regression, Regression diagnostics-outlier, Multicollinearity, Heteroscedasticity and autocorrelation, logit/ probit model.

Unit 4

Scaling Techniques: Ranking, Rating and Paired Comparison. Scaling techniques -

Likert, Thurston and Guttman Scales. Construction and standardization; Knowledge test, Test of reliability and validity. Non-parametric tests- Signed Rank, Rank sum and Kruskal-Wallis tests. Test for independence and homogeneity. Multivariate techniques – cluster analysis, discriminant analysis and Factor analysis: Different rotations and interpretation of results.

VI. Practical

Exercises on different statistical tools and their interpretations

VII. Suggested Reading

- Cunningham BJ. 2012. *Using SPSS: An Interactive Hands-on approach*
- Edwards Allen L. 1969. *Techniques of Attitude Scale construction*. Vakils, Feffer and Simons Pvt. Ltd, Bombay
- Gupta SC and VK Kapoor. 2007. *Fundamentals of Mathematical Statistics*. Sultan Chand and Sons.
- Hair Joseph F, William C Black, Barry J Babin and Rolph E. Anderson. 2010. Multivariate *Data Analysis*. Pearson Pub.
- Hogg RV, AT Craig and JW. Mckean. 2005. *Introduction to Mathematical Statistics*, Pearson Education.
- Sukhatme PV, BV Sukhatme, S Sukhatme and C Ashok. 1984. *Sampling Theory of Surveys with Applications*, Lowa State University Press, Lowa, USA.

Course Title with Credit Load
Ph.D. in Veterinary Extension Education

Course Code	Course Title	Revised Credits
RPE 700	Research and Publication Ethics	1+1 #
EXT 701	Organizational Leadership and Management	2+0
EXT 702	Recent Trends in Research Techniques in Social Sciences	2+1
EXT 703	Training for Development	1+1
EXT 704	Policies and Regulations in Livestock Sector	1+0
EXT 705	Educational Technology	2+1
EXT 706	Dynamics of Social Change	2+0
EXT 707	Monitoring and Evaluation of Livestock Development Programmes	2+1
EXT 708	Theory Constructions in Social Sciences	1+0
EXT 709	Facilitation for Development	2+1
EXT 710	Managing Extension Organizations	2+1
EXT 711	Doctoral Seminar-I	1+0
EXT 712	Doctoral seminar-II	1+0
EXT 713	Doctoral Research	0+75

Mandatory Major course for all Ph D students. Other Core Courses to the extent of 10 credits are to be taken from remaining 700 series courses listed above

List of specified Minor subjects (Departments)

Major Subject	Minor subjects (Departments)*
Veterinary Extension Education	Animal Nutrition, Poultry Science, Livestock Production Management, Public Health and Epidemiology, Livestock Economics, Statistics, LPT.

*The Minor courses may be taken from any number of disciplines/ departments listed against major discipline limiting to credits prescribed as decided by the Chairman of Advisory Committee of the student.

Minor courses may also be taken from the disciplines/ departments other than those listed above on the recommendations of advisory committee, if essentially required as per the research problem with the concurrence of Head of the Department and Concerned Authorities.

Course Contents
Ph.D. in Veterinary Extension Education

I. Course Title : Organizational Leadership and Management

II. Course Code : EXT 701

III. Credit Hours : 2+0

IV. Aim of the course

To orient students with leadership and management perspectives for organizational change and development.

V. Theory

Unit I

Organizational Leadership – Introduction, Definition, Importance, Distinguishing differences between leadership and management within an organization, Theories of leadership, Current trends in leadership development, Competencies needed to be an effective leader and develop strategies for improving effective leadership potential.

Unit II

Concept, Approaches and functions of management, Principles and process of organization, hierarchy of organization, departmentalisation, Authority and responsibility. Components of individual behaviour in organization, Organizational climate, Decision making by consensus and participation by subordinates, Organization development– history, nature, characteristics, assumptions and process, Organization development interventions.

Unit III

Organizational communication, Communication network, Essentials of organizational communication. Conflict – types and management, Leadership and its role in conflict resolution, Morale in organizations, organizational factors affecting morale, attitude and productivity, methods of improving moral and evaluation of morale. Performance appraisal processes.

Unit IV

Supervision– principles, techniques and functions of supervision. Qualities of supervisor, supervisor-subordinate relationship and interaction process. Changing organizational structure and system, changing organizational climate and interpersonal style, issues and choice involved in making organizational climate effective.

VI. Suggested Reading

- Bhattacharyya DK. 2011. *Organizational Change and Development*, Oxford University Press.
- Hellriegel D, Sloccum JW and Woodman. 2001. *Organizational Behaviour*.
- Luthans F. 2002. *Organizational Behaviour*. Tata McGraw-Hill, New York
- Newstrom JW and Davis K. *Organizational Behaviour: Human behaviour at Work*. Tata-McGraw Hill, New Delhi.

- Peter MS. 1998. *The Fifth Discipline: The Art and Practice of Learning Organization*. Random House, London.
- Pradip NK. 1992. *Organisational Designs for Excellence*. Tata McGraw Hill, New Delhi.
- Shukla Madhukar. 1996. *Understanding Organisations*. Prentice Hall of India, New Delhi.
- Thomas GC and Christopher GW. 2013. *Organizational development and change* (10th edition), South-Western college publishing.
- Wendell LF and Cecil HB. 1999. *Organisational Development: Behavioural Science Interventions for Organization Improvement*, Pearson. 368 pp.
- Gary A Yukl. 2013. *Leadership in Organizations* (8th edition), Pearson
- Anita Satterlee. 2018. *Organizational Management and Leadership* (3rd edition, Synergistics Inc.
- Patricia D Witherspoon. 1997. *Communicating Leadership: An Organizational Perspective*, Allyn and Bacon, Inc.

Course Outline

S. No.	Topic	No. of Lectures
Theory		
1	Introduction, Definition and Importanceof Organizational Leadership with special reference to Animal Husbandry Organizations	1
2	Distinguishing differences between leadership and management within an organization	1
3	Theories of leadership, Current trends in leadership development	2
4	Competencies needed to be an effective leader and develop strategies for improving effective leadership potential.	2
5	Concept, approaches and functions of management with special reference to Animal Husbandry organizations	2
6	Principles and process of organization, hierarchy of organization, departmentalisation, Authority and responsibility.	3
7	Components of individual behaviour in organization.	1
8	Organizational climate, decision making by consensus and participation by subordinates.	1
9	Organizational development – history, nature, characteristics, assumptions and process.	1
10	Organization development interventions.	2
11	Organizational communication, Communication network, Essentials of organizational communication.	2
12	Conflict – types and management.	2
13	Leadership and its role in conflict resolution.	1
14	Morale in organizations, organizational factors affecting morale, attitude and productivity, methods of improving morale and evaluation of morale.	2
15	Performance appraisal processes	2
16	Principles, techniques and functions of supervision.	1
17	Qualities of supervisor, supervisor-subordinate relationship and interaction process.	1
18	Changing organizational structure and system	2
19	Changing organizational climate and interpersonal style, issues and choice involved in making organizational climate.	3
	Total	**32**

I. Course Title : Recent Trends in Research Techniques in Social Sciences

II. Course Code : EXT 702

III. Credit Hours : 2+1

IV. Aim of the course

To train the students on research and management techniques/ methods applicable to animal husbandry research.

V. Theory

Unit I

Importance and relevance of scales, Tests, Index, Quotient in social science research. Techniques of attitude scale construction, viz., paired comparison, equal appearing interval, successive interval, summated ratings, scalogram analysis.

Unit II

Measurement of reliability and validity of tests and scales. Sociometry. Qualitative, quantitative and mixed methods of research. Critical incidence techniques. Q-sort technique, Observation techniques, Case studies, etc.

Unit III

Experimental and quasi experimental research designs and randomized control trials. Delphi techniques, Propensity score matching, Content analysis and projective techniques.

Unit IV

Multivariate analysis, Systems analysis, Conjoint analysis, Panel data analysis, Principal component analysis, Discriminant analysis, Non-parametric tests and their application in extension research.

VI. Practical

Exercises on scaling techniques, attitude scale construction – Paired Comparison, Equal Appearing interval, Summated Rating Scale, Critical Incident Technique, Exercise on construction of Knowledge Test. Assessing the reliability and validity of measuring instruments Exercise on observation skills.

VII. Suggested Reading

- Babbie E. 2008. *The basics of social research* (4th Edition), Belmont, CA, USA; Thompson Wordsworth.
- Creswell JW. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. Third edition. Thousand Oaks: Sage Publications.
- Creswell JW. 2012. *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th edition). Boston, MA: Pearson.
- Kerlinger FN and Lee HB. 2000. *Foundations of Behavioral Research*. Orlando, FL: Harcourt College Publishers.
- Kumar R. 2014. *Research Methodology: A Step- by- Step Guide for Beginners*. (4th Edition). Thousand Oaks, California: Sage Publications.
- Malhotra NK. 2010. *Marketing research: An applied orientation. Sixth Edition*. Upper Saddle River NJ: Prentice Hall.
- Neuman WL. 2006. *Social Research Methods: Qualitative and Quantitative Approaches*. Toronto: Pearson.
- Sekaran U and Bougie R. 2013. *Research Methods for Business A Skill-Building Approach*. (6th Edition), Wiley, New York.

• Sivakumar PS, Sontakki BS, Sulaiman RV, Saravanan R and Mittal N. (eds). 2017. *Good Practices in Agricultural Extension Research. Manual on Good Practices in Extension Research and Evaluation. Agricultural Extension in South Asia.* Centre for research on innovation and science and policy (CRISP), Hyderabad. India.

Course outlines

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Importance and relevance of scales, tests, index, quotient in social science research.	3
2.	Techniques of attitude scale construction, viz., paired comparison, equal appearing interval, successive interval, summated ratings, scalogram analysis.	5
3.	Measurement of reliability and validity of tests and scales.	2
4.	Sociometry.	1
5.	Qualitative, quantitative and mixed methods of research.	3
6.	Critical incidence techniques, Q-sort technique, observation techniques, case studies	3
7.	Experimental and quasi experimental research designs and randomized control trials.	2
8.	Delphi techniques, propensity score matching, content analysis and projective techniques.	3
9.	Multivariate analysis	2
10.	Systems analysis	1
11.	Conjoint analysis	1
12.	Panel data analysis	1
13.	Principal component analysis	1
14.	Discriminant analysis	1
15.	Non-parametric tests and their application in extension research.	3
	Total	**32**
Practicals		
1.	Scaling techniques	2
2.	Attitude scale construction – Paired Comparison, Equal Appearing interval, Summated Rating Scale, Critical Incident Technique	6
3.	Construction of Knowledge Test	3
4.	Assessing the reliability and validity of measuring instruments	3
5.	Exercise on observation skills	2
	Total	**16**

I. Course Title : Training for Development

II. Course Code : EXT 703

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on planning, implementation and evaluation of various training programmes.

V. Theory

Unit I

Concept of training and education. Role of institution, Organization, Trainer and participants in success of training programme. Training infrastructure for extension personnel and livestock farmers.

Unit II

Planning, Development and execution of training programmes. Concept of need Assessment; Approaches in need Analysis- Performance Analysis, Task Analysis, Competency Study; Needs Survey.

Unit III

Training curriculum design and development. Training models, Methods and methodologies and strategies - Evaluation of Training (Kirkpatric model, CIPP Model, Logic Model, etc.), and follow-up of training programmes. Training Transfer– Barriers and factors effecting transfer of training (training design, trainee characteristics, Trainer capabilities, Training environment, Organization role, etc.).

Unit IV

Training, Capacity building, Capacity development and HRD-Meaning and differences; Need and principles of capacity development; Types and levels of capacities. Approaches in Capacity Development -Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach; Capacity Development Strategies - Academic strategy, Laboratory strategy, Activity strategy, Action strategy, Personal development strategy, Organizational development strategy.

VI. Practical

Exercise on Training Need Assessment. Development of training modules. Organization of training programmes for farmers, Evaluation of training programmes. Impact assessment of training programmes. Analysis of training institutions. Studies on training transfer.

VII. Suggested Reading

- Bentaya GM and Hoffmann V (Eds). 2011. *Rural Extension Volume 3 -Training Concepts and Tools*, Margraf Publishers GmbH, Scientific books, KanalstraBe 21; D-97990, weikersheim, 191 pp.
- DFID. 2003. *Promoting Institutional and Organisational Development. A Source Book of Tools and Techniques*, Department for International Development, United Kingdom
- FAO 2010. FAO. *Capacity Assessment Approach and Supporting Tools* - Discussion Draft, Food and Agriculture Organisation of the United Nations
- FAO 2012. *Capacity Development: Learning Module 2*. FAO Approaches to Capacity Development in Programming. Processes and Tools, Food and Agriculture Organisation of the United Nation
- GFRAS. 2012. *The New Extensionist: Roles, Strategies, and Capacities to Strengthen Extension and Advisory Services*, Global Forum for Advisory Services
- GFRAS. 2015. *The New Extensionist: Core Competencies for Individuals*, GFRAS Brief 3.
- Horton D. 2002. *Planning, Implementing, and Evaluating Capacity Development*. ISNAR Briefing Paper 50.
- Maguire. 2012. *Module 2: Agricultural Education and Training to Support Agricultural Innovation Systems. Overview. Agricultural Innovation Systems: An Investment Sourcebook.* The World Bank.
- Mishra DC. 1990. *New Directions in Extension Training. Directorate of Extension*, Ministry of Agriculture, Govt. of India, New Delhi.
- OECD/ DAC. 2006. *The Challenge of Capacity Development: Working Towards Good Practice*, Organisation for Economic Cooperation and Development.

- Pretty JN, Gujit I, Thompson J, and Scoones I. 1995. *A Trainer's Guide for Participatory Learning and Action*. IEED Participatory Methodology Series.
- Rolf PL and Udai P. 1990. *Training for Development*, (3rdedn) by (West Hartford, Kumarian Press, 1990, pp. 333.
- Rolf PL and Udai P. 1992. *Facilitating Development: Readings for Trainers, Consultants and Policy-makers*, New Delhi: Sage Publications, pp. 359

Course outlines

S. No.	Topic	No. of classes
Theory		
1.	Concept of training and education.	1
2.	Role of institution, organization, trainer and participants in success of training programme.	1
3.	Training infrastructure for extension personnel and livestock farmers	1
4.	Planning, development and execution of training programmes – importance, scope and relevance to animal husbandry sector	1
5.	Concept of Need Assessment – Scope and Importance in animal husbandry sector	1
6.	Approaches in Need Analysis- Performance Analysis, Task Analysis, Competency Study; Needs Survey.	2
7.	Training curriculum design and development.	1
8.	Training models, methods and methodologies and strategies	1
9.	Training Evaluation (Kirkpatrick model, CIPP Model, Logic Model, etc.) and follow-up of training programmes.	2
10.	Training Transfer– Barriers and Factors effecting transfer of training (training design, trainee characteristics, trainer capabilities, training environment, organization role, etc.)	1
11.	Training, capacity building, capacity development and HRD -Meaning and differences;	1
12.	Need and principles of capacity development; Types and levels of capacities.	1
13.	Approaches in Capacity Development -Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach;	1
14.	Capacity Development Strategies - Academic strategy, Laboratory strategy, Activity strategy, Action strategy, Personal development strategy, Organizational development strategy.	1
	Total	**16**
Practicals		
1.	Training Need Assessment of farmers, entrepreneurs/ AHD functionaries	3
2.	Development of training modules – for farmers/ entrepreneurs	2
3.	Organization of training programmes for farmers/ entrepreneurs	3
4.	Evaluation of training programmes of farmers/ entrepreneurs	2
5.	Impact assessment of training programmes	3
6.	Analysis of training institutions	2
7.	Identification of Capacity Developmentapproaches and strategies followed by Animal Husbandry Department/ other related organization	2
	Total	**16**

I. Course Title : Policies and Regulations in Livestock Sector

II. Course Code : EXT 704

III. Credit Hours : 1+0

IV. Aim of the course

To sensitize students on policies and regulations in animal husbandry sector.

V. Theory

Unit I

Concept, importance of development of policies and its framework. State, National and Global policies related to livestock sector. World Trade Organization in relation to livestock sector. Impact of WTO on Indian international trade of food products of animal origin, Intellectual Property Rights in relation to animal husbandry.

Unit II

HACCP, Sanitary and phyto-sanitary measures to protect the animals' life and health, Food safety uses in relation to animal husbandry sector. Introduction to Agreement on Technical Barriers to Trade (ATBT).

Unit III

Indian livestock sector related policies, National Livestock Policy, Regional Trade Agreements (RTAs) and Indian Livestock sector; Case studies – Impact of global trade agreements on livestock sector. Food safety acts and institutional arrangements for implementation; Agriculture Produce and Livestock Marketing (APLM) Act. Livestock products pricing policy. Government of India Systems, viz., Sanitary Import Permit System for livestock products

Unit IV

Animal welfare - Philosophical bases of animal welfare; Evolution of basic animal welfare principles; Animal Welfare laws- legislations in veterinary and animal sciences.

VI. Suggested Reading

- Jessica Vapnek Megan Chapman. 2010. *Legislative and regulatory options for animal welfare* (FAO Legislative Study 104) http://www.fao.org/docrep/013/i1907e/i1907e00.pdf
- Richard A Sprenger 2018. The HACCP Handbook (7th Edition)
- Sara E Mortimore and Carol A. Wallace. 2015. HACCP: *A food industry briefing,* Second Edition Sara E. Mortimore and Carol A Wallace
- World Society for the Protection of Animals. 2007. *Universal Declaration on Animal Welfare* https://www.worldanimalprotection.ca/sites/default/files/ca_-_en_files/case_for_a_udaw_tcm22-8305.pdf
- https://awbi.org/awbi-pdf/APL.pdf
- https://www.petaindia.com/wp-content/uploads/2017/05/Prevention-of-Cruelty-to-Animals-Dog-Breeding-and-Marketing-Rules-2017.pdf
- https://www.wto.org/

Course Outlines

S. No.	Topic	No. of Lectures
Theory		
1.	Concept, importance of development of policies and its framework.	1
2.	State, National and Global policies related to livestock sector.	1

S. No.	Topic	No. of Lectures
3.	World Trade Organization in relation to livestock sector.	1
4.	Impact of WTO on Indian international trade of food products of animal origin.	1
5.	Intellectual Property Rights in relation to animal husbandry.	1
6.	HACCP, Sanitary and phyto-sanitary measures to protect the animals' life and health, food safety uses in relation to animal husbandry sector.	1
7.	Introduction to Agreement on Technical Barriers to Trade (ATBT).	1
8.	Indian livestock sector related policies.	2
9.	Regional Trade Agreements (RTAs) and Indian Livestock sector	1
10.	Case studies – Impact of global trade agreements on livestock sector.	1
11.	Case studies – Food safety acts and institutional arrangements for implementation;	1
12.	Agriculture Produce and Livestock Marketing (APLM) Act.	1
13.	Livestock products pricing policy.	1
14.	Animal Welfare - Philosophical bases of animal welfare; Evolution of basic animal welfare principles	1
15.	Animal Welfare laws- legislations in veterinary and animal sciences legislations in veterinary and animal sciences	1
	Total	**16**

I. Course Title : Educational Technology

II. Course Code : EXT 705

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with different concepts of education technology for the enhancement of quality of education.

V. Theory

Unit I

Educational Technology – Meaning, Nature, Scope Concepts and Components of Educational Technology- Basics of Teaching and Learning- Theories of teaching and learning. Curriculum development at macro and micro levels. Formulation of instructional objectives. Teaching Competencies –Need and Importance in teaching – competency mapping and development.

Unit II

Preparation of course outline for instructions, lesson planning. Designing instructions for theory and practical, Innovative Teaching Methods/ methodologies – Student Centric and Teacher Centric; Instructional tools and devices in class room instruction, computer aided learning. Understanding learner's behaviour, learning styles, motivating learners. Measurement of learning outcomes.

Unit III

Students' counselling, guidance and mentoring – concepts, types and importance in higher education- Student evaluation – meaning and methods, construction of measuring instrument – question banking. Performance appraisal of teachers – meaning and methods, construction of assessment instruments. Use of library for effective learning.

Unit IV

Emerging Educational Technologies- Open and Distance Learning (ODL) for quality Veterinary Education; Concepts of ODL – Implications to Veterinary Education. Online Education - Synchronous and Asynchronous learning – models – eLearning, Massive Open Online Courses – SWAYAM, Open Education Resources (OERs), RLOs, Digital Initiatives in Education, viz., Swayam Prabha, National Digital Library, National Academic Depository, E-Shodh Sindhu, E Acharya, EVidhwaan, Agriculture Education Portal, e-KrishiShiksha, KrishiKosh, CeRA, National Educational Alliance for Technology (NEAT) etc.

VI. Practical

Preparation of lesson plans, Planning and preparation of instructional aids, Individual classroom instructional exercises, Micro Teaching Exercise, Development and testing of student evaluation instrument, Development of performance appraisal instrument for teachers., Critical analysis of different online education platforms.

VII. Suggested Reading

- Aggarwal JC. 2000. *Essential of Educational Technology: Teaching Learning Innovations in Education*. New Delhi: Vikas Publishing House.
- Alston, Antoine JW, Wade Millerand, David L Williams. 2003. *The future role of instructional technology in agricultural education in North Carolina and Virginia*. Journal of Agricultural Education, Volume 44, Number 2, 2003.
- Breslow L, Pritchard DE, DeBore J, Stump GS, Ho AD, Seaton DT. 2013. *Studying Learning in the Worldwide Classroom Research into edX's First MOOC*.
- Davies IK. 1971. *The Management of Learning*. New York: McGraw-Hill Publications.
- Fred Percival and Phil Race. 2005. *Handbook of Educational Technology 3rd Edition*. New Jersey: Nichols Publishing Company.
- Holz-Clause MS and Guntuku D. 2010. *Global Agricultural Knowledge Initiative: Strengthening the global competence of students, faculty and extension agents*.
- Kumar KL. 2000. *Educational Technology*. New Delhi: New Age International Publishers.
- Leith GO *et al.*1966. *A Hand Book of Programmed Learning and Birmingham*.
- Mangal SK. 2002. *Foundation of Educational Technology*. Ludhiana: Tondan Publication. 137.
- Mangal SK. 2006. *Essentials of Educational Technology*. New Delhi: Prentcile-Hall Publications.
- Mithra, Shiv K. 1968. *Proceeding of Symposium on Educational Technology*. IPAL, NCERT. P.4.
- Purabi Jain. March 1968. *Educational Technology*. New Delhi: Dominant Publishers and Distributers.
- Sampath K, Panneerselvam A, Santhanam M. 2001. *Introduction to Educational Technology*. New Delhi: Sterling Publishers Pvt. Ltd.
- Sharma RA. 2007. *Educational Technology and Management*. Agra: Vinod Pustak Mandir.

Course Outlines

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Meaning, nature, Scope, Concepts and Components of Educational Technology	2
2.	Basics of Teaching and Learning	1
3.	Theories of teaching and learning	2
4.	Curriculum development at macro and micro levels	2

S. No.	Topic	No. of Lectures/ Practicals
5.	Formulation of instructional objectives	1
6.	Teaching Competencies – Need and Importance in teaching	2
7.	Competency mapping and development	1
8.	Lesson planning – definition, importance, steps in preparation	1
9.	Preparation of course outline for instructions, Designing instructions for theory and practical	2
10.	Innovative Teaching Methods/ methodologies – Student Centric and Teacher Centric	2
11.	Instructional tools and devices in class room instruction, computer aided learning	
12.	Understanding learner's behaviour, learning styles, motivating learners.	2
13.	Measurement of learning outcomes	1
14.	Students' counselling, guidance and mentoring – concepts, types and importance in higher education	2
15.	Student evaluation – meaning and methods, construction of measuring instrument – question banking	1
16.	Performance appraisal of teachers –meaning and methods, construction of assessment instruments.	2
17.	Use of library for effective learning	1
18.	Emerging Educational Technologies - Open and Distance Learning (ODL) for quality Veterinary Education	2
19.	Concepts of ODL – Implications to Veterinary Education.	1
20.	Online Education - Synchronous and Asynchronous learning – models – eLearning,	2
21.	Massive Open Online Courses – SWAYAM, Open Education Resources (OERs), RLOs, Digital Education and its application in Veterinary Education	2
	Total	**32**
Practicals		
1.	Preparation of lesson plans	3
2.	Planning and preparation of instructional aids	3
3.	Individual classroom instructional exercises	2
4.	Exercise on Micro teaching	2
5.	Development and testing of student evaluation instrument	2
6.	Development of performance appraisal instrument for teachers.	2
7.	Critical analysis of different online education platforms	2
	Total	**16**

I. Course Title : Dynamics of Social Change

II. Course Code : EXT 706

III. Credit Hours : 2+0

IV. Aim of the course

To provide understanding on the dynamics of social change and its implications to livestock development.

V. Theory

Unit I

Definition of change, development, social and cultural change. Dimensions, characteristics, Types, rate and directions of social change. General conditions of social change. New dynamics in social change.

Unit II

Concept, importance and problems of planned change. Role of change agents. Approaches of change agents towards planned change. Acceptance and rejection to planned change in animal husbandry. Techniques for accelerating change.

Unit III

Theories of change: Darwin, Kurt, Lewin and Ogburn: Process of change, assessment of resources, fixation of change objective, evaluating change effect. Barriers to change-psychological, Social and economic, Stimulants to change: psychological, social and economic.

Unit IV

Social Change and its implication with reference to livestock development. Temporal changes in livestock development – national and global, Climate change and its impact on livestock development.

VI. Suggested Reading

- Chandra Shekhar. 2009. *Dynamics of Social Change*. Popular Prakashan.
- Johannes Dragsbaek Schmidt, Jacques Hersh. 2000. *Globalization and Social Change*, Routledge.
  John Solomos, Les Back. 1995. *Race, Politics, and Social Change*, Routledge.

Course outlines

S. No.	Topic	No. of Lectures
Theory		
1.	Definition of change, development, social and cultural change	2
2.	Dimensions, characteristics, types, rate and directions of social change	2
3.	General conditions of social change	2
4.	New dynamics in social change	1
5.	Concept, importance and problems of planned change	2
6.	Role of change agents in social change and Approaches of change agents towards planned change	2
7.	Acceptance and rejection to planned change in animal husbandry	2
8.	Techniques for accelerating change	1
9.	Theories of change: Darwin, Kurt, Lewin and Ogburn	3
10.	Process of change	1
11.	Assessment of resources	2
12.	Fixation of change objective	1
13.	Evaluating change effect	2
14.	Barriers to change-psychological, social and economical	1
15.	Stimulants to change: psychological, social and economic	2
16.	Social Change and its implications with reference to livestock development	2
17.	Temporal changes in livestock development – national and global	2
18.	Climate change and its impact on livestock development	2
	Total	**32**

I. Course Title : Monitoring and Evaluation of Livestock Development Programmes

II. Course Code : EXT 707

III. Credit Hours : 2+1

IV. Aim of the course

To appraise the students about the monitoring and evaluation of livestock development programmes.

V. Theory

Unit I

Monitoring, evaluation and impact assessment - Importance and scope in livestock based developmental programmes; Approaches and Types of Monitoring Indicators- Approaches to Monitoring Indicators, Types of Monitoring Indicators; Indicators of Monitoring in Development Programmes - Capability Indicators, Performance Indicators; Monitoring and Progress Reporting; Evaluation: Data Collection Methods - Conventional Methods, Participatory Methods; Evaluation Approaches; Challenges in Programme Evaluation.

Unit II

Conceptual framework, result framework and logic models; Quantitative and qualitative indicators – characteristics and their selection criteria; indicators and information systems for sustainable livestock development - Testing and improving indicators; Integration of M and E systems into development programs.

Unit III

Difference between outcome and impact; Types of impact assessment: Climate impact assessment; Demographic impact assessment; Development impact assessment; Ecological and environmental impact assessment; Economic and fiscal impact assessment; Risk assessment; Social impact assessment; Strategic impact assessment; technology assessment, Project evaluation, Public participation and consultation.

Unit IV

Impact assessment methods: Formative and summative evaluation, Types-within-without; before-after; case study; social auditing; performance audit; quantifying the impact parameters.

VI. Practical

Development of M and E plans and procedures for livestock developmental programmes using participatory approach. Developing indicators (social and economic) and information system for sustainable livestock development; analysis of different reports, conducting impact assessment exercises, case studies, data generation, report writing.

VII. Suggested Reading

- Carlson GA, Miranowski J and Zilberman D. 1998. *Agricultural and Environmental Resource Economics*. Oxford Univ. Press. 63
- Hanley N, Shogren J and White B. 2007. *Environmental Economics in Theory and Practice*. Palgrave, London.
- Kolstad C. 1999. *Environmental Economics*. Oxford Univ. Press.
- Little IMD and Mirlees JA. 1974. *Project Appraisal and Planning for Developing Countries*. Oxford and IBH Publ.

- Prato T. 1998. *Natural Resource and Environmental Economics*. Iowa State Univ. Press.
- Sterner T. 2003. *Policy Instruments for Environmental and Natural Resource Management*. *Resources for the Future*. The World Bank and SIDA.

Course Outlines

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Monitoring, evaluation and impact assessment - importance and scope in livestock based developmental programmes	2
2.	Approaches to Monitoring Indicators	1
3.	Types of Monitoring Indicators	1
4.	Indicators of Monitoring in Development Programmes Capability Indicators, Performance Indicators	2
5.	Monitoring and Progress Reporting	1
6.	Evaluation: Data Collection Methods - Conventional Methods, Participatory Methods	3
7.	Evaluation Approaches	1
8.	Challenges in Programme Evaluation	1
9.	Conceptual framework, result framework and logic models	2
10.	Quantitative and qualitative indicators – characteristics and their selection criteria	2
11.	Indicators and information systems for sustainable livestock development - testing and improving indicators	2
12.	Integration of M and E systems into development programs	1
13.	Difference between outcome and impact	1
14.	Types of impact assessment: climate impact assessment; demographic impact assessment; development impact; assessment; ecological and environmental impact assessment; economic and fiscal impact assessment; risk assessment; social impact assessment; strategic impact assessment; technology assessment	5
15.	Project evaluation	1
16.	Public participation and consultation	1
17.	Impact assessment methods: Formative and summative evaluation	2
18.	Types of impact assessment -within-without; before-after; case study; social auditing; performance audit	2
19.	Quantifying the impact parameters	1
	Total	**32**
Practicals		
1.	Development of M and E plan for livestock developmental programmes using participatory approach.	3
2.	Development of procedures for livestock developmental programmes using participatory approach	2
3.	Developing indicators (social and economic) and information system for sustainable livestock development	3
4.	Analysis of different reports	2
5.	Conducting impact assessment exercises	2
6.	Case studies	1
7.	Data generation	1
8.	Report writing	2
	Total	**16**

I. Course Title : Theory Constructions in Social Sciences

II. Course Code : EXT 708

III. Credit Hours : 1+0

IV. Aim of the course

To provide the foundation for construction of theories in social science.

V. Theory

Unit I

Importance of theory construction in Extension. Hypothesis, Theory, Principle and Law; Meaning, elements, Ideal Criteria, Functions, Types of theories. Definitions: Meaning, types and Rules.

Unit II

Generalizations: Meaning, Classification. Relationship: Meaning Types.

Unit III

Terminologies used in theory constructions: Axiom, Postulate, Proposition, Theorem, Fact, Concept, Construct, Probability and Measurement Basic Derived.

Unit IV

Steps in theory building - Axiomatic techniques, Historical approaches and scientific application. Theoretical concept in social sciences. Test of Theory: Applying appropriate statistical tests.

VI. Suggested Reading

- Blalock HM. 1969. *Theory Construction: Form verbal to Mathematical Formulations*. Prentice Hall.
- Dubin R. 1978. *Theory Building*. The Free Press, New York.
- Hage J. 1973. *Techniques and Problems of Theory Constructions in Sociology*. John Wiley and Sons
- Jack P Gibbs. 1972. *Sociological Theory Construction*. The Dryden Press, Illionis.
- Stinchombe AL. 1968. *Construction of Sociological Theories*. Harcourt, Brace and World.
- Wionton CA. 1974. *Theory and Measurement in Sociology*. John Wiley and Sons.

Course Outlines

S. No.	Topic	No. of classes
Theory		
1.	Importance of theory construction in Extension. Hypothesis, Theory, Principle and Law	2
2.	Theory construction definitions - Meaning, types and Rules.	1
3.	Theory - Meaning, elements, Ideal Criteria, Functions, Types	1
4.	Generalizations: Meaning, Classification.	2
5.	Relationship - Meaning Types.	1
6.	Terminologies used in theory constructions: Axiom, Postulate, Proposition, Theorem, Fact, Concept, Construct, Probability and Measurement Basic Derived	3
7.	Steps in theory building - Axiomatic techniques, historical approaches and scientific application.	2
8.	Theoretical concept in social sciences.	2
9.	Test of Theory: Applying appropriate statistical tests	2
	Total	**16**

I. Course Title : Facilitation for Development

II. Course Code : EXT 709

III. Credit Hours : 2+1

IV. Aim of the courses

- To orient students on the importance facilitation.
- To inspires students to understand facilitation tools to influence change at the individual, group and organisational levels.
- To develop capacities in multi-stakeholder engagement, facilitation and networking.

V. Theory

Unit 1

Facilitation for development in the AIS; Understanding facilitation for development; Importance of facilitation as a core function of extension within the Agricultural Innovation Systems (AIS); Basic principles of facilitation for development; Desired attributes of facilitator for development- Cognitive attributes, Emotional attributes (Emotional intelligence), Social, behavioural and attitudinal attributes; Technical skills of a facilitator for development- Design processes, Facilitation techniques and tools, the art of questioning and probing, Process observation and documentation, Visualisation.

Unit 2

Facilitating Change in Individuals, Groups And Organisations - Self-discovery to realize our potentials, Tools for self-discovery, formulating a personal vision, Taking responsibility for your own development; Understanding the dynamics of human interaction, Group dynamics and power relations, Managing relationships, Shared vision and collective action, Tools for team building; Organizational change process, Organisational learning to adapt to changing environments, Enhancing performance of organisations, Leadership development, Tools for organisational change.

Unit 3

Facilitating Operational Level Multi-Stakeholder Engagements - Defining stakeholders, Development of collective and shared goals, Building trust and accountability, Tools for stakeholder identification and visioning; Visualising innovation platforms (IPs), Why are IPs important?, Different models of IPs for multi-stakeholder engagement, policy engagement platforms, Generating issues and evidence for policy action, Advocacy for responsive policy processes.

Unit 4

Brokering Strategic Partnerships, Networking And Facilitation- Brokering linkages and strategic partnerships, Identification of critical links, Knowledge brokering, Creating linkages with markets, Learning alliances and networking, Coordination of pluralistic service provision within the AIS, The concept of action learning and reflective practitioners, Networking; Facilitating Capacity Development-Facilitate participation and learning in development programs and projects. Virtual platforms-skills for strengthening dialogue, collaboration, shared commitment amongst diverse actors and stakeholders.

Course Outlines

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Facilitation for development in the AIS; Understanding facilitation for development;	1
2.	Importance of facilitation as a core function of extension within the Agricultural Innovation Systems (AIS);	1
3.	Basic principles of facilitation for development; Desired attributes of facilitator for development- Cognitive attributes, Emotional attributes (Emotional intelligence), Social, behavioural and attitudinal attributes;	2
4.	Technical skills of a facilitator for development- Design processes, Facilitation techniques and tools, the art of questioning and probing,	2
5.	Process observation and documentation, Visualisation	1
6.	Facilitating Change In Individuals, Groups And Organisations - Self-discovery to realize our potentials,	2
7.	Tools for self-discovery, formulating a personal vision, Taking responsibility for your own development;	1
8.	Understanding the dynamics of human interaction, Group dynamics and power relations, Managing relationships, Shared vision and collective action,	2
9.	Tools for team building;	1
10.	Organizational change process, Organisational learning to adapt to changing environments, Enhancing performance of organisations,	2
11.	Leadership development, Tools for organisational change	1
12.	Facilitating Operational Level Multi-Stakeholder Engagements - Defining stakeholders, Development of collective and shared goals, Building trust and accountability,	2
13.	Tools for stakeholder identification and visioning;	1
14.	Visualising innovation platforms (IPs), Why are IPs important?, Different models of IPs for multi-stakeholder engagement	2
15.	Policy engagement platforms, Generating issues and evidence for policy action,	2
16.	Advocacy for responsive policy processes	1
17.	Brokering Strategic Partnerships, Networking and Facilitation- Brokering linkages and strategic partnerships, Identification of critical links, Knowledge brokering, Creating linkages with markets,	2
18.	Learning alliances and networking, Coordination of pluralistic service provision within the AIS,	1
19.	The concept of action learning and reflective practitioners, Networking;	1
20.	Facilitating Capacity Development-Facilitate participation and learning in development programs and projects.	2
21.	Virtual platforms- skills for strengthening dialogue, collaboration, shared commitment amongst diverse actors and stakeholders	2
	Total	**32**
Practicals		
1.	Practicing facilitation techniques	1
2.	Self discovery exercises	1
3.	Working together and interaction (task based)	1
4.	Arrangement for multi-stakeholder interactions	1
5.	Understanding organisational change process tools and techniques	1

S. No.	Topic	No. of Lectures/ Practicals
6.	Case analysis on organisational change process	1
7.	Participating with innovation platforms	1
8.	Policy engagement platforms	1
9.	Stakeholder analysis mapping	2
10.	Exercise on networking skills	2
11.	Facilitating capacity building programmes	1
12.	Facilitating virtual platforms	1
13.	Filed visit to multi-stakeholder partnership projects	2
	Total	**16**

VI. Suggested Reading

- Account Ability 2005. AA 1000, *Stakeholder Engagement Standard Exposure draft*. http://www.empresa.org/doc/AA1000_STHEngagement.pdf
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- Clarke S, Blackman R and Carter I. 2004. *Facilitation skills workbook -Training material for people facilitating small group discussions and activities using PILLARS Guides*. Tearfund, England. https://www.tearfund.org/~/media/files/tilz/fac_skills_english/facilitation__e.pdf
- Davis S. 2014. Using the Socratic Method as a Learning Facilitator https://facilitatoru.com/training/using-the-socratic-method-as-a-learning-facilitator/
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- Jost C, Alvarez S and Schuetz T. 2014. CCAFS *Theory of Change Facilitation Guide*. CGIAR Research Program on Climate Change, Agriculture and Food Security. https://cgspace.cgiar.org/bitstream/handle/10568/41674/CCAFS%20TOC%20facilitation%202014%20FINAL.pdf
- Kennon N, Howden P and Hartley M. 2002. *Who really matters? A stakeholder analysis tool*. Extension Farming Systems Journal volume 5 number 2. https://www.csu.edu.au/__data/assets/pdf_file/0018/109602/EFS_Journal_vol_5_no_2_02_Kennon_et_al.pdf
- Koutsouris A. 2012. *Exploring the emerging facilitation and brokerage roles for agricultural extension education*. AUA Working Paper Series No. 2012-4. Agricultural University of Athens. Department of Agricultural Economics and Rural Development. http://aoatools.aua.gr/RePEc/aua/wpaper/files/2012-4_koutsouris.pdf
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- Lindynorris. *How to Develop Your Personal Vision Statement: A Step-by-Step Guide to Charting Your Future With Purpose and Passion* http://static1.squarespace.com/static/5765deb1be659449f97fcbf5/t/5770b309579fb313164a7a37/1467003657818/LINDYNORRIS.COM+-+How+to+Develop+a+Personal+Vision+Statement.pdf
- Lundy M, Gottret MV and Ashby J. *Learning alliances: An approach for building multistakeholder innovation systems.* http://documents.worldbank.org/curated/en/564521467995077219/pdf/103509-BRI-PUBLIC-ADD-series-ILAC-brief.pdf
- Makini FW, Kamau GM, Makelo MN, Adekunle W, Mburathi GK, Misiko M, PaliM, and

Dixon J. 2015. *Operational Field Guide for Developing and Managing Local Agricultural Innovation Platforms*. Australian Centre for International Agricultural Research https://www.aciar.gov.au/file/103711/download?token=EPYmwxnE
- Mind Tools. n.d. *The Role of a Facilitator-Guiding an Event through to a Successful Conclusion*. https://www.mindtools.com/pages/article/RoleofAFacilitator.htm
- Mittal N, Sulaiman RV and Prasad RM. 2016. *Assessing Capacity Needs of Extension and Advisory Services A Guide for Facilitators*. Agricultural Extension in South Asia. http://www.aesanetwork.org/assessing-capacity-needs-of-extension-and-advisory-services-a-guide-for-facilitators/
- Mulema AA. 2012. *Organisation of innovation platforms for Agricultural Research and Development in the Great Lakes Region of Africa*. Graduate Theses and Dissertations. Paper 12631. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=3638 and context=etd
- Nederlof S, Wongtschowski M and Van der Lee (eds.). 2011. *Putting Heads Together-Agricultural Innovation Platform in Practice*. KIT Publishers.
- Ngwenya H and Kibwika P. 2016. *NELK Module 7 Introduction to Facilitation for Development, New Extensionist Learning Kit (NELK)*, Global Forum for Rural Advisory Services (GFRAS) http://www.g-fras.org/en/knowledge/new-extensionist-learning-kit-nelk.html#module-7-introduction-for-facilitation-for-development
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- Pye-Smith C. 2012. *Agricultural extension: A Time for Change. Linking knowledge to policy and action for food and livelihoods.* https://cgspace.cgiar.org/handle/10568/75389
- Steinlin M and Jenkins CW. *Knowledge Sharing for Change- Designing and Facilitating Learning Process with a Transformational Impact.Ingenious Peoples Knowledge.* http://www.fsnnetwork.org/sites/default/files/ipk_trainingmanual_midres.pdf
- Tallia AF, Holly J, Lanham HJ, McDaniel RR Jr., and Benjamin F Crabtree BF. 2013. 7 *Characteristics of Successful Work Relationships.* https://www.aafp.org/fpm/2006/0100/p47.pdf
- Van Rooyen A, Swaans K, Cullen B, Lema Z and Mundy P. 2013. *Facilitating Innovation Platforms in: Innovations platforms practice* brief 10. https://assets.publishing.service.gov.uk/media/57a08a28ed915d3cfd000602/Brief10.pdf
- Villet VV. 2015. *Motivation Theory by David McClelland*. https://www.mindtools.com/pages/article/human-motivation-theory.htm

I. Course Title : Managing Extension Organizations

II. Course Code : EXT 710

III. Credit Hours : 2+1

IV. Aim of the courses

- To orient students on the importance of knowledge and skills on various management functions, as applicable to extension organizations
- Discuss ways of running extension services as managers of livestock -ventures
- To develop capacities for becoming effective managers of livestock -ventures

V. Theory

Unit 1

Management- An Over view - Management and Extension management – Meaning, concept, nature and importance; Management, administration and supervision - meaning, definition and scope; Approaches to management, Principles, functions and levels of management; Qualities and skills of a manager; Interpersonal relations in the organization; Reporting and budgeting; Extension Management in public, private sector and other sectors - Extension management (POSDCORB) in public sector, Department of Agriculture, Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendra (KVK), SAUs, ICAR Institutes, Private sector, Cooperatives, NGOs, FPOs, etc. Organisational Structure, Relations between different units- Challenges in management.

Unit 2

Concepts in Management - Decision making – Concept, Types of decisions, Styles and techniques of decision making, Steps in DM Process, Guidelines for making effective decisions; Human Resource Management: Manpower planning, Recruitment, Selection, Placement and Orientation, Training and Development; Dealing with fund and staff shortages in different extension organizations (KVK, ATMA, etc.); Leadership – Concept, Characteristics, Functions, Approaches to leadership, Leadership styles; Authority and responsibility, Delegation and decentralization, line and staff relations.

Unit 3

Challenges of co-ordination in extension organizations; Managing interdepartmental coordination and convergence between KVK, ATMA and line departments; Co-ordinating pluralism in extension services; Challenges in managing public-private partnerships (PPPs) at different levels in agricultural development in general and extension in particular; Performance appraisal – Meaning, Concept, Methods.

Unit 4

Motivation and Communication- Managing work motivation – Concept, Motivation and Performance, Approaches to motivation, team building; Organizational Communication – Concept, Process, Types, Networks, Barriers to Communication; Mentoring, Time management, Team work and team-building strategies; Modernization of information handling; Supervision and Control - Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision; Managerial Control – Nature, Process, Types, Techniques of Control, Observation, PERT and CPM, Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organisations.

VI. Practicals

- Simulated exercises on techniques of decision making
- Study the structure and function of agro-enterprises, Designing organizational structure/organograms
- Group activity on leadership development skills
- Simulated exercise to understand management processes
- Field visit to extension organizations (ATARI, KVKs, NGOs), FPOs, dairy cooperatives to understand the functions of management
- Practical exercises on PERT and CPM

- Group exercise on development of short term and long term plans for agro-enterprises
- Developing model agriculture-based projects including feasibility study, financial planning and cost-benefit analysis

VII. Suggested Reading

- Bitzer V. 2016. *Incentives for enhanced performance of agricultural extension systems*, KIT Working Paper 2016-6, Royal Tropical Institute, Amsterdam https://www.kit.nl/wp-content/uploads/2018/08/Incentives-for-enhanced-performance-of-agricultural-extension-systems.pdf
- Bitzer V, Wennik B and de Steenhuijsen B. 2016. *The governance of agricultural extension systems*, KIT Working Paper 2016-1 Royal Tropical Institute, Amsterdam. https://www.kit.nl/wp-content/uploads/2018/08/The-governance-of-agricultural-extension-systems.pdf
- Chand S. *Modern Management Theory: Quantitative, System and Contingency Approaches to Management.* http://www.yourarticlelibrary.com/management/modern-management-theory-quantitative-system-and-contingency-approaches-to-management/25621
- Daniel RG, James AFS and Freeman RE. 2003. *Management* (6th Edition). Pearson India.
- Fahimifard SM and Kehkha AA. 2009. *Application of Project Scheduling in Agriculture* (Case Study: Grape Garden Stabilization) American-Eurasian *J. Agric. and Environ. Sci.*, **5**(3): 313-321. https://www.idosi.org/aejaes/jaes5(3)/3.pdf
- Gabathuler E, Bachmann F and Klay A. 2011. *Reshaping Rural Extension Learning for Sustainability: An integrated and learning based advisory approach for rural extension with small scale farmers*- Chapter 4. Margraf Publishesrs, Kanalstr.
- GFRAS 2017. Module 3: *Agricultural Extension Programme Management, The New Extensionist Learning Kit, Global Forum for Rural Advisory Services* (GFRAS) http://www.g-fras.org/fr/component/phocadownload/category/70-new-extensionist-learning-kit-nelk.html?download=564:nelk-module-3-agricultural-extension-programme-management-textbook
- Gupta CB. 2001. *Management Theory and Practice*. Sultan Chand and Sons, New Delhi.
- Hoffmann V, Gerster BM, Christnick A and Lemma M. 2009. *Rural Extension Volume 1*-Chapter 7. Margraf Publishesrs, Kanalstr.
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- Mind Tools. *Core Leadership Theories: Learning the Foundations of Leadership*
- *Why are some leaders successful, while others fail?* Available online https://www.mindtools.com/pages/article/leadership-theories.htm
- Qamar KM. 2005. *Modernizing National Agricultural Extension Systems: A Practical Guide for Policy-Makers of Developing Countries*, Food and Agriculture Organization of the United Nations http://www.fao.org/uploads/media/modernizing%20national.pdf
- Swanson BE, Bentz RP and Sofranko AJ. 1997. *Improving Agricultural Extension. A Reference Manual*. Food and Agriculture Organization of the United Nations, Rome.
- Van den Ban AW and Hawkins HS. 1998. *Agricultural extension*- Chapter 10, BSL, CBS Publishers and Distributors.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Management- An Over view - Management and Extension management – Meaning, concept, nature and importance;	1
2	Management, administration and supervision - meaning, definition and scope;	1
3	Approaches to management, Principles, functions and levels of management;	1
4	Qualities and skills of a manager; Interpersonal relations in the organization;	1
5	Reporting and budgeting; Extension Management in public, private sector and other sectors	2
6	Extension management (POSDCORB) in public sector, Department of Agriculture, Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendra (KVK), SAUs, ICAR Institutes, Private sector, Cooperatives, NGOs, FPOs, etc.	2
7	Organisational Structure, Relations between different units- Challenges in management	1
8	Concepts in Management - Decision making – Concept, Types of decisions, Styles and techniques of decision making, Steps in DM Process	2
9	Guidelines for making effective decisions; Human Resource Management: Manpower planning, Recruitment, Selection, Placement and Orientation, Training and Development	2
10	Dealing with fund and staff shortages in different extension organizations (KVK, ATMA, etc.)	1
11	Leadership – Concept, Characteristics, Functions, Approaches to leadership, Leadership styles; Authority and responsibility, Delegation and decentralization, line and staff relations	2
12	Challenges of co-ordination in extension organizations	1
13	Managing interdepartmental coordination and convergence between KVK, ATMA and line departments; Co-ordinating pluralism in extension services	2
14	Challenges in managing public-private partnerships (PPPs) at different levels in agricultural development in general and extension in particular	2
15	Performance appraisal – Meaning, Concept, Methods	2
16	Motivation and Communication- Managing work motivation – Concept, Motivation and Performance, Approaches to motivation, team building	2
17	Organizational Communication – Concept, Process, Types, Networks, Barriers to Communication; Mentoring, Time management, Team work and team-building strategies	2
18	Modernization of information handling; Supervision and Control - Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision	2
19	Managerial Control – Nature, Process, Types, Techniques of Control, Observation, PERT and CPM, Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organisations	3
	Total	**32**
Practicals		
1	Simulated exercises on techniques of decision making	2

S. No.	Topic	No. of Lectures/ Practicals
2	Study the structure and function of agro-enterprises, Designing organizational structure/ organograms	2
3	Group activity on leadership development skills	2
4	Simulated exercise to understand management processes	1
5	Field visit to extension organizations (ATARI, KVKs, NGOs), FPOs, dairy cooperatives to understand the functions of management	3
6	Practical exercises on PERT and CPM	2
7	Group exercise on development of short term and long term plans for agro-enterprises	2
8	Developing model agriculture-based projects including feasibility study, financial planning and cost-benefit analysis	2
	Total	**16**

List of Journals

- *Communicator*
- *Development communication*
- *Indian Dairyman*
- *Indian journal of Adult Education*
- *Indian Journal of Dairy Science*
- *Indian Journal of Extension Education*
- *Indian Journal of Psychology*
- *Indian Journal of Public Administration*
- *Journal of Dairy Research*
- *Journal of Extension Systems*
- *Journal of Rural Development*
- *Journal of Training and Development*
- *The Indian Journal of Animal Sciences*
- *The Indian Veterinary Journal*
- *Journal of Agriculture Extension and Education*
- *Indian Journal of Animal Research*
- *Indian Journal of Gender of Studies*
- *Kurukshetra*
- *Yojana*
- *Economic and Political weekly*
- *Indian Farming*

e-Resources

- www.informaworld.com (Journal of Agricultural Education and Extension)
- www.blackwellpubllishing.co (International Journal of Training and Development)
- www.blackwellpubllishing.co Educational Measurement: Issue and Practices
- www.academicjournals.net (International Journal of Dairy Science)
- www. cipav.org.co (Livestock Research for Rural Development)
- www.joe.org Journal of Extension

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Basic Veterinary Sciences
– Veterinary Physiology

Preamble

At Masters level in Veterinary Physiology new courses, Endocrinology of domestic animals and Physiology of wild animals are introduced. Similarly at Doctorate level new courses, Recent Trends in ruminant digestion, Cellular and molecular physiology and Recent trends in reproductive physiology are introduced keeping in view of the importance of these fields.

Course Title with Credit Load
M.V.Sc. in Veterinary Physiology

Course Code	Course Title	Credit Hours
VPY 601	Physiology of Digestion	2+1
VPY 602	Cardiovascular and Respiratory Physiology	2+1
VPY 603	Renal Physiology and Body Fluid dynamics	2+1
VPY 604	Haematology	2+1
VPY 605	Growth and Environmental Physiology	2+0
VPY 606	Physiology of Animal Reproduction	2+1
VPY 607	Clinical Physiology	1+1
VPY 608	Neuromuscular Physiology	2+0
VPY 609	Endocrinology of Domestic Animals	2+0
VPY 610	Instrumentation and Research Techniques in Veterinary Physiology	0+2
VPY 611	Physiology of Wild Life	1+0
VPY 612	Masters Seminar	1+0
VPY 613	Masters Research	0+30

Course Contents
M.V.Sc. in Veterinary Physiology

I. Course Title : Physiology of Digestion
II. Course Code : VPY 601
III. Credit Hours : 2+1
IV. Aim of the course

To teach comparative physiology of digestive system of monogastricanimals, ruminants and birds, and basic techniques.

V. Theory

Unit I

Basic characteristics and comparative physiology of digestive system of monogastric and polygastric animals. Appetite andcontrol of feed intake.

Unit II

Gastro-intestinal motility, secretary functions of gastro-intestinal tract, their regulation and gastro-intestinal hormones.

Unit III

Digestion, absorption and metabolism of carbohydrate, protein and fat in simple and compound stomach. Absorption of water and electrolytes.

Unit IV

Development of ruminant stomach, rumen microbiology and rumen environment. Ruminantmicrobial digestion, its advantages and disadvantages. Fate of rumen fermentation products. Rumino-reticularmotility, its significance and control. Digestion in birds.

VI. Suggested Reading

- *Dukes' Physiology of Domestic Animals*, 13th Edn. William O Reece, Howard H Erickson, Jesse P Goff, Etsuro E Uemura. 2015.
- *Cunningham's Textbook of Veterinary Physiology* 5th Edn. Bradley G. Klein 2012
- *Digestive Physiology and Nutrition of Ruminants* by D C Church, 1975
- *The Rumen Microbial. Ecosystem.* 2nd Edn. Ed. by. P.N. HOBSON and C.S Stewart 1997
- Hungate RE. 1966. *Rumen and its Microbes*. Acad. Press. N.Y.
- *Rumen Microbiology*, Burk A Dehority. 2003. Nottingham University Press

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Basic characteristics and comparative physiology of digestive system of domestic animals. Classification of animals on the basis of feeding habits, differences in the anatomy of digestive tract	1
2.	General functions of Gastrointestinal tract and its control	1
3.	Functional anatomy of digestive tract of monogastric animals- structural differences among the monogastric animals	1

S. No.	Topic	No. of Lectures/ Practicals
4.	Functional anatomy of digestive tract of ruminants: Development of ruminant stomach	1
5.	Structural details of rumen, reticulum, omasum and abomasum, Rumino-reticular motility, its significance and control	1
6.	Pseudoruminants, reticular groove reflex, rumination process and its phases.	1
7.	Prehension, prehensile organs in different animals, grazing, browsing, rooting, mastication, deglutition, feed intake, water requirements and intake, drinking habits of water in different animals	1
8.	Motility of esophagus, gastro-intestinal motility, primary peristalsis and secondary peristalsis, functions and zones of stomach	1
9.	Rate of gastric emptying, interdigestive motility patterns, migrating myoelectric complex, emesis or vomiting	
10.	Motility in small intestine, nervous and hormonal control, peristaltic reflex and segmentation reflex. Motility in large intestine: caecum, colon, haustral contractions, oral and aboral peristaltic contractions, antiperistaltic contractions, Rate of passage of digesta and its estimation	1
11.	Appetite and control of feed intake, hunger contractions, thirst, constipation, defecation, diarrhea	1
12.	Regulation of GIT functions, gastro-intestinal hormones and their functions	1
13.	Salivary secretion, its composition and functions	1
14.	Secretion of gastric juice, phases of gastric secretion, composition, zymogen, autocatalysis and digestion in stomach	1
15.	Pancreatic juice, secretion, control and composition,	1
16.	Proteases, lipases, amylases and other enzymes of pancreatic juice.	1
17.	Trypsin inhibitor and end products of pancreatic digestion	1
18.	Liver, structure of liver lobule: secretion of bile and its regulation bile acids, bile salts, bile pigments: functions of bile	1
19.	Enterohepatic recirculation: gall bladder function and contractions.	1
20.	Intestinal juices, their secretions, composition and functions	1
21.	Absorption of nutrients in the digestive tract and the effect of nutrient interactions	1
22.	Bacterial fermentation in large intestine, fermentative products, absorption of end products of fermentation	1
23.	Metabolism and excretion of various nutrients,	1
24.	Development of ruminant system and rumen environment	1
25.	Rumen microbiology, Rumen microbes: classification of rumen bacteria, protozoa, fungi	2
26.	Ruminant microbial digestion, Fermentation pathways: fermentation of carbohydrates, protein and fat, microbial activities in ruminant stomach and intestine	2
27.	Rumen degradable proteins, rumen undegradable proteins and urea feeding	1
28.	Volatile fatty acids, Absorption of end products and place of absorption and mechanism of absorption	1
29.	Advantages and disadvantages of ruminant digestion, artificial rumen	1
30.	Digestion in birds: functional anatomy of avian digestive system, swallowing, crop, proventriculus, ventriculus, caeca, nitrogen metabolism	1
	Total	**32**

S. No.	Topic	No. of Lectures/ Practicals
Practicals		
1.	Collection of saliva and its enzymatic studies	1
2.	Gastric and intestinal motility, Rate of passage of digesta and its estimation	1
3.	Rumino-reticular movements	
4.	Activity of pepsin and trypsin enzymes	1
5.	Estimation of digestive metabolites such as glucose and ketone bodies,	1
6.	Estimation of triglycerides, cholesterol	1
7.	Estimation of urea nitrogen and total proteins	1
8.	Liver function tests	2
9.	Pancreatic function tests	1
10.	Methods of collection of rumen liquor, merits and demerits	1
11.	Determination of pH, total volatile fatty acids in rumen liquor	1
12.	Determination of ammonia-nitrogen and total-nitrogen in strained rumen liquor	2
13.	Counting of protozoa and bacteria in rumen liquor	1
14.	Demonstration of fermentation of feed-stuff in artificial rumen	1
	Total	**16**

I. Course Title : Cardiovascular and Respiratory Physiology

II. Course Code : VPY 602

III. Credit Hours : 2+1

IV. Aim of the course

To teach function and regulation of heart, recording of ECG and respiration in different animals and basic techniques.

V. Theory

Unit I

Functional anatomy of heart and properties of cardiac muscle, Origin and propagation of cardiac impulses. Rhythmic excitation of heart, Electrophysiology of heart, Cardiac cycle, Cardiac sounds.

Unit II

Cardiac output and its measurements, Factors affecting cardiac output. Venous return and its regulation. Regulation of the cardiac functions.

Unit III

Normal electrocardiogram, Electrocardiographic interpretation in common cardiac disorders. Cardiac murmurs and cardiac arrhythmias. Echocardiography.

Unit IV

Circulation - coronary, systemic and pulmonary circulation and their regulation. Regional circulation. Pathophysiology of circulation. Hemodynamics. Arterial pressure. Capillary exchanges. Lymphatic circulation.

Unit V

Respiration, Mechanism of ventilation, Transport and exchange of respiratory gases at alveolar and tissue level, Respiratory adjustments at high altitude, Stress and exercise. Pulmonary volumes and capacities. Neural and chemical control of respiration. Respiration in birds.

VI. Suggested Reading

- Guyton and Hall *Textbook of Medical Physiology* 13th Edn John E. Hall Ph.D. 2015
- *Ganong's Review of Medical Physiology*, 26th Edn Kim E. Barrett, Susan M. Barman, Scott Boitano, Heddwen Brooks, 2019
- *Dukes' Physiology of Domestic Animals*, 13th Edn. William O. Reece, Howard H. Erickson, Jesse P. Goff, Etsuro E. Uemura 2015.
- *Cunningham's Textbook of Veterinary Physiology* 5th Edn. Bradley G. Klein 2012.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Functional anatomy of heart	1
2	Electrophysiology of heart	1
3	properties of cardiac muscle	1
4	Origin and propagation of cardiac impulses	1
5	Rhythmic excitation of heart	1
6	Cardiac cycle	1
7	Cardiac sounds	1
8	Cardiac output and its measurements	1
9	Factors affecting cardiac output	1
10	Regulation of the cardiac functions	1
11	Venous return and its regulation	1
12	Normal electrocardiogram	1
13	Electrocardiographic interpretation in common cardiac disorders.	1
14	Cardiac murmurs	1
15	Cardiac arrhythmias	1
16	Echocardiography	1
17	Hemodynamics	1
18	Blood pressure - factors affecting it and measurement	1
19	Regulation of blood pressure	1
20	Systemic circulation and pulmonary circulation	1
21	Coronary circulation	1
22	Regional circulation	1
23	Introduction to respiration	1
24	mechanism of ventilation	1
25	Pulmonary volumes and capacities	1
26	Transport and exchange of respiratory oxygen at alveolar and tissue level	1
27	Transport and exchange of respiratory carbondioxide at alveolar and tissue level	1
28	Neural and chemical control of respiration	1
29	Respiratory adjustments at high altitude	1
30	Respiratory adjustments to stress	1
31	Respiratory adjustments to exercise	1
32	Respiration in birds	1
	Total	**32**
Practical		
1.	Determination and recording of cardiac output	1
2.	Measurement of blood pressure by sphygmomanometer	1
3.	Recording of heart rate by physiograph	1

S. No.	Topic	No. of Lectures/ Practicals
4.	Effect of various ions and electrolytes on heart	1
5.	Effect of hormones on heart	1
6.	Effect of temperature on heart	1
7.	Recording and interpretation of normal ECG	1
8.	Recording and interpretation of cardiac disorders by ECG	1
9.	Determination of blood volume	1
10.	Effect of exercise on heart rate, pulse rate rate	1
11.	Estimation of cardiac marker enzymes	1
12.	Determination of lung volumes and capacities by spirometry	1
13.	Estimation of blood gases	1
14.	Estimation of blood pyruvate	1
15.	Estimation of blood lactate	1
16.	Effect of exercise on respiration rate	1
	Total	**16**

I. Course Title : Renal Physiology and Body Fluid Dynamics

II. Course Code : VPY 603

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge regarding excretory system of mammals and birds, maintenance of body fluid homeostasis

V. Theory

Unit I

An overview of nephron structure and function. Renal function in mammals.

Unit II

Renal haemodynamics. Glomerular filtration, Tubular reasbsorption and secretion. Urine formation- stages and factors affecting different stages.

Unit III

Role of kidney in acid-base balance, Physiology of micturition, Endocrine control of renal function- Renin angiotensin aldosterone system. Non excretory functions of kidney.

Unit IV

Excretory system in birds.

Unit V

Body fluids – various body fluid compartments, Different types of body fluids and their functions, Composition of different body fluids and their regulation.

VI. Suggested Reading

- Guyton and Hall *Textbook of Medical Physiology* 13th Edn John E Hall Ph.D.. 2015
- *Ganong's Review of Medical Physiology*, 26th Edn Kim E Barrett, Susan M Barman, Scott Boitano, Heddwen Brooks. 2019.
- *Dukes' Physiology of Domestic Animals*, 13th Edn. William O Reece, Howard H Erickson, Jesse P Goff, Etsuro E Uemura. 2015.
- *Cunningham's Textbook of Veterinary Physiology* 5th Edn. Bradley G Klein. 2012.
- Klahar S. 1983. *The Kidney and Body Fluids in Health and Diseases*. Plenum Press.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to physiology of mammalian kidney	1
2.	Theories of renal formation and Functional anatomy of kidney	1
3.	Renal homeostatic function	1
4.	Renal circulation and Pressures in renal function	1
5.	Glomerular filtration	1
6.	Solute reabsorption	1
7.	Tubular secretion	1
8.	Water excretion	1
9.	Absorbtive capabilities of different segments of nephron	1
10.	Renal mechanism for concentration of urine	1
11.	Renal mechanism for dilution of urine	1
12.	Autoregulation of renal blood flow and GFR	1
13.	Renal function tests	1
14.	Hormonal regulation of kidney function	1
15.	Characteristics of urine in different species	1
16.	Renin-angiotensin-aldosterone system	1
17.	Micturition	1
18.	Non excretory functions of kidney	1
19.	Acids and bases in the body	1
20.	Buffers in the body	1
21.	Role of buffers in acid base balance	1
22.	Disturbances in acid base balance	1
23.	Urine formation in birds	1
24.	Characteristics of avian urine	1
25.	Body fluid compartments	1
26.	Regulation of ECF osmolality and volume	1
27.	Regulation of ECF electrolytes	1
28.	Water balance	1
29.	Measurement of body water	1
30.	Water loss from routes other than kidney	1
31.	Water conservation in domestic animals	1
32.	Diuretics	1
33.	Determining the degree of dehydration in an animal	1
34.	Fluid therapy	1
	Total	**34**
Practical		
1.	Collection and preservation of urine	1
2.	Qualitative analysis of physiological constituents of urine	1
3.	Qualitative analysis of pathological constituents of urine	1
4.	Quantitative analysis of BUN in blood and urine	1
5.	Quantitative analysis of creatinine in blood and urine	1
6.	Quantitative analysis of phosphate and glucose in blood and urine	1
7.	Determination of sodium, potassium in serum	1
8.	Determination of calcium and chloride in serum	1
9-16.	Demonstration of various kidney function tests- glomerular filtration rate, creatinine clearance rate, urea clearance rate and glucose tolerance test.	8
	Total	**16**

I. Course Title : Hematology

II. Course Code : VPY 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students about haematology of different animals including hands-on training.

V. Theory

Unit I

Hematopoietic stem cells, Blood cells and hematological indices, Anaemia, Different types of anaemia, Polycythemia and their effect on circulation in mammals and birds. Fate of erythrocytes. Porphyrias.

Unit II

Resistance of the body to infection, Leukocytes, tissue macrophage system and inflammatory response.

Unit III

Haemoglobin and its types, Iron binding proteins in blood, Haemoglobin disorders. Hemophilias. Immunity, Ommunoglobulins complement system.

Unit IV

Hemostasis and coagulation factors, Role of platelets, Fibrinolysis. Conditions causing bleeding disorders. Blood groups, transfusion of blood.

VI. Suggested Reading

- Jain NC. 1993. *Essentials of Veterinary Hematology*. Lea and Febiger.
- *Schalm's Veterinary Hematology* 6th Ed - D Weiss J Wardrop, Wiley-Blackwell. 2010.
- *Guyton and Hall Textbook of Medical Physiology* 13th Edn John E Hall Ph.D. 2015.
- *Cunningham's Textbook of Veterinary Physiology* 5th Edn. Bradley G Klein. 2012.
- *Dukes' Physiology of Domestic Animals*, 13th Edn. William O Reece, Howard H Erickson, Jesse P Goff, Etsuro E Uemura. 2015.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Haematology- blood - composition-solutes of blood-plasma-interstitial fluid-lymph	1
2.	Functions of blood-general characteristics of blood-haematocrit-ESR-viscosity-temperature- volume-pH- colour- lifespan	1
3.	Haematocrit-methods of determination -colour index- icterus index-blood volume- methods of determination	1
4.	Plasma proteins – fractions- electrophoretic separation- general functions	1
5.	Functions of pre albumin-albumin-globulins and its fractions-	1
6.	Haematopoiesis- multipotent stem cells-definition-organs of hematopoisis- red and yellow marrow	1
7.	Multipotent lymphoid and myeloid stem cells- differentiation and maturation	1
8.	Bone marrow micro environment for haematopoiesis- stages of erythropoiesis	1
9.	Erythropoiesis- its regulation- vitamins and erythropoietin- haematinics	1

S. No.	Topic	No. of Lectures/ Practicals
10.	Haemoglobin- stages of Hb synthesis- regulation	1
11.	Types of Hb	1
12.	Iron metabolism- Fe requirement- hepcidin	1
13.	Intravascular and extravascular haemolysis	1
14.	Catabolism of Hb	1
15.	Plasma bilirubin- types- hyperbilirubinemia	1
16.	Jaundice - types- etiology - differential diagnosis	1
17.	Anisocytosis- poikilocytosis- RBC membrane structure- composition of RBC membrane	1
18.	RBC metabolism-physiological and pathological conditions associated with polycythemia and oligocythemia	1
19.	Anemias- classification- defective formation-excessive destruction-abnormal heme- abnormal globin chains- causes	1
20.	Erythrocyte indices- cytometric classification of anemias- causes-Red cell distribution width	1
21.	Leucocytopoiesis- granulocytopoiesis- lymphopoiesis	1
22.	Functions of neutrophils- phagocytosis- opsonisation-eosinophils-basophils-monocytes	1
23.	Conditions associated with altered number of neutrophils, eosinophils, basophils, monocytes and lymphocytes	1
24.	Hemostasis- blood fluidity maintenance- injury leading to primary hemostatic plug formation	1
25.	Secondary hemostatic pathways- intrinsic and extrinsic pathways-regulation-stabilisation of clot	1
26.	Fibrinolysis- retraction of clot- haemostatic disorders	1
27.	Types of immunity-innate-acquired- types of acquired immunity-Passive immunity-types-antibody-mechanism of actions of Ab-	1
28.	NK cells-functions-T-cell lymphocytopoiesis- thymus- functions-thymosin-thymopoietin-maturation of T cells- T cell receptors-blood thymus barrier	1
29.	Formation of T helper, cytotoxic and regulatory cells	1
30.	Plasma cells-structure – formation and functions	1
31.	Blood group antigens- cross reactivity- transfusion immunology	1
32.	Rh blood group- erythroblastosisfoetalis-treatment	1
	Total	**32**

Practical

1.	Enumeration of RBC, WBC	1
2.	Enumeration of platelets	1
3.	Enumeration of reticulocytes	1
4.	Enumeration of differential leucocytes	1
5.	Special staining techniques for leucocytes	1
6.	Haemogram by automated blood cell counter	1
7.	Anemic blood: Hb, PCV	1
8.	Icterus index calculation using plasma and standard	1
9.	Colour index calculation using plasma and standard	1
10.	Band cell count and arneth count	1
11.	Blood viscosity and RBC fragility determination	1
12.	Activated partial thromboplastin time	1
13.	Prothrombin time	1

S. No.	Topic	No. of Lectures/ Practicals
14.	Avian blood: haemogram-I (erythrocyte relates parameters using special stain)	1
15.	Avian blood-haemogram-II (leucocyte relates parametersusing special stain)	1
16.	Preparation of blood cells for electron microscopic analysis	1
	Total	**16**

I. Course Title : Growth and Environmental Physiology

II. Course Code : VPY 605

III. Credit Hours : 2+0

IV. Aim of the course

To teach the Growth process and its regulation, effect of mineral and vitamins on body functions and influence of environmental conditions on homeothermy.

V. Theory

Unit I

Growth - Introduction and Concepts. Hormonal regulation of growth. Growth promoters.

Unit II

Minerals - Classification-functions and disorders. Chelated minerals, nanominerals.

Unit III

Vitamins - Classification-functions and disorders. Synthetic vitamins.

Unit IV

Environment - Introduction and concepts. Weather and climate. Homeothermy, Poikilothermy. Hibernation and estivation. Thermoregulation, thermal stress. Effect of environment on production and reproduction.

VI. Suggested Reading

- Samuel Brody. 1945. *Bioenergetics and growth*. Reinhold Publishing Corp., New York
- Hossner KL. 2005. *Hormonal Regulation of Farm Animal Growth*. CABI.
- McDowell LR. 1989. *Vitamins in Animal Nutrition*. Academic Press.
- Underwood EJ. 1977. *Trace Elements in Human and Animal Nutrition*. Academic Press.
- ESE Hafez. 1968. *Adaptation of Domestic Animals*. Lea and Febiger.
- *Dukes' Physiology of Domestic Animals*, 13th Edn. William O Reece, Howard H Erickson, Jesse P Goff, Etsuro E Uemura 2015.

S. No.	Topic	No. of Lectures/ Practicals
1.	Growth - Definition, concepts, terminologies used in expression of growth	1
2.	Hormonal regulation of growth	2
3.	Commercial and synthetic hormones used in growth regulation	1
4.	Growth promoters used in livestock	1
5.	Growth promoters used in poultry	1
6.	Minerals - Introduction, Classification, sources	1
7.	Bioavailability of different minerals	1

S. No.	Topic	No. of Lectures/ Practicals
8.	Physiological role of minerals	1
9.	Disorders of mineral metabolism in livestock	1
10.	Disorders of mineral metabolism in poultry	1
11.	Chelated minerals	1
12.	Nanotechnology in mineral supplementation	1
13.	Vitamins - Introduction, Classification, sources	1
14.	Physiological role of fat soluble vitamins	1
15.	Physiological role of water soluble vitamins	1
16.	Disorders of fat soluble vitamins	1
17.	Disorders of water soluble vitamins	1
18.	Synthetic vitamins in animal production	1
19.	Environment - Introduction, physical components	1
20.	Physical principles of heat exchange	1
21.	Weather and climate	1
22.	Homeothermy, Poikilothermy, endothermy and ectothrmy	1
23.	Hibernation and estivation	1
24.	Body temperature in different species	1
25.	Thermoregulation in livestock	1
26.	Thermoregulation in poultry	1
27.	Thermal stress	1
28.	Heat tolerance coefficient	1
29.	Effect of weather variables on production - Milk, meat, wool	2
30.	Effect of weather variables on reproduction	1
	Total	**32**

I. Course Title : Physiology of Animal Reproduction

II. Course Code : VPY 606

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge of male and female reproductive system of different species of animals including birds.

V. Theory

Unit I

Functional histomorphology of male and female reproductive system. Development of male and female sex organs in different domestic animals. Neuro-endocrine reflexes.

Unit II

Puberty and its endocrine control. Sexual cycles and mating behaviours in females, oogenesis, folliculogenesis and ovulation. Secretions of female reproductive tract in different species of animals. Endocrine regulation of female reproduction.

Unit III

Male mating behaviour, Spermatogenesis, Spermiogenesis, Spermatogenic cycles. Spermatozoa- structure and composition, Maturation and transportation. Secretions of male reproductive tract. Endocrine regulation of male reproduction.

Unit IV

Transport of male and female gametes, Fertilization, implantation. Early embryo development and maternal recognition of pregnancy. Hormones of pregnancy. Placentation, parturition and Uterine Involution. Avian reproduction and formation of egg.

VI. Suggested Reading

- *Reproduction in Farm Animals*, 7th Edn ESE Hafez, B Hafez. 2013.
- *McDonald's Veterinary Endocrinology*, Pineda and Doley. Iowa State University Press, Ames, 2003.
- *Physiology of Reproduction and Artificial Insemination*, Salisbury GW and Demark NL. WB Saunders, 1978.
- *Dukes' Physiology of Domestic Animals*, 13th Edn. William O Reece, Howard H Erickson, Jesse P Goff, Etsuro E Uemura. 2015.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Functional histomorphology of male reproductive system	1
2	Functional histomorphology of female reproductive system	1
3	Development of male sex organs in different domestic animals	1
4	Development of female sex organs in different domestic animals	1
5	Neuro-endocrine reflexes	1
6	Puberty and its endocrine control in male domestic animals	1
7	Puberty and its endocrine control in female domestic animals	1
8	Sexual cycles in females	1
9	Mating behaviour in females	1
10	Oogenesis	1
11	Folliculogenesis	1
12	Ovulation	1
13	Secretions of female reproductive tract in different species of animals	1
14	Endocrine regulation of female reproduction in different species of animals	1
15	Spermatogenesis	1
16	Spermiogenesis	1
17	Spermatogenic cycles	1
18	Spermatozoa- structure and composition	1
19	Spermatozoa- maturation and transportation	1
20	Secretions of male reproductive tract.	1
21	Endocrine regulation of male reproduction in different species of animals	1
22	Transport of male and female gametes	1
23	Fertilization	1
24	Implantation	1
25	Early embryo development	1
26	Maternal recognition of pregnancy	1
27	Hormones of pregnancy	1
28	Placentation	1
29	Gestation	1
30	Parturition and Uterine Involution	1
31	Post-partum recovery in different species of domestic animals	1
32	Avian reproduction and formation of egg	1
	Total	**32**
Practical		
1.	Methods of heat detection in different species of domestic animals	1

S. No.	Topic	No. of Lectures/ Practicals
2.	Palpation of reproductive organs	1
3.	Examination of fern pattern in cervical mucus	1
4.	Semen evaluation - Gross	1
5.	Semen evaluation - Microscopical	1
6.	Semen evaluation - Biochemical	1
7.	Demonstration of preservation of semen	1
8.	Isolation of different follicles	1
9.	Collection of oocytes and their grading	1
10.	Estimation of reproductive hormones	3
11.	Demonstration of estrus behaviour	1
12.	Demonstration of mating	1
13.	Demonstration of parturition	1
14.	Demonstration of oviposition	1
	Total	**16**

I. Course Code : Clinical Physiology

II. Course Title : VPY 607

III. Credit Hours : 1+1

IV. Aim of the course

To teach physiological basis of clinical abnormalities in body functions.

V. Theory

Unit I

Introduction and basic concepts of understanding of alteration in system functions Relationship of cardiovascular, renal, respiratory systems and liver in healthy domestic animals and compensatory mechanisms during failure/ disorder of one or other systems Clinical Haematology and enzymology.

Unit II

Metabolism of carbohydrate, protein, lipid, vitamin and minerals in health and disease of various species of domestic animals and poultry.

Unit III

Evaluation of common endocrine disorders – pituitary, thyroid, parathyroid, pancreas in domestic animals (with reference to species and profile). Reproductive function alterations in male and female domestic animals during stress- productive, environmental, nutritional.

Unit IV

Clinical evaluation of Gastrointestinal tract; Clinical evaluation of Special Senses; Neuromuscular disorders and clinical correlation; Assessment of acid base and electrolyte balance.

VI. Suggested Reading

- *Clinical Biochemistry of Domestic Animals* 6th Edn, Jiro Jerry Kaneko, John W Harvey, Michael L Bruss, Academic Press. 2008.
- *Hawk's Physiological Chemistry*. Oser BL Tata McGraw-Hill. 1976.
- *Clinical Biochemistry: An Illustrated Colour* Text. Allan Gaw; Michael Murphy; Robert Cowan; Denis O'Reilly; Michael Stewart; James Shepherd, 2004

- *Clinical Physiology of Acid Base and Electrolyte Disorders*. Rose BD. McGraw-Hill. 1989.
- *Clinical Physiology: An Examination Primer*. 1st Edn, Ashis Banerjee, Cambridge University Press. 2005.
- *Textbook of Veterinary Physiological Chemistry* 3rd Edn, Larry R Engelking. 2014.
- *Practical Clinical Biochemistry: Methods and Interpretations*. 4th Edn. Chawla Ranjna. 2014.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Introduction and basic concepts of understanding of alteration in system functions	1
2	Relationship of cardiovascular, renal, respiratory systems and liver in healthy domestic animals and compensatory mechanisms during failure/ disorder of one or other systems	2
3	Clinical Haematology	1
4	Clinical enzymology	1
5	Metabolism of Carbohydrate in health and disease of various species of domestic animals and poultry	1
6	Metabolism of protein in health and disease of various species of domestic animals and poultry	1
7	Metabolism of lipid in health and disease of various species of domestic animals and poultry	1
8	Metabolism of vitamins in health and disease of various species of domestic animals and poultry	1
9	Metabolism of minerals in health and disease of various species of domestic animals and poultry	1
10	Evaluation of common endocrine disorders – pituitary, thyroid, parathyroid, pancreas in domestic animals (with reference to species and profile)	2
11	Reproductive function alterations in male and female domestic animals during stress- productive, environmental, nutritional	1
12	Clinical evaluation of Gastrointestinal tract and special senses	1
13	Neuromuscular disorders and clinical correlation	1
14	Acid base and electrolyte balance	1
15	Biological fluid analysis	1
	Total	**17**
Practical		
1	Hematological analysis of clinically recovered animals	2
2	Liver function testsof clinically recovered animals	2
3	Electrocardiography and interpretations of clinically recovered animals	2
4	Sphygmomanometry of clinically recovered animals	1
5	Respiratory Function tests of clinically recovered animals	1
6	Digestive function tests of clinically recovered animals	1
7	Renal function tests of clinically recovered animals	1
8	Estimation of serum enzymes related to cardiovascular functions of clinically recovered animals	1
9	Estimation of serum enzymes related to liver functionsof clinically recovered animals	1
10	Estimation of serum enzymes related to kidney functions of clinically recovered animals	1
11	Clinical Examination of endocrinology disorder animals Bioassay of steroid hormonesof clinically recovered animals	2
12	Physiographic study of body parameters of clinically recovered animals	1
	Total	**16**

I. Course Title : Neuromuscular Physiology
II. Course Code : VPY 608
III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of coordination of body functions and regulation of brain functions and sense organs.

V. Theory

Unit I

Functional anatomy, types and classification of muscles, of muscles. Properties of skeletal muscle, Contractile elements, Membrane and action potential, Molecular mechanism of muscle contraction, Myoneuronal junction and transmission of impulse, Smooth muscle contraction.

Unit II

Length and tension relationship, Force and velocity relationship. Skeletal muscle energetics, Metabolism and lactate shuttle. Exercise, adaptation to training and performance.

Unit III

Classification of nervous system. Neuron and its classification, Properties. Development of action potential and transmission of nerve impulse in nerve and synapse. Regulatory centres in brain. Reflexes. Functions of Cerebrum, Cerebellum, Hypothalamus, Limbic system.

Unit IV

Receptors and its types. Special senses.

VI. Suggested Reading

- *Guyton and Hall Textbook of Medical Physiology* 13th Edn John E Hall Ph.D. 2015.
- *Ganong's Review of Medical Physiology*, 26th Edn Kim E Barrett , Susan M Barman, Scott Boitano, Heddwen Brooks, 2019.
- *Dukes' Physiology of Domestic Animals*, 13th Edn. William O Reece, Howard H Erickson, Jesse P Goff, Etsuro E Uemura. 2015.
- *Cunningham's Textbook of Veterinary Physiology* 5th Edn. Bradley G. Klein. 2012.
- *Fundamentals of Neurophysiology*. Smith RF Springer Verlag. 1978.

S. No.	Topic	No. of Lectures
1.	Introduction, Organisation of Nervous system	1
2.	Cellular communication- concept of membrane potential	1
3.	Synapse and its properties, Synaptic transmission	1
4.	Neurotransmitters	1
5.	Sensory systems and Receptors	1
6.	Pain Physiology	1
7.	Cerebral cortex –Anatomy and Physiology	1
8.	Interbrain, thalamus and hypothalamus	1
9.	Midbrain – Physiological capability	1
10.	Brain stem – Physiological anatomy	1
11.	Sleep and EEG	1
12.	Memory and its types	1
13.	Pons and medulla – Anatomy and Physiology	1

S. No.	Topic	No. of Lectures
14.	Cerebellum – Anatomy and Physiology	1
15.	Spinal cord - Anatomy and Physiology	1
16.	Spinal reflexes and properties	1
17.	Postural reflexes	1
18.	Peripheral nervous system	1
19.	Autonomic nervous system – Sympathetic nervous system	1
20.	Autonomic nervous system – Parasympathetic nervous system	1
21.	Enteric nervous system	1
22.	Overall motor control	1
23.	Sensory Physiology – Photoreception	1
24.	Sensory Physiology – Auditory and equilibrium maintenance	1
25.	Sensory transduction – Gustation and olfaction	1
26.	Muscle structure and types	1
27.	Physiological properties of muscle	1
28.	Mechanism of muscle contraction	1
29.	Properties of muscle contraction	1
30.	Muscle metabolism	1
31.	Anatomy of Neuromuscular junction	1
32.	Smooth muscle physiology	1
	Total	**32**

I. Course Title : Endocrinology of Domestic Animals

II. Course Code : VPY 609

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of chemical integration of body functions.

V. Theory

Unit I

Methods of study of bioregulation including methods of endocrine analysis. Manipulation and disruption of biorhythms in homeostatic and natural ecosystem.

Unit II

Hormonal relationship in animal production. Concepts in hormone function, classification and methods of study, Hormonal assay, Mechanism of hormone synthesis, Release and transport. Mechanisms of hormone action, Target cell interactions.

Unit III

Genetic and genomic approaches in endocrinology. Animal models and alternate uses of animal model. Regulation and metabolism of hypothalamic, hypophyseal, thyroid and adrenal hormones.

Unit IV

Gonadal and placental hormones, their regulation and mechanism of action. Hormonal principles of pineal gland and its role in production.

Unit V

Endocrine control of carbohydrate and calcium homeostasis. Hormones and adaptation to environment. Hormonal regulation of gastro-intestinal activity. Prostaglandins. Hormones in fertility regulation and production augmentation. Avian endocrinology.

VI. Suggested Reading

- *McDonald's Veterinary Endocrinology*, Pineda and Doley. Iowa State University Press, Ames, 2003
- *General Endocrinology*. Turner CD and Bagnara JT, WB Saunders. 1976
- *Canine and Feline Endocrinology and Reproduction*, 3rd Edition, Edward C Feldman, Richard W Nelson. 2003.
- *Applied Animal Endocrinology* 2nd Edn. E James Squires. 2010

S. No.	Topic	No. of Lectures
1	Introduction to bioregulation – Scientific methods – Controlled experimental testing – Representative sampling – Dose response Relationship – Biological Rhythm – Endocrine–Nervous -Immune system interaction	1
2	Methods of endocrine secretion analysis – Extirpation -observation: Replacement –observation – Imaging – Radioimmunoassay – Enzyme immunoassay – High Performance Liquid Chromatography/ spectroscopy – Immunohistochemistry – Bioassays – Techniques for determining the number and characteristics of hormone receptor	1
3	Disruption of biorhythms in homeostatic and natural ecosystem – Endocrine disruptors or modulators – Assessment of endocrine disruptor activity – Sources of endocrine disruptors – Xenobiotics – Environmental pollutants altering endocrine secretions	1
4	Concepts in hormone function – Morphological functions Biological functions – Physiological functions – Molecular functions	1
5	Mechanism of hormone synthesis of – Protein hormones – Steroid hormones – Eicosanoids – Thyroid hormones – Monoamines	1
6	Release and transport in blood Mechanisms for regulating release – In response to Trophic hormone – In response to Nervous stimuli (environmental cues) – In response to levels of various metabolites	

S. No.	Topic	No. of Lectures
	Transport – Carrier proteins – Half life – Control of hormone release – Pulsatile release – Sustained release – Feed back mechanism	1
7	Mechanisms of hormone action Extracellular receptors – G protein coupled receptors – Catalytic receptors Intracellular receptors – cytoplasmic – intranuclear Target cell interactions – Upregulation – Down regulation	2
8	Genomic approaches in endocrinology. – Use of transgeneic animals – Knockout animals – Proteomics – Two dimensional gel electrophoresis – X ray crystallography – Tomography – MRI	2
9	Animal models to study endocrine disorder – Whole animal model – Isolated organs or tissues – *In vitro* models	2
10	Hypothalamic, hypophyseal hormones – Structure – function relationship of pituitary and hypothalamus Anterior pituitary hormones **Growth hormone** – structure, production, biological functions, disorders of growth hormone production **Prolactin** – structure, production, biological – functions, disorders of growth hormone production **ACTH** – structure, production, biological – functions **FSH** – structure, production, biological functions **LH** – structure, production, biological functions Posterior pituitary hormones **Oxytocin** – structure, production, biological functions **Vasopressin** – structure, production, biological functions	

S. No.	Topic	No. of Lectures
	Hypothalamic releasing and release inhibiting hormones	
	– Growth hormone inhibiting hormone	
	– Gonadotropin releasing hormone	2
11	Thyroid hormones	
	– Transport	
	– Receptors	
	– Metabolism	
	– Metabolic effects	
	– Effect on growth, development, fertility and milk production	2
12.	Adrenal hormones	
	• Structure of adrenal and synthesis of cortical hormones	
	• Physiological roles of	
	– Glucocorticoids	
	– Mineralocorticoids	
	• Physiological role of medullary hormones	2
13.	Pineal gland and its role in production.	
	• Melatonin	
	• Photoperiodism	
	• Seasonal breeding	
	• Manipulation of breeding cycle	
	– Implants	
	– Sustained release bolus	1
14.	Endocrine control of carbohydrate homeostasis	
	– Insulin	
	– Glucagon	
	– Epinephrine	
	– Growth hormone	
	– Glucocorticoids	
	– Thyroxine	2
15.	Endocrine control of calcium homeostasis	
	– Parathyroid hormone	
	– Calcitonin	
	– Calcitriol (Vitamin D3)	
	– Estrogens/ Androgens	
	– Glucocorticoids	
	– Thyroid hormones	
	– Insulin like growth factors	2
16.	Hormonal regulation of gastro-intestinal activity	
	– Gastrin	
	– Secretin	
	– Gastrin releasing peptide	
	– Cholecystokinin	
	– Gastric inhibitory peptide	
	– others	1
17.	Prostaglandins-Synthesis, types, release and mode of action	1
18.	Hormones in fertility regulation	
	• Manipulation of reproduction	
	• Regulation and manipulation of oestrous cycle	
	• Use of hormone agonists to control fertility	
	• Detection and synchronization of oestrusMethods for detection oestrus	
	• Strategies for synchronizing oestrusProstaglandin $F_2\alpha$ based systems Progestin and other hormones based systems	
	• Superovulation and embryo transfer	

S. No.	Topic	No. of Lectures
	• *In-vitro* production of embryos • Recognition and maintenance of pregnancy • Induction of abortion/ parturition • Advancing cyclicity in seasonal breeders, and puberty in animals • Immunological manipulation of reproduction	3
19.	Hormones in production augmentation • Somatotrophin • Adipokines • Leptin • Anabolic steroids and Analogues –mechanism of action delivery systems and safety aspects • β Adrenergic Agonists –mechanism of action delivery systems and safety aspects • Dietary supplements – chromium, PUFA and CLA • Regulation of feed intake – Orexigenic hypothalamic neurohormones – Anorexigenic hypothalamic neuropepetides – Hormonal regulation of mammary gland development and milk secretion Artificial induction of lactation	2
20	Avian endocrinology – Reproductive hormones – Hormonal manipulation of egg production – Control of broodiness in poultry – Manipulation of moulting	2
	Total	**32**

I. Course Title : Instrumentation and Research Techniques in Veterinary Physiology

II. Course Code : VPY 610

III. Credit Hours : 0+2

IV. Aim of the course

Training in various techniques for application in research in AnimalPhysiology

V. Suggested Reading

- *Hawk's Physiological Chemistry*. Oser BL Tata McGraw-Hill. 1976.
- *Varley's Practical Clinical Biochemistry* Alan H Gowenlock
- *Handbook of Radioimmunoassay*. Abraham GE Marcel Dekker. 1977.
- *Electrocardiograms: A Systematic Method of Reading Them* Armstrong ML. 1978
- *Rumen Microbiology*, Burk A Dehority 2003 Nottingham University Press

S. No.	Topic	No. of Lectures
1.	Design and types of research laboratory	1
2.	Maintenance of research equipments	1
3.	Imparting knowledge about preparation of various solutions	1
4.	Basic principles and concepts of pH	1
5.	Determination of pH of various solutions and biological samples	1
6.	Basic principles and concepts of ECG	1
7.	Recording of ECG in animals	1

S. No.	Topic	No. of Lectures
8.	Basic principles and concepts of physiograph and its accessories for *in-vitro* live tissue experiments	1
9.	Recording of blood pressure by physiograph and sphygmomanometer	1
10.	Recording of pulse rate by physiograph	1
11.	Recording of respiratory volumes by spirometer	1
12.	Neuro muscular experimental physiology using physiograph	1
13.	Physical and chemical principles of chromatography	1
14.	Extraction of active compounds from biological samples	1
15.	Protein separation and isolation methods – basic concepts	1
16.	Methods of protein determination	1
17.	Electrophoresis	1
18.	Thin layer chromatography	1
19.	Gas liquid chromatography	1
20.	Basic concepts of mineral estimation	1
21.	Flame photometry	1
22.	Laws of colorimetry	1
23.	Spectrophotometry	1
24.	Organ bath – Applications in experimental physiology	1
25.	Experiments using organ bath	1
26.	Enumeration of ruminal microflora	1
27.	Estimation of VFA	1
28.	Estimation of ammonia nitrogen	1
29.	Estimation of body water	1
30.	*In-vitro* rumen studies	1
31.	ELISA for estimation of various hormones	1
32.	RIA for estimation of various hormones	1
	Total	32

I. Course Title : Physiology of Wild Life

II. Course Code : VPY 611

III. Credit Hours : 1+0

IV. Aim of the course

To impart the knowledge on physiology of wild animals. The course content refers to wild animals related to Indian forests restricted to small and large animals. This course does not cover insects and other species for which veterinarian are not usually called for.

V. Theory

Unit I

Overview of Indian forests – Identification of sex in wild animals and birds - Blood collection methods in wild animals – Hematology - Common clinical biochemical estimations.

Unit II

Body temperature measurement techniques – Measurement of stress - Measuring senescence.

Unit III

Reproduction management in wild animals - Understanding sound mechanics and communication methods – Ethology of wild animals - Government policies for wild life protection.

VI. Suggested Reading

Standard text books and Government policies pertaining to wild life.

S. No.	Topic	No. of Lectures
Theory		
1.	Animal Species Overview of Indian forests.	1
2.	How to identify the sex of wild animals and birds.	1
3.	Collection of Clinical materials for laboratory examination; methods	1
4.	Heamtology	1
5.	Common clinical biochemical estimations.	1
6.	Methods of measuring body temperature of wild animals	1
7.	Measuring capture and immobilization stress in wildlife	1
8.	Measuring senescence in wild animal populations	1
9.	Reproduction management in wild animals	2
10.	Understanding sound mechanics and communication methods	1
11.	Wild animal ethology	2
12.	Government policies for wild life protection (respective state)	1
13.	Lecture by wildlife vet or conservationist	2
	Total	16

Course Title with Credit Load
Ph.D. in Veterinary Physiology

Course Code	Course Title	Credit Hours
RPE 700	Research and Publication Ethics*	1+1
VPY 701	Applied physiology of body fluidsand electrolytes	2+1
VPY 702	Physiology of animal behaviour	2+0
VPY 703	Recent trends in ruminant digestion	2+1
VPY 704	Recent trends in neuroendocrinology	2+1
VPY 705	Myophysiology and kinesiology	2+0
VPY 706	Avian physiology	2+1
VPY 707	Physiology of lactation	2+1
VPY 708	Recent trends in environmental physiologyand growth	2+1
VPY 709	Cellular and molecular physiology	2+0
VPY 710	Recent trends in immuno-physiology	2+1
VPY 711	Physiology of stress	2+0
VPY 712	Recent trends in reproductive physiology	2+1
VPY 713	Doctorate Seminar-I	1+0
VPY 714	Doctorate Seminar-II	1+0
VPY 715	Doctorate Research	0+75

*Compulsory Major course for Doctorate programme. The other 10 credits can be registered from remaining 700 Series courses listed above.

Suggested list of specified Minor subjects (Departments)

Major Subject	Minor subjects (Departments)*
Veterinary Physiology	Animal Nutrition, Biochemistry, Gynaecology and Obstetrics, Animal Genetics and Breeding, Biotechnology, Surgery and Radiology, Livestock Production Management, Pharmacology and Toxicology, Anatomy, Medicine, poultry science, pathology.

*The Minorl courses may be taken from any number of disciplines/ departments listed against major discipline limiting to credits prescribed as decided by the Chairman of Advisory Committee of the student.

Minor courses may also be taken from the disciplines/ departments other than those listed above on the recommendations of advisory committee, if essentially required as per the research problem with the concurrence of Head of the Department and Concerned Authorities.

Course Contents
Ph.D. in Veterinary Physiology

I. Course Title : Applied Physiology of Body Fluids and Electrolytes

II. Course Code : VPY 701

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge regarding physiology of body fluids and electrolytes in relation to homeostasis.

V. Theory

Unit I

Volume and composition of body fluids, Exchange of water and electrolytes between body compartments and transport mechanisms, Blood and external environment. Osmolarity and osmolality of body fluids.

Unit II

Regulation of volume and osmolarity of extracellular fluid. Regulation of pH and acid base balance. Formation and composition of cerebrospinal fluid and lymph.

Unit III

Clinical implications of change in electrolytes and body fluids. Functional consideration of plasma volume and its composition. Diuresis and endocrine control of renal functions.

Unit IV

Clinical feature in fluid and electrolyte imbalances, clinicopathological indictors of fluid and electrolyte imbalances. Physiological basis of fluid therapy.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Body fluid compartments-Extracellular and Intracellular fluid compartment (ECF and ICF), Volume of ECF and ICF. Composition of various body fluids	1
2.	Total Body water, Water requirement, daily intake and loss of water from the body	1
3.	Different transport mechanisms for exchange of water and electrolytes-Active and passive transport, filtration, diffusion and osmosis	1
4.	Exchange of nutrients and other substances between blood and interstitial fluid. Capillary pressure, interstitial fluid pressure, exchange of fluids through capillary membrane	1
5.	Principles of osmosis and osmotic pressure, osmotic equilibrium between ICF and ECF, Tonicity of body fluids	1
6.	Composition of synovial fluid and peritoneal fluid	1

S. No.	Topic	No. of Lectures/ Practicals
7.	Osmolarity and Osmolality of ICF and ECF, regulation of volume and osmolarity of ECF	1
8.	Contribution of different molecules viz glucose, sodium and urea towards osmolarity of ECF	1
9.	pH of different body fluids, factors affecting pH of body fluids, Physiology of acid base balance, buffer systems of ICF and ECF	1
10.	Different types of Acidosis and Alkalosis, their etiology and compensation	1
11.	Evaluation of acid–base status- Siggaard–Andersen alignment nomogram, Anion gap, base excess and deficit	1
12.	Role of Respiratory system and Kidneys in maintenance of Acid base balance	1
13.	Formation and composition of Cerebrospinal fluid and lymph	1
14.	Clinical disorders resulting into loss of electrolytes from body fluids.	1
15.	Changes in plasma volume and its composition under different clinical conditions-vomition and diarrhoea	1
16.	hypervolemia and hypovolemia, Implications of hypovolemic and hemorrhagic shock	1
17.	Dehydration - its types and causes. Water intoxication	1
18.	Role of kidneys in regulation of water balance. Renin-angiotensin system	1
19.	Role of kidneys in formation and excretion of concentrated and diluted urine	1
20.	Hormonal regulation of important electrolytes in plasma	1
21.	Role of Hormones in renal regulation of water and electrolytes	1
22.	Diuresis and pressure natriuresis, polyuria and oligouria	1
23.	Clinical considerations in fluid and electrolyte imbalances	1
24.	Clinicopatholiogical indicators of fluid and electrolyte imbalance	1
25.	Clinical Physiology of Dehydration – Signs, symptoms, evaluation of intensity of dehydration	1
26.	Clinical Physiology of vomition and diarrhoea- Signs and symptoms	1
27.	Clinical Physiology of edema Signs and symptoms, causes and prevention	1
28.	Role of serum sodium, hyponatremia, hypernatremia; Role of serum potassium, hypokalemia, hyperkalemia	1
29.	Role of serum chloride, hypocholeremia and hypercholeremia, bicarbonate ions	1
30.	Principle and indications of fluid therapy	1
31.	Types of solution used for fluid therapy, role of their components and their use in different clinical conditions	1
32.	Effect of adding different saline, glucose solutions to ECF-isotonic, hypertonic and hypotonic solutions	1
	Total	**32**

Practical

1.	Estimation of pH of different body fluids and evaluation of acid base status.	1
2.	Determination of sodium in serum sample of farm animals (by flame photometry/ colorimetric method)	1
3.	Determination of potassium in serum sample of farm animals (by flame photometry/ colorimetric method)	1
4.	Determination of chloride in serum sample of farm animals (by flame photometry/ colorimetric method)	1

S. No.	Topic	No. of Lectures/ Practicals
5.	Determination of bicarbonate in serum sample of farm animals	1
6.	Determination of Calcium in serum sample of farm animals	1
7.	Determination of Magnesium in serum sample of farm animals	1
8.	Determination of phosphate in serum sample of farm animals	1
9.	Determination of total body water (simulated demonstration)	1
10.	Determination of blood volume (simulated demonstration)	1
11.	Determination of plasma volume (simulated demonstration)	1
12.	Determination of Interstitial Fluid Volume (simulated demonstration)	1
13.	Estimation of osmolarity and osmolality of urine of farm animals	1
14.	Estimation of osmolarity and osmolality of milk	1
15.	Estimation of osmolarity and osmolality of blood of farm animals	1
16.	Evaluation of dehydration in animal and choosing the fluid type, its volume and rate for fluid therapy	1
	Total	**16**

I. Course Title : Physiology of Animal Behaviour

II. Course Code : VPY 702

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students about physiology of animal behaviour in different species of domestic animals.

V. Theory

Unit I

Introduction to animal ethology. Neurophysiological basis of animal behaviour.

Unit II

Behaviour in relation to changes in the environment. Feeding, Grazing, Stall feeding and rumination behaviour.

Unit III

Sexual behaviour in female and male animals. Maternal behaviour. Milk let down.

Unit IV

Social behaviour, Communication in animals, Animal temperament. Responses of dogs and horses to training.

S. No.	Topic	No. of Lectures
Theory		
1.	Introduction to ethology and its importance in Veterinary Science.	1
2.	Ethology-definition and its importance in animal welfare	1
3.	Types of animal behaviour	2
4.	Behavioural Ecology, evolutionary basis for animal behavior	2
5.	Ecological pressures, ontogeny and phylogeny of behaviour	1
6.	Physiological concept of behaviour, neuro-endocrine integration for behavioural manifestation	2
7.	The concept of instinct, Habituation, imprinting, reinforcement, conditioning, reasoning and intelligence. Temperament scoring	2

S. No.	Topic	No. of Lectures
8.	Ingestive/ feeding behaviour in ruminants: Prehension, grazing behaviour in cattle, sheep and goats, rumination behaviour	2
9.	Ingestive behaviour in dogs	1
10.	Ingestive behaviour in swine	1
11.	Special feeding patterns; Abnormal feeding behaviour	2
12.	Precopulatory behavior (Searching, Courtship, Sexual arousal, Erection, Penile protrusion): Species differentiation	1
13.	Copulatory behaviour (Mounting, intromission and ejaculation): Species differentiation	2
14.	Post copulatory behaviour (Dismounting and refractory period)	1
15.	Manifestation of behavioural estrus, estrus intensity scoring	1
16.	Role of pheromon in sexual behaviour manifestation	1
17.	Abnormal sexual behavioural pattern	1
18.	Maternal behaviour: Formation of bond between mother and fetus, concept of critical period, vocalization	1
19.	Maternal behaviour in different species, abnormal maternal behaviour	1
20.	Milking behaviour: Milking temperament, milk let down reflex and the factors affecting milking behaviour	1
21.	Social behaviour: Dominance, Social hierarchy	1
22.	Agonistic (combat or aggressive) behaviour, Gregarious, Peck order in chicken	1
23.	Communicating behaviour: Attraction, Repulsion and Submission	1
24.	Mode of communication (visual, auditory, chemical) in different species.	1
25.	Responses of dogs and horses to training	1
	Total	**32**

I. Course Title : Advances in Ruminant Digestion

II. Course Code : VPY 703

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about advances in digestion of ruminant animals.

V. Theory

Unit I

Introduction to rumen bacteria, protozoa and fungi. Development and natural fluctuation in rumen microbial population. Salivary secretion and its regulation.

Unit II

Microbial ecology and physiology of feed degradation within the rumen. Metabolism of nitrogen containing compounds.

Unit III

Degradation of carbohydrate, fat and protein by rumen microbes, Microbe- microbe interaction. Protected nutrients and other feed additives.

Unit IV

Genetics and biotechnology of rumen microbes, rumen anaerobic fungi, their role and interaction with other rumen microbes. Probiotics supplementation, etc. Rumen flow rate and rumen volume.

S. No.	Topic	No. of Lectures
Theory		
1.	Functional development of ruminant stomach	1
2.	Microbial ecosystem of fermentative digestion	1
3.	Fluctuation in rumen microbial population	1
4.	Substrates for fermentative digestion	1
5.	Salivary secretion and its regulation	1
6.	Role of saliva on fermentative digestion	1
7.	Rumen motility and its regulation	1
8.	Rumen bacteria	2
9.	Rumen protozoa – its importance and its interaction with other group	2
10.	Anerobic fungi	1
11.	Polysaccharide degradation by rumen microbes	2
12.	Metabolism of nitrogen containing compounds	1
13.	Lipid metabolism in rumen	1
14.	Rumen metabolites and their assimilation	1
15.	Microbe-microbe interaction	1
16.	Comparative efficiency of rumen function in different species.	2
17.	Protected nutrients	1
18.	Digestive disorders of rumen	1
19.	Nutritional toxicity and strategy to address it	1
20.	Stoichiometry of fermentative digestion	1
21.	Approaches to modification of ruminal fermentation	2
22.	Modifiers of ruminal microbial activity	1
23.	Biological models of rumen function	2
24.	Rumen simulation technique	2
25.	Rumen flow rate and rumen volume	1
	Total	**32**
Practical		
1.	Reticulo-ruminal motility	1
2.	Total volatile fatty acids and their fractions	2
3.	Culture of rumen bacteria	3
4.	Protozoal counting	1
5.	Culture of rumen fungi	3
6.	Demonstration of effect of defaunation	2
7.	Flow rates of ruminal contents	2
8.	Artificial rumen techniques	2
	Total	**16**

I. Course Title : Advances in Neuro-endocrinology

II. Course Code : VPY 704

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students about advances in neuro-endocrinology of domestic animals.

V. Theory

Unit I

Neuroendocrine integrating mechanism. Structure of hypothalamus, pituitary gland, limbic and other neural pathways and endocrine functions.

Unit II

Neural control of oxytocin, adrenocorticotropic hormone, aldosterone, thyrotropic hormone, growth hormone, gonadotrophins, Hypothalamic releasing factors and the neuro-vascular link between brain and anterior pituitary.

Unit III

Role of afferent impulses from genitals and other regions in reproductive system. Influence of hormones on brain activity.

Unit IV

Effects of drugs on neuro-endocrine system. Neuro-endocrine mechanisms in birds. Interaction of nervous, endocrine and immune system in animal production and reproduction.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Evolution and theory of hormones	1
2	Development of endocrine glands	1
3	Neuroendocrine integrating mechanism	1
4	Homeostatic regulation by hormones; Feedback regulation of hormones	1
5	Biorhythms, manipulation and disruption of biorhythms in homeostatic and natural ecosystem	1
6	Hormones and adaptation to environment	1
7	Endocrine methodologies in study of bioregulation	1
8	Animal models and alternate uses of animal model in endocrine studies	1
9	Methods of hormonal assays - Radioimmunoassay, Immunorediometric assay, Radioceptors assay, enzyme linked immunosorbent assay, chemi-luminiscence assay	2
10	Hormone secretion, transport and clearance	1
11	Cellular receptors for hormone; Hormones and target cells	1
12	Genomic and non genomic effects of hormones	1
13	Second messenger system; Receptor signal transduction; Hormone receptor interaction – protein and peptide hormones; Hormone receptor interaction – steroid and other hormones	2
14	Half-life of hormones, pattern of hormone release;	1
15	Types and family of hormones	1
16	Hormones regulating growth	1
17	Hormones regulating energy metabolism	1
18	Hormones regulating digestion	1
19	Hormones regulating calcium and phosphorus	1
20	Hormones regulating electrolytes – Na and K	1
21	Hormones regulating hyper and hypoglycemia	1
22	Hormones regulating blood volume and blood pressure	1
23	Alleviation of stress by hormones	1
24	Endocrine role of pineal gland	1
25	Hormones and behavior	1
26	Endocrine pathophysiology	2
27	Avian endocrinology	1
28	Synthetic hormones	1
29	Application of nanotechnology in endocrine studies	1
	Total	**32**

S. No.	Topic	No. of Lectures/ Practicals
Practical		
1.	Extraction of hormones	1
2.	Immunohistochemistry of hormones	2
3.	Radio-immuno assay of hormones	3
4.	Enzyme linked immunosorbent assay of hormones	2
5.	Bioassy of hormones	2
6.	Induction of atherosclerosis	1
7.	Induction of hypoglycemia in laboratory models by allaxon and streptozotocin	2
8.	Induction of hyperglycemia in laboratory models by administration of epinephrine and glucagon, etc.	1
9.	*In-vitro* effects of certain hormones such as adrenaline, histamine and acetyl choline on excised intestine	1
10.	Hormone assay in fecal samples	1
	Total	**16**

I. Course Title : Myophysiology and Kinesiology

II. Course Code : VPY 705

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge to the students about myophysiology and kinesiology.

V. Theory

Unit I

Morphology of muscle; Chemical composition of muscle; Electrical phenomena and iron influxes; Muscle contraction and irritability; Neuromuscular transmission; Excitation contraction coupling; Mechanical properties of skeletal muscle; Types of chemical muscle fibres; Coordination among muscles.

Unit II

Thermal properties of muscles; Chemical correlates of contraction.

Unit III

Molecular basis of muscular contraction of skeletal muscle; Energetics of Muscle Contraction; Electromyogram; Pathophysiology of muscles; Myocardium – electrical properties; Myocardium – mechanical properties; Pacemaker tissue; Endurance of muscle.

Unit IV

Lever systems of body joints; Synovial fluid formation and its physiology; Principles of Kinesiology and its application in work physiology.

S. No.	Topic	No. of Lectures
1.	Morphology of muscle	1
2.	Chemical composition of muscle	1
3.	Electrical phenomena and iron influxes	2
4.	Muscle contraction and irritability.	2

S. No.	Topic	No. of Lectures
5.	Neuromuscular transmission	2
6.	Excitation contraction coupling	2
7.	Mechanical properties of skeletal muscle	1
8.	Types of chemical muscle fibres	1
9.	Coordination among muscles.	1
10.	Thermal properties of muscles.	1
11.	Chemical correlates of contraction.	1
12.	Molecular basis of muscular contraction of skeletal muscle	2
13.	Energetics of Muscle Contraction	2
14.	Electromyogram	1
15.	Pathophysiology of muscles	1
16.	Myocardium – electrical properties	2
17.	Myocardium – mechanical properties	2
18.	Pacemaker tissue	1
19.	Endurance of muscle	1
20.	Lever systems of body joints,	2
21.	Synovial fluid formation and its physiology.	1
22.	Principles of Kinesiology and its application in work physiology	2
	Total	**32**

I. Course Title : Avian Physiology

II. Course Code : VPY 706

III. Credit Hours : 2 + 1

IV. Aim of the course

To teach physiology of birds.

Unit I

Digestive and urinary system.

Unit II

Blood, cardiovascular and respiratory system.

Unit III

Reproductive and endocrine system.

Unit IV

Nervous system and musculo-skeletal system.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Digestive system Comparative Functional Anatomy of the Digestive Tract -Gastrointestinal Function	1
2.	Food Intake Regulation GI Motility, Neural and Hormonal Control of Motility	1
3.	Secretions and Digestion	1
4.	Absorption - Carbohydrates, Amino Acids and Peptides, Fatty Acids and Bile Acids, Volatile Fatty Acids	1
5.	Urinary system Functional anatomy of The Kidneys- Intake of Water and Solutes	1

S. No.	Topic	No. of Lectures/ Practicals
6.	Formation of Urine- Osmoregulation	1
7.	Postrenal Modification of Ureteral urine	1
8.	Salt Glands - Evaporative Water Loss	1
9.	Blood, Cardiovascular Blood -Components – Effects of Altitude	1
10.	Gross Structure and Function	1
11.	General Circulatory Hemodynamics	1
12.	Control of the Cardiovascular System	1
13.	Integrative Neural Control	1
14.	Respiratory system Anatomy of the Avian Respiratory System-Air Sacs	1
15.	Ventilatory Reflexes -Respiratory System Volumes	1
16.	Gas Exchange -Ventilation and Respiratory Mechanics	1
17.	Basic Principles of Oxygen Transport - Cross-Current Gas Exchange	1
18.	High-Altitude Flight -Control of Breathing	1
19.	Reproductive system Anatomy of the Female Reproductive Breeding and Ovulation–Oviposition Cycles	1
20.	Ovarian Hormones Hormonal and Physiologic Factors Affecting Ovulation	1
21.	Effect of Light on the Ovary and Ovulation PhotorefractorinessMolt	1
22.	Incubation Physiology	1
23.	Male Reproductive Tract Anatomy Hormonal Control of Testicular Function, Spermatogenesis Extragonadal Sperm Transport and Maturation	1
24.	Endocrine system. Synthesis, Release of Hormones and functions of endocrine glands	1
25.	Hypothalamus and Pituitary Hormones	1
26.	Pancreatic and Adrenal hormones	1
27.	Secretions of Thyroid gland, parathyroid gland	1
28.	Nervous system and musculo-skeletal system Sensory Physiology - Uniqueness of avian brain	1
29.	Functional Organization of the Spinal Cord	1
30.	The Autonomic Nervous System of Avian Species	1
31.	Skeletal MuscleMuscle Fiber Types, Electrical Properties of Muscle Fibers -Contractile Properties	1
32.	Neurotransmission, Smooth muscle	1
	Total	**32**
Practical		
1.	Collection of blood from the birds and blood processing.	1
2.	Study of blood cells RBC count	1
3.	WBC count	1
4.	DLC	1
5.	Thrombocyte count	1
6.	Haemoglobin concentration	1
7.	Packed cell volume (haematocrit)	1
8.	Erythrocyte sedimentation rate	1
9.	Determination of feed passage rate in birds	1
10.	Enzymatic profile under various physiological states of birds	1
11.	Collection of semen and its evaluation	1
12.	Demonstration of cold shock resistant of avian spermatozoa and sperm stimulatory and inhibitory agents	1
13.	Determination of glucose and calcium in blood	1
14.	Determination of uric acid and urea in blood	1
15.	Electrophoretic separation of plasma proteins and egg proteins	1
16.	Localization of different endocrine glands	1
	Total	**16**

I. Course Title : Physiology of Lactation

II. Course Code : VPY 707

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on physiology of lactation in dairy animals.

Unit I

Functional anatomy, histology and cytology of mammary gland in domestic animals.

Unit II

Development of mammary gland, Hormonal control of mammogenesis.

Unit III

Process of lactation, Initiation of milk secretion, Hormonal control of lactation. Biochemical and histological changes in mammary gland during lactation. Mechanism of galactopoiesis.

Unit IV

Neural control of lactation, Milk let down, Milk ejection and inhibition of milk ejection. Induced lactation. Composition of milk in animals.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Introduction to the mammary gland and milk production	1
2.	Mammary gland anatomy - macrostructure	1
3.	Mammary gland anatomy - microstructure	1
4.	Mammary gland anatomy – blood supply, nerve supply and lymphatic network	1
5.	Comparative anatomy and physiology of mammary gland of different domestic animals	1
6.	Basic histology of parenchyma and cellular organization of the mammary epithelial cell	1
7.	Mammary growth and development I: fetal through puberty	1
8.	Mammary growth and development II: Post-puberty through involution	2
9.	Hormonal control of mammogenesis	1
10.	Lactogenesis	1
11.	Lactation	2
12.	Biochemical changes in mammary gland during lactation	1
13.	Histological changes in mammary gland during lactation	1
14.	Galactopoiesis	1
15.	Neuro endocrine control of lactation	1
16.	Milk letdown and its inhibition	1
17.	Factors affecting milk yield	1
18.	Dry period – importance, different strategies and beliefs	1
19.	Mammary involution	1
20.	Milk properties and composition	1
21.	Colostrum	1
22.	Milk carbohydrate synthesis and secretion	1
23.	Milk protein synthesis and secretion	1
24.	Milk lipids synthesis and secretion	1
25.	Mammary gland immunology	1

S. No.	Topic	No. of Lectures/ Practicals
26.	Other important milk components	1
27.	Contaminants and pollutants in milk	2
28.	Manipulation of milk production	1
29.	Diseases associated with mammary gland	1
	Total	**32**
Practical		
1.	External structure of cow's udder	1
2.	Internal structure of cow's udder	2
3.	Histological examination of udder in cows	1
4.	Milk letdown response in dairy animals	2
5.	Composition of colostrum	1
6.	Composition of milk during different phases of lactation	2
7.	Artificial induction of lactation	3
8.	Estimation of lactogenic hormones	4
	Total	**16**

I. Course Title : Advances in Ecosystem, Environmental Physiology and Growth

II. Course Code : VPY 708

III. Credit Hours : 2+1

IV. Aim of the course

To teach physiology of growth process in animals and effect of environmental factors on homeostasis of animals.

V. Theory

Unit I

Ecology of farm animals, Biological rhythms, Mammalian circadian rhythms, their regulation. Components of physical environment, Biometeorology and principles of thermoregulation in mammals and birds.

Unit II

Physiological response of farm animals to heat and cold. Effect of various climatic components on health and production (growth and egg production), reproduction and climatic adaptation.

Unit III

Concept and definitions of cellular, prenatal and postnatal growth - Patterns in animals.

Unit IV

Factors affecting growth - Nutrition, Hormones, Vitamins, Antibiotics, Environment. Ageing and senescence. Growth anomalies.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1	Ecology and its scope in livestock productivity;	1
2	Disciplines of ecology; fundamental principles of ecology	1

S. No.	Topic	No. of Lectures/ Practicals
3	Biosphere and biodiversity	1
4	Ecosystem and Components of Ecosystem; Types of Species Found in Ecosystems; Principal Ways Species Interact	2
5	Adaptation, Acclimation and Acclimatization	1
6	Temperature Regulation -*Thermoregulators and Thermoconformer*	1
7	Principles of Heat gains and losses in animals	1
8	Warm-blooded versus cold-blooded animals and its relevance to survival	1
9	Heat production in birds and mammals	
10	Hibernation, Estivation and Daily Torpor; Cold Habitation	1
11	Body Temperature of Homeotherms - concept of core temperature measurements -Rectal Temperature of different animal species; Diurnal Variations	1
12	Physiological responses to heat in animals and birds	1
13	Temperature regulation in birds	1
14	Bioclimatology with respect to livestock and poultry farming	1
15	Surface temperature of earth- its measurements	1
16	earth's atmosphere-Geographic Belts, Composition of the Atmosphere	1
17	Climatic elements- components – measurements	2
18	Cold stress, Heat stress- impact on animal health and production	2
19	Adaptation to atmospheric pressure differences [altitude]-physiological changes and phenotypic characters;	1
20	Physiology of growth and its measurements	1
21	Periods of growth- prenatal and postnatal	2
22	Pattern of growth	1
23	Factors affecting growth	1
24	Recent concepts in manipulation of growth	1
25	Growth promoters	2
26	Ethical issues in use of growth promoters	2
27	Growth anomalies	1
28	Ageing and senescence	1
	Total	**32**
Practical		
1	Atmosphere definition- understanding the globe	1
2	Temperature Recording in animal house, poultry house, and laboratory	1
3	Calculation of RH	1
4	Calculation of THI	1
5	Calculation of Heat Loading index	1
6	Measurement of sweating rate in cattle	2
7	Stress assessment- different methods and indicators	2
8	Weather forecast models followed in India	1
9	Date analysis of rain and temperature for 20 years in the respective region	2
10	Assessing impact of different shades and houses on milk production in the college farms	1
11	Measurements of growth rate and chart of crossbred calves, native breed calf, etc.	1
12	Visit to meteorology stations	1
13	Purpose and role Satellites of ISRO related to the course (invited lecture)	1
	Total	**16**

I. Course Title : Cellular and Molecular Physiology

II. Course Code : PHY 709

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about cellular and molecular physiology.

V. Theory

Unit I

Cell membrane, Organelles and their functions. DNA synthesis and replication.

Unit II

Physiology of cell signaling. Basic classification and characterization of membrane receptors. Intracellular/ nuclear receptors.

Unit III

Major signaling pathways: SPs associated with second messengers; Cell signaling and apoptosis.

Unit IV

Cell cycle and Checkpoints in Cell Cycle Regulation. Regulators of the Cell cycle, cyclin-dependent kinases (CDKs) Signaling defects. Modern methods to study signaling.

S. No.	Topic	No. of Lectures
Theory		
1.	Cell and its organelles – structure and function, difference between prokaryotic and eukaryotic cell	2
2.	Structural organization of bimembranes	1
3.	Transport of molecules through cell membrane	1
4.	Membrane proteins and their functions	1
5.	Cell adhesion molecules and their functions	1
6.	Transmembrane signalling pathways	2
7.	Cell signaling and apoptosis	1
8.	Modern methods to study signaling	1
9.	Cell cycle-stages, mitosis and meiosis and regulatory molecules	3
10.	Organization of eukaryotic and prokaryotic genome	3
11.	DNA replication in prokaryotes and eukaryotes	4
12.	Transcription in prokaryotes and eukaryotes	2
13.	Translation in prokaryotes and eukaryotes	2
14.	Techniques in molecular biology – PCR, DNA sequencing, DNA micro-array, DNA finger printing in situ hybridization	4
15.	Recombinant DNA technology and its applications	2
16.	Gene silencing by RNA interface technology	2
	Total	**32**

I. Course Title : Advances in Immuno Physiology

II. Course Code : VPY 710

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge regarding physiology of immune system.

V. Theory

Unit I

Introduction, History, Body defense, Organs of immune system, Ontogeny and phylogeny of immune system, Vertical transmission of immunity in animals.

Unit II

Immunoglobulins – Basic structure and functions, Hematopoiesis, T-cell and B-cell-evolution, Development and their functions, Cytokines-sources and actions, MHC, genetic organization of immunoglobulin, MHC and complement system.

Unit III

Immune-endocrine interactions, Immune-reproduction, Ageing, Stress and other physiological functions, Immune modulation.

Unit IV

Hypersensitivity, diseases related to immune system, dysfunction, autoimmune disorders and their genesis, immunodeficiency.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Types of immunity	1
2.	Host cell receptors of innate immunity	1
3.	Passive immunity.	1
4.	Acute phase reactant proteins (APRs) – positive APRs and negative APRs	1
5.	Significance of CRPs	1
6.	Antigen	1
7.	Factors influencing immunogenicity of antigens	1
8.	Heterophile antigens	1
9.	Antibody	1
10.	Functions of immunoglobulin	1
11.	Isotypes	1
12.	Hybridomas	1
13.	Monoclonal antibodies (mAB)	1
14.	Antigen antibody reaction	1
15.	Neutralisation	1
16.	Western blotting technique	1
17.	Complement pathways	1
18.	Leucocytopoiesis	1
19.	Central lymphoid organs I	1
20.	Central lymphoid organs II	1
21.	Characteristics and functions of different T and B lymphocytes	1
22.	NK cells	1
23.	Major histocompatibility	1
24.	Cytokines: interleukins, interferons, TNF, CSF	1
25.	Antigen presenting cells	1
26.	Cell mediated immunity	1
27.	Humoral/ Ab mediated immunity	1
28.	Immediate type	1
29.	Hypersensitivity type III – mechanism	1
30.	Autoimmunity	1

S. No.	Topic	No. of Lectures/ Practicals
31.	Immunological tolerance	1
32.	Transplant immunology	1
	Total	**32**
Practical		
1.	Isolation of lymphocytes from blood by density gradient centrifugation	1
2.	Determination of live and dead lymphocytes in the separated sample	1
3.	Estimation of CRP in serum by immunoturbidimetric assay	1
4.	Hyperimmuneseum production	1
5.	Haemagglutination test	1
6.	Haemagglutination inhibition assay	1
7.	Immunoprecipitation test	1
8.	Complement fixation test	1
9.	ELISA methodology	1
10.	ELISA diagnostic test	1
11.	RIA methodology	1
12.	RIA diagnostic test	1
13.	Antibody-dependent cell-mediated cytotoxicity methodology	1
14.	Immunofluorescence- Immunohistochemistry	1
15.	Western blotting methodology	1
	Total	**15**

I. Course Title : Physiology of Stress

II. Course Code : VPY 711

III. Credit Hours : 2+0

IV. Aim of the course

To understand impact of various stress factors on the physiology of animals.

V. Theory

Unit I

Definition of stress, Various types of stresses, Their effect on animal production and reproduction.

Unit II

Physico-chemical changes of blood composition due to exercise and work. Energy utilization and requirement of muscles during work and exercise.

Unit III

Capacity of work under field and controlled laboratory conditions, Factors that regulate it.

Unit IV

Effect of various stresses on endocrine status of animals, Endurances in animals.

Unit V

Energy partitioning in lactating animals under stress, Physiological basis of ameliorative measures to combat stress in lactating animals.

S. No.	Topic	No. of Lectures
Theory		
1.	Definition of Stress, distress and eustress - Concept of Stressors – types of stressors – Acute and chronic stress - Broad measures of stress in animals – Behavioral, Physiological and molecular measures of stress	1
2.	Neuroendocrinology of stress response - sympathetic-adrenal-medullary (SAM) pathway - the hypothalamic-pituitary-adrenal (HPA) axis	1
3.	Effect of stress on musculoskeletal system – Exercise and Draft associated stress - Physiological assessment and indices for evaluating work load – concept of acceptable work load.	1
4.	Effects of stress on reproduction (including birds) – pregnancy, prenatal growth, lactation and Egg production	1
5.	Effect of stress on lactation - Energy partitioning in lactating animals under stress - Physiological basis of strategies to combat stress in lactating animals	1
6.	Effect of stress on immune system – altered cellular responses and cytokine production patterns and their consequences	1
7.	Effect of Stress on learning and memory – Areas of brain associated with stress induced alterations in learning and memory	1
8.	Environmental characteristics affecting animals – Role of Temperature, Humidity, wind, Rainfall and solar radiation on animals	1
9.	Concept of Homeothermy and Thermal stress in animals – Thermoneutral and Thermocomfort Zone – Upper and lower critical temperatures	1
10.	Thermal exchanges between animal and environment – Conduction, Convection, Radiation and Evaporation	1
11.	Physical and biological measures of thermal stress – Temperature Humidity Index (THI), The Livestock Weather Safety Index (LWSI), A wind chill index (WCI), Comprehensive climate index (CCI), Tunica Dartos Index (TDI), Infra-red thermography (IRT) based measures	1
12.	Effect of other environmental stressors like Solar UV radiation, high altitude, pollution related stressors	1
13.	Concept of Adaptation, Acclimatization, Acclimation - Types and levels of Adaptation	1
14.	Morphological, Anatomical Adaptation of Animals and Birds to various kinds of environments – Theories associated with such adaptations	1
15.	Physiological adaptations to heat stress – circulatory, respiratory, endocrine adjustments – Panting and Sweating in animals –	1
16.	Physiological adaptations to cold stress – circulatory, respiratory, endocrine adjustments – Thermogenesis in cold – Tissues associated with thermogenesis	1
17.	Cellular and Molecular adaptations to thermal stress – Heat shock response – Chaperones and their role in thermotolerance	1
18.	Behavioral adaptations to thermal stress in Animals and Birds – Individual and Group adaptation behaviors	1
19.	Special adaptations to Extreme environments like Deserts, polar regions – Estivation, hibernation and torpor	1
20.	Physiology of thermal reception and processing – Central and peripheral thermo receptors – Fever, Hyperthermia and Hypothermia	1
21.	Overview of all thermal adaptation features in Farm animals including camel and donkeys, Yak	1
22.	Special thermal adaptation features in birds – Thermal adaptation during flight	1

S. No.	Topic	No. of Lectures
23.	Measures of thermotolerance in animals – Rhoads, Gaala's, Benezra's, Iberian heat tolerance indices and cooling efficiency test of Dowling	1
24.	Adaptation of animals to High Altitude Stress – Pulmonary circulation changes adjustments in blood–O_2 affinity with change in altitude	1
25.	Concept of Global warming and climate change – Approaches to alleviate the adverse effects of climate change induced heat stress.	1
26.	Concept of redox biology, oxidative eustress and oxidative distress– History of oxidative stress concept	1
27.	Kinds and forms of Oxidative stress – Classification of oxidative stress (Basal, low intensity, intermediate intensity and high intensity)	1
28.	Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) – Different types of ROS and RNS– Sources of ROS and RNS generation – Oxidative and Nitrosative damage	1
29.	Concept of Redox signaling – Role of redox signaling in physiological and pathological processes	1
30.	Measuring Reactive Oxygen Species – Direct and indirect assays measuring ROS including chemiluminescence and electron spin resonance	1
31.	Antioxidant defense and their mechanism of cytoprotective actions – Enzymatic and non-enzymatic antioxidants in the body	1
32.	Dietary antioxidants in livestock and poultry production including synthetic and herbal antioxidants	1
	Total	**32**

I. Course Title : Advances in Reproductive Physiology

II. Course Code : VPY 712

III. Credit Hours : 2+1

IV. Aim of the course

To understand recent developments in physiology of reproduction in domestic animals.

V. Theory

Unit I

Estrus synchronization, Superovulation and Embryo transfer in farm animals.

Unit II

Seminal plasma proteins; Sexing of spermatozoa; Cryopreservation of semen.

Unit III

Collection and grading of oocytes; IVM, IVF and IVC; Cryopreservation of embryos; sexing of embryos; Micromanipulation of gametes and embryos.

Unit IV

Transgenic animals; applications of stem cells and nano technology in reproduction.

S. No.	Topic	No. of Lectures/ Practicals
Theory		
1.	Estrus synchronization in farm animals (Cattle, Buffalo, Sheep and Goat)	3
2.	Superovulation and Embryo transfer in farm animals(Cattle, Buffalo, Sheep and Goat)	3

S. No.	Topic	No. of Lectures/ Practicals
3.	Collection of Semen in farm animals	1
4.	Seminal plasma proteins and their importance in determining male fertility	2
5.	Sexing of spermatozoa	1
6.	Cryopreservation of semen in farm animals	1
7.	Collection of oocytes from live animals and slaughter house specimens	1
8.	Grading of oocytes	1
9.	*In-vitro* maturation of oocytes	2
10.	*In-vitro* fertilization of oocytes	2
11.	*In-vitro* culture of embryos	1
12.	Cryopreservation of embryos in farm animals	2
13.	Sexing of embryos	2
14.	Micromanipulation of gametes and embryos (Intracytoplasmic sperm injection and somatic cell nuclear transfer) and their applications	3
15.	Transgenic animal production and its importance	2
16.	Stem cell production and its clinical applications	3
17.	Nanotechnology and its use in farm animal breeding and reproduction	2
	Total	**32**
Practical		
1.	Semen analysis – Fructolytic index, zona free ovum test, Acrosomal integrity test	2
2.	Synchronization and superovulation protocols.	1
3.	Ovum pick up from superovulated animals	1
4.	Collection of oocytes from slaughter house derived ovaries, grading and evaluation	1
5.	Capacitation of spermatozoa	1
6.	*In-vitro* fertilization, *In-vitro* embryo production	1
7.	Collection of embryos using non-surgical procedures, Transferring embryos using non- surgical procedures.	2
8.	Oocyte/ Embryo/ ovarian/ testicular tissue freezing protocols.	1
9.	Demonstration on Intracytoplasmic sperm injection	1
10.	Micromanipulation of early embryos.	2
11.	Isolation and identification of embryonic stem cells	3
	Total	**16**

Note: The course teachers shall conduct the above practicals by utilizing facilities from semen/ IVF lab in the university/ college, if not available in the department.

List of Journals

- *Acta Endocrinologica*
- *Advances in Clinical Chemistry*
- *Advances in Reproductive Physiology*
- *Advances in Veterinary Sciences*
- *American Journal of Clinical Nutrition*
- *American Journal of Physiology*
- *American Journal of Veterinary Research*
- *Animal Nutrition and Feed Technology*
- *Animal Reproduction Science*
- *Animal Sciences*
- *Annual Review of Physiology*
- *Buffalo Journal*

- *Domestic Animal Endocrinology*
- *Indian Journal of Animal Reproduction*
- *Indian Journal of Animal Nutrition*
- *Indian Journal of Animal Physiology*
- *Indian Journal of Animal Research*
- *Indian Journal of Animal Science*
- *Indian Veterinary Journal*
- *Journal of Endocrinology*
- *Journal of Physiology*
- *Journal of Reproduction and Fertility*
- *Neuroendocrinology*

e-Resources

- http://intl-joe, endocrinology-journals.org (Journal of Endocrinology)
- http://intl-ajpcon.physiology.org (American Journal of Physiology)
- http://arjournals.annualreviewes.org (Annual Review of Physiology)
- www.jneurosci.org (Journal of Neuroscience)
- www3.interscience.wiley.com (Journal of Physiology and Animal Nutrition)
- http://jp.physioc.org. (Journal of Physiology)

I. Course Title : Research and Publication Ethics

II. Course Code : RPE 700

III. Credit Hours : 1+1

IV. Overview

This course has total 6 units focusing on basics of philosophy of science and ethics, Research integrity, Publication ethics. Hands-on-sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, Research metrics (citations, h-index, Impact Factor, etc.) and plagiarism tools will be introduced in this course.

V. Pedagogy

- Class room teaching, Guest lectures, Group discussions and practical sessions.

VI. Evaluation

- Continuous assessment will be done through tutorials, assignments, quizzes, and group discussions. Weightage will be given for active participation. Final written examination will be conducted at the end of the course.

VII. Course Structure

- The course comprises of six modules listed in table below. Each module has 4-5 units.

VIII. Theory

RPE 01: Philosophy and Ethics

- Introduction to philosophy: definition, nature and scope, concept, branches
- Ethics: definition, moral philosophy, nature of moral judgements and reactions

RPE 02: Scientific Conduct

- Ethics with respect to science and research
- Intellectual honesty and research integrity
- Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
- Redundant publications: duplicate and overlapping publications, salami slicing
- Selective reporting and misrepresentation of data

RPE 03: Publication Ethics

- Publication ethics: definition, introduction and importance
- Best practices/ standards setting initiatives and guidelines: COPE, WAME, etc.
- Conflicts of interest
- Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
- Violation of publication ethics, authorship and contributorship
- Identification of publication misconduct, complaints and appeals
- Predatory publishers and journals

IX. Practice

RPE 4: Open Access Publishing

- Open access publications and initiatives
- SHERPA/ RoMEO online resource to check publisher copyright and self-archiving policies
- Software tool to identify predatory publications developed by SPPU
- Journal finder/ journal suggestion tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggested, etc.

RPE 05: Publication Misconduct

A. Group Discussions

- Subject specific ethical issues, FFP, authorship
- Conflicts of interest
- Complaints and appeals: examples and fraud from India and abroad

B. Software tools

- Use of plagiarism software like Tumitin, Urkund and other open source software tools

RPE 06: Databases And Research Metrics

A. Databases

- Indexing databases
- Citation databases: Web of Science, Scopus, etc.

B. Research Metrics

- Impact Factor of journal as per Journal Citation Report, SNIP, SIR, IPP, Cite Score
- Metrics: h-index, g index, i10 index, altmetrics

Common Courses

I. Course Title : Technical Writing and Communications Skills
II. Course Code : PGS 601
III. Credit Hours : 0+1
IV. Aim of the course

- To equip the students/ scholars with skills to write dissertations, research papers, etc.
- To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

V. Theory

Scientific Writing - Various forms of scientific writings- theses, technical papers, reviews, manuals, etc; Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion); Writing of abstracts, summaries, précis, citations, etc.; commonly used abbreviations in the theses and research communications; illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations; Writing of numbers and dates in scientific write-ups; Editing and proof-reading; Writing of a review article. Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks); Error analysis (Common errors); Concord; Collocation; Phonetic symbols and transcription; Accentual pattern: Weak forms in connected speech: Participation in group discussion: Facing an interview; presentation of scientific papers. Plagiarism – importance in scientific writing.

VI. Practicals

- Exercises on Various forms of scientific writings - theses, technical papers, reviews, manuals
- Writing of abstracts, summaries, précis, citations
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion)
- Editing and proof-reading
- Writing of a review article
- Communication Skills
- Exercises on plagiarism

VII. Suggested Reading

- Abhishek Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
- Chicago Manual of Style. 14th Ed. 1996. Prentice Hall of India.
- Collins' Cobuild English Dictionary. 1995. Harper Collins.
- Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed. Holt, Rinehart and Winston.
- Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed.

Oxford University Press.
- James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
- Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
- Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
- Richard WS. 1969. *Technical Writing*. Barnes and Noble.
- Robert C. (Ed.). 2005. *Spoken English*: Flourish Your Language.
- Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand and Co.

I. Course Title : Agricultural Research, Research Ethics and Rural Development Programmes

II. Course Code : PGS 602

III. Credit Hours : 1+0

IV. Aim of the course

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

V. Theory

Unit I

History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), Partnership with NARS, Role as a partner in the global agricultural research system, Strengthening capacities at national and regional levels; International fellowships for scientific mobility.

Unit II

Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

Unit III

Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

VI. Suggested Reading

- Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
- Punia MS. *Manual on International Research and Research Ethics*. CCS, Haryana Agricultural University, Hisar.
- Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
- Singh K. 1998. *Rural Development - Principles Policies and Management*. Sage Publ.

I. Course Title : Basic Concepts in Laboratory Techniques

II. Course Code : PGS 603

III. Credit Hours : 0+1

IV. Aim of the course

To acquaint the students about the basics of commonly used techniques in laboratory.

V. Practical

Safety measures while in Lab; Handling of chemical substances; Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets; washing, drying and sterilization of glassware; Drying of solvents/ chemicals. Weighing and preparation of solutions of different strengths and their dilution; Handling techniques of solutions; Preparation of different agro-chemical doses in field and pot applications; Preparation of solutions of acids; Neutralisation of acid and bases; Preparation of buffers of different strengths and pH values. Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath; Electric wiring and earthing. Preparation of media and methods of sterilization; Seed viability testing, testing of pollen viability; Tissue culture of crop plants; Description of flowering plants in botanical terms in relation to taxonomy.

VI. Suggested Reading

- Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.
- Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

I. Course Title : Intellectual Property and its Management in Agriculture

II. Course Code : PGS 604

III. Credit Hours : 1+0

IV. Aim of the course

The main objective of this course is to equip students and stakeholders with knowledge of intellectual property rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

V. Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, Geographical indications, Designs and layout, Trade secrets and Traditional knowledge, Trademarks, protection of plant varieties and farmers' rights and bio- diversity protection; Protectable subject matters, Protection in biotechnology, protection of other biological materials, ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

VI. Suggested Reading

- Erbisch FH and Maredia K. 1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
- Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
- *Intellectual Property Rights: Key to New Wealth Generation. 2001*. NRDC and Aesthetic Technologies.
- Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. *Technology Generation and IPR Issues*. Academic Foundation.
- Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
- Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.
- The Indian Acts - *Patents Act, 1970 and amendments; Design Act*, 2000; Trademarks Act, 1999; *The Copyright Act, 1957 and amendments;* Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; *National Biological Diversity Act*, 2003.

I. Course Title : Library and Information Services
II. Course Code : PGS 605
III. Credit Hours : 0+1

IV. Aim of the course

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

V. Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

ANNEXURE I

List of BSMA Committee Members for Basic Veterinary Sciences

(Veterinary Anatomy, Veterinary Biochemistry, Veterinary Biotechnology, Veterinary Extension Education, Veterinary Physiology)

(Constituted by ICAR vide Office order No. F. No. Edn 7/6/2017- EQR dated 4-4-2018)

Name	Address	Specialization.
Dr T.S. Chandrasekhara Rao Chairman	Dean, Faculty of Veterinary Science Sri Venkateswara Veterinary University Tirupati	Veterinary Anatomy
Dr Nirmal Sangwan Member	Director, Human Resource Development LUVAS, Hisar	Veterinary Biochemistry
Dr Taru Sharma Member	Principal Scientist and Head-cum-Director Centre of Advanced Faculty Training in Veterinary Physiology, Division of Physiology and Climatology, ICAR-IVRI, Izatnagar	Veterinary Physiology
Dr Sachinandan De Member	Principal Scientist, Animal Biotechnology Centre, ICAR-NDRI, Karnal	Veterinary Biotechnology
Dr P. Selvaraj Member	Professor, Dept. of Veterinary Physiology Veterinary College and Research Institute, Namakkal	Veterinary Physiology
Dr M. Parthiban Member	Professor and Head, Dept. of Animal Biotechnology Madras Veterinary College, Chennai	Veterinary Biotechnology
Dr Naresh Kumar Member	Professor, Dept. of Vety. Physiology and Biochemistry, Khalsa College of Veterinary and Animal Sciences, Amritsar	Veterinary Biochemistry

Name	Address	Specialization.
Dr S.C. Dubal Member	Professor of Anatomy College of Veterinary Science, Anand	Veterinary Anatomy
Dr D. Thammi Raju Member	Principal Scientist, ICAR, NAARM, Hyderabad	Veterinary Extension
Dr B.P. Singh Convener	Principal Scientist, Division of Veterinary Extension. ICAR-IVRI, Izatnagar	Veterinary Extension

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 3

Veterinary Clinical Subjects

- Animal Reproduction Gynaecology and Obstetrics
- Veterinary Surgery and Radiology
- Veterinary Medicine

Contents

Acknowledgements

Veterinary Clinical Subjects are considered as 'Mirror' of Veterinary College. Presently, worldover the ecosystem of Veterinary Clinical Subjects is being dominated by technology driven management and treatment of different clinical entities. Under each discipline of clinical subjects, i.e. Medicine, Surgery and Gynaecology, there is need to introduce specialised courses. This will allow each discipline to grow and render treatment of animals with improved protocols at field level. Further, the spectrum of treatment by private practitioners has widened. All this increases responsibility of University Teaching Hospitals to evolve affordable and state-of-the-art treatment protocols with continuous veterinary education programmes.

Amidst limitations and as per the guidelines of ICAR, restructuring of PG Syllabi in Veterinary Clinical Subjects is undertaken, after deliberations held during the meetings and workshops. The contribution of all Stakeholders including Heads of Department of Veterinary Clinical Subjects is duly acknowledged. BSMA Committee Members for Veterinary Clinical Subjects joins us in conveying special thanks to Hon'ble Vice Chancellors of Kamdhenu University, RAJUVAS and MAFSU for permission to organise meetings/ workshops. The cooperation rendered by Deans of Veterinary Colleges at CVAS, Udaipur, BVC, Mumbai and their team is appreciable. Dr G.S. Khandekar from BVC, Mumbai deserves special mention for his efforts.

A scope for refinement exists, which can be undertaken at University level, within the prescribed guidelines of ICAR.

Happy teaching of Clinical Subjects !

Dr D. B. Patil
Convener
Dr Jit Singh
Chairman
ICAR-BSMA Committee for
Veterinary Clinical Subjects

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Clinical Subjects
– Animal Reproduction Gynaecology and Obstetrics

Preamble
(Animal Reproduction, Gynaecology and Obstetrics)

At Masters' level, BSMA committee members thoroughly examined the existing course contents and deleted those portions which were of repetitive nature and non-pertinent. Also, the titles of many existing courses have suitably been modified. Some of the new chapters, both in theory as well as practical courses, viz., Role of pineal gland, endogenous opioids and neuropeptides in reproduction, Negative energy balance w.r.t. infertility, its prevention and amelioration, White side test, Endometrial cytology, Transition cow, Onset of postpartum ovarian activity, Caesarean section, Anaesthesia for caesarean section, Ovariohysterectomy, Seminiferous epithelial cycle, Spermatogonial wave, Mechanism of sperm motility, Influence of seminal plasma proteins in modulating fertility, Heat stress and it's effect on sperm production, Screening of the breeding bulls to be selected for semen collection, Biosecurity measures in semen production and controlling microbial load, Quality assurance for quality semen production, Instrumentation in semen laboratory, MSP for semen production, Sexed semen production, sexing of embryos, *in-vitro* culture of granulosa cells, cumulus cells, luteal cells and oviductal cells, Recovery of bovine oocytes from abattoir ovaries and live animals, Principles and application of PCR technique in animal reproduction, etc., were suitably added in the different chapters of existing courses. Eight new courses, viz., Canine and feline reproduction, Caprine and ovine reproduction, Equine reproduction, Camel reproduction, Elephant reproduction, Wild and zoo animal reproduction, Porcine reproduction and Ultrasonography in animal reproduction has been introduced at masters level. These new courses will be helpful in introducing new insights to the students. This will increase the wide coverage of area specific courses essentially required with respect to regional prospective of the country. These new courses will also be helpful in enhancing the competency of students in a global prospective.

At doctoral level, different existing courses were examined thoroughly and chapters of repetitive nature were deleted from the course contents. Also, the titles of four existing courses have suitably been modified. Some of the new chapters, viz., Assessment of neonatal viability, Care of the newborn, Care of the postpartum dam, Seminiferous eipithelial cycle, Theory of sperm motility and ultrastructure of sperm. Sperm passage in female reproductive tract; capacitation and acrosome reaction, Karyotyping to identify sperm defect and DNA mapping for parentage, Collection of preputial washings and semen for bacterial load and venereal pathogens, Cryopreservation of embryos, Intracytoplasmic sperm injection (ICSI), Gene expression in oocyte and embryo, identification of cellular organelles of Gamete, Semen sorting for production of sexed semen, Contribution of gonads and accessory sex glands to semen ejaculate. Factors affecting semen production. Morphology of sperm and their defects. Biochemical composition of semen, Metabolism of sperm. Role of seminal plasma proteins. Species variation in seminal characteristics, Commercial extenders used for bovine semen, Microbial contamination of semen and measures for its prevention, Quality control and quality assurance of semen, Antisperm antibodies, Flow cytometric assessment of sperm quality, Sperm vitrification, Freeze drying of sperm and sperm encapsulation, *in-vitro* tests for sperm function, i.e. BCMPT, HOST, etc., Physical and enzymatic changes in semen following cryopreservation, Tests to assess acrosomal integrity, mitochondrial activity, DNA damage, binding assays, etc. Fluorescent probe based assessment of sperm quality. Comet assay, Sperm chromatin structure assay, TUNEL assay, etc. were added in different units of revised courses of both in theory and practical portions. The revised courses will be helpful in introducing new insights and improve competency in the students in a global context.

Course Title with Credit Load
M.V.Sc. in Animal Reproduction Gynaecology and Obstetrics

Course Code	Course Title	Credit Hours
VGO 501	General Gynaecology*	2+1
VGO 502	Female Infertility in Farm Animals*	2+1
VGO 503	Veterinary Obstetrics*	2+1
VGO 504	Andrology and Male Infertility*	2+1
VGO 505	Semen Preservation and Artificial Insemination	2+1
VGO 506	Basics of Reproductive Biotechnology*	2+1
VGO 507	Clinical Practice-I*	0+3
VGO 508	Clinical Practice-II*	0+3
VGO 509	Canine and Feline Reproduction	2+1
VGO 510	Caprine and Ovine Reproduction	2+1
VGO 511	Equine Reproduction	2+1
VGO 512	Camel Reproduction	2+1
VGO 513	Elephant Reproduction	2+1
VGO 514	Wild and Zoo Animal Reproduction	2+1
VGO 515	Porcine Reproduction	2+1
VGO 516	Ultrasonography In Animal Reproduction	1+2
VGO 590	Special Problem	0+1
VGO 591	Master’s Seminar	1+0
VGO 599	Master’s Research	30

*Core Courses

Course Contents
M.V.Sc. in Animal Reproduction Gynaecology and Obstetrics

I. Course Title : General Gynaecology

II. Course Code : VGO 501

III. Credit Hours : 2+1

IV. Aim of the course

To understand the basics of physiology of female reproduction and it's hormonal regulation/ manipulation/ control.

V. Theory

Unit I

Functional anatomy, puberty and sexual maturity, Role of hypothalamic-pituitary-gonadal axis in attainment of puberty and sexual maturity, Endocrine regulation of estrous cycle. Role of pineal gland, endogenous opioids and neuropeptides in reproduction.

Unit II

Folliculogenesis, Oogenesis and ovulation and associated endocrine pattern, manipulation of follicular waves, Synchronization of estrus and ovulation and induction of ovarian activity.

Unit III

Gamete transport, Fertilization, Implantation and maternal recognition of pregnancy.

Unit IV

Embryonic and fetal development, Placentation, Fetal circulation and gestation, position of fetus in the uterus, age characteristics of fetus.

Unit V

Pregnancy diagnosis: Clinical, Ultrasonographic, Endocrinological and other diagnostic laboratory tests.

Unit VI

Lactation and artificial induction of lactation.

VI. Practical

Clinical examination of female genitalia. Biometry of female genital organs. Rectal and vaginal examination to diagnose cyclic phases of estrous cycle. Fern pattern of cervical mucus and exfoliated vaginal cytology. Pregnancy diagnosis in large and small animals by various methods. Estimation of age of the fetus. Use of ultrasound/ RIA/ ELISA in gynaecology. Synchronization of estrus and ovulation in farm animals.

VII. Suggested Reading

- Perry T Cupps. 2009. *Reproduction in Domestic Animals*. Academic Press.
- Hafez ESE and B Hafez. 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.
- Mauricio Pineda and Michael P Dooley. 2008. *McDonald's Veterinary Endocrinology* and Wiley-Blackwell.

- David Noakes, Timothy Parkinson and Gary England 2018. *Veterinary Reproduction and Obstetrics*. Saunders Ltd.
- Roberts SJ. 2005. *Veterinary Obstetrics and Genital Diseases*. Scientific Book Agency.

I. Course Title : Female Infertility in Farm Animals

II. Course Code : VGO 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training in diagnosis and treatment of infertility in female domestic animals.

V. Theory

Unit I

Introduction to infertility, classification, economic impact. Anatomical causes of infertility, congenital and hereditary causes and acquired defects.

Unit II

Nutritional causes of infertility. Importance of body condition score. Negative energy balance, its prevention and amelioration.

Unit III

Managemental and environmental causes of infertility. Out of season breeding.

Unit IV

Infectious causes of female infertility, Specific and non-specific infections; It's diagnosis, treatment, prevention and control.

Unit V

Ovarian dysfunction; Anoestrus, Cystic ovarian degeneration, Anovulation, Delayed ovulation and luteal insufficiency; causes, diagnosis and treatment.

Unit VI

Repeat breeding; its causes, diagnosis and treatment.

Unit VII

Early embryonic death (EED); it's causes, Diagnosis and therapeutic management.

Unit VIII

Abortion; causes, diagnosis and prevention of abortion.

Unit IX

Interactions in immunological mechanisms and infertility.

VI. Practical

Record keeping, herd fertility assessment and management, diagnosis and treatment of infertility in female animals, use of uterine swabs for bacterial and fungal culture, histo-pathological evaluation of uterine biopsy, white side test, endometrial cytology and hormone assay. Use of ultrasonography in diagnosis of infertility. Immuno- diagnostic techniques.

VII. Suggested Reading

- Laing JA. 1979. *Fertility and Infertility in Domestic Animals*. English Language Book Soc. and Bailliere Tindall.

- Morrow DA. 1986. *Current Therapy in Theriogenology*. WB Saunders.
- David Noakes. Timothy Parkinson and Gary England 2018. *Veterinary Reproduction and Obstetrics*. Saunders Ltd.
- Roberts SJ. 2005. *Veterinary Obstetrics and Genital Diseases*. Scientific Book Agency.

I. Course Title : Veterinary Obstetrics

II. Course Code : VGO 503

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training on problems of pregnancy and parturition and their management in domestic animals.

V. Theory

Unit I

Parturition; stages of parturition, Mechanism of initiation of parturition, Hormonal profiles associated with parturition, Transition cow, Onset of postpartum ovarian activity.

Unit II

Principles of handling of dystocia, Obstetrical procedures: Mutations, Fetotomy, caesarean section. Obstetrical anaesthesia and analgesia, epidural anesthesia.

Unit III

Fetal and maternal dystocia; causes, diagnosis and management.

Unit IV

Uterine torsion; causes, diagnosis and its correction. Caesarean section, anaesthesia for caesarean section, ovariohysterectomy.

Unit V

Diseases and accidents during gestation and around parturition.

Unit VI

Etiology, diagnosis and treatment of ante-partum and post-partum uterine and vaginal prolapse.

Unit VII

Induction of parturition and elective termination of pregnancy.

Unit VIII

Involution of uterus following normal and abnormal parturition.

Unit IX

Care of dam and the newborn.

VI. Practical

Pelvimetry of different species of farm animals. Diagnosis and correction of abnormal fetal presentation, position and posture in phantom box. Epidural anesthesia, episiotomy, ovariohysterectomy and caesarean operation. Management of incomplete cervical dilation. Fetotomy operations. Detorsion of uterus. Management of cervico-vaginal and uterine prolapse. Handling of clinical cases of dystocia.

VII. Suggested Reading

- David Noakes, Timothy Parkinson and Gary England 2018. *Veterinary Reproduction and Obstetrics*. Saunders Ltd.
- Roberts SJ. 2005. *Veterinary Obstetrics and Genital Diseases*. Scientific Book Agency.
- Sloss V and Dufty JH. 1980. *Handbook of Bovine Obstetrics*. Williams and Wilkins.

I. Course Title : Andrology and Male Infertility

II. Course Code : VGO 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training about male reproduction and treatment of male infertility in domestic animals.

V. Theory

Unit I

Structure and function of reproductive tract of male.

Unit II

Sexual behavior and examination of bulls for breeding soundness.

Unit III

Spermatogenesis, Seminiferous epithelial cycle, Spermatogonial wave, Structure of spermatozoa, Semen and its composition. Mechanism of sperm motility.

Unit IV

Diseases transmitted through semen. Factors affecting semen quality, semen culture, tests for assessment of sperm motility, sperm survival and fertilizing capacity of spermatozoa.

Unit V

Causes of infertility; hereditary, congenital, infectious, nutritional and hormonal. Pathological and functional disturbances of epididymis, vas deferens and accessory sex glands.

Unit VI

Impotentia coeundi and impotentia generandi. Testicular hypoplasia and degeneration; causes and affect on semen and fertility. Coital injuries and vices of male animals.

Unit VII

Influence of seminal plasma proteins in modulating fertility. Heat stress and it's effect on sperm production.

Unit VIII

Screening of the breeding bulls to be selected for semen collection.

VI. Practical

General and rectal examination for biometrics of male genitalia and accessory sex glands. Breeding soundness evaluation of male animals. Semen evaluation for sperm abnormalities, fertility and determination of other biochemical constituents of seminal plasma, Microbiological load of semen. Examination, diagnosis and treatment of infertile male animals.

VII. Suggested Reading

- Hafez ESE and B Hafez. 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.
- Mann T and Lutwak-Mann C. 1981. *Male Reproductive Function and Semen*. Springer-Verlag.
- Morrow DA. 1986. *Current Therapy in Theriogenology*. WB Saunders.
- Roberts SJ. 2005. *Veterinary Obstetrics and Genital Diseases*. Scientific Book Agency.
- Salisbury GW, VanDemark NL and Lodge JR. 1978. *Physiology of Reproduction and Artificial Insemination of Cattle*. WH Freeman and Co.

I. Course Title : Semen Preservation and Artificial Insemination

II. Course Code : VGO 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training about collection, evaluation and preservation of semen and artificial insemination in domestic animals.

V. Theory

Unit I

History of artificial insemination. Methods of semen collection.

Unit II

Semen evaluation; macroscopic, microscopic, biochemical and microbiological tests.

Unit III

Semen preservation. Extenders for preservation of semen at different temperatures. Semen additives for enhancement of motility and fertilizing capacity of spermatozoa. Dilution of semen.

Unit IV

Cryopreservation of semen. Effect of cryopreservation on spermatozoa, semen quality and fertility. Liquid Nitrogen (LN2) cylinders; it's handling, care and maintenance.

Unit V

Thawing protocols of frozen semen. Factors affecting post-thaw semen quality.

Unit VI

Ideal protocol for AI in different species of animals. Factors affecting success of AI.

Unit VII

Biosecurity and biosafety guidelines for frozen semen stations, semen processing laboratories and quarantine stations. Minimum standards and standard operating procedures for artificial insemination, Quality testing of straws and sheath for use in artificial insemination.

VI. Practical

Instrumentation in semen laboratory, Minimum standards of protocols and Standard operating procedures for semen production, Computer assisted semen analysis (CASA), Collection and evaluation of semen. Preparation of extenders. Preservation of semen; room temperature, refrigeration and cryopreservation. Handling and evaluation of processed semen. Practice of AI techniques.

VII. Suggested Reading

- Hafez ESE and B Hafez 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.
- Enos Johnson Perry 2013. *Artificial Insemination of Farm Animals*. Jodhpur: Axis Books (India).
- Salisbury GW, VanDemark NL and Lodge JR. 1978. *Physiology of Reproduction and Artificial Insemination of Cattle*. WH Freeman and Co.

I. Course Title : Basics of Reproductive Biotechnology

II. Course Code : VGO 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training on biotechniques in animal reproduction.

V. Theory

Unit I

Embryo transfer technology: selection of donors and recipients.

Unit II

Synchronization, super-ovulation, surgical and non-surgical collection of embryos and evaluation of embryos.

Unit III

Cryopreservation of embryos, transfer of embryos to donors. Sexed semen production, sexing of embryos. Guidelines for export and import of bovine germplasm. Guidelines and standards regarding embryo production.

Unit IV

In-vitro culture of granulosa cells, cumulus cells, luteal cells and oviductal cells. Recovery of bovine oocytes; from abattoir ovaries and live animals, *in-vitro* fertilization, *in-vitro* maturation, micromanipulation of embryos.

Unit V

Immuno-neutralization of hormones. Immunomodulation of fertility.

VI. Practical

Synchronization of estrus in donors and recipients, superovulation, surgical and non-surgical collection and transfer of embryos. Collection of oocytes from slaughter house genitalia. *In-vitro* fertilization, *in-vitro* maturation and cryopreservation of embryos. Sexing of embryos.

VII. Suggested Reading

- Ian Gordon. 2017. *Reproductive Technologies in Farm Animals*. Wallingford, Oxfordshire CABI.
- Hafez ESE and B Hafez. 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.
- B Singh, SK Gautam and MS Chauhan. 2012. *Textbook of Animal Biotechnology*, Pearson Education.
- Heiner Niemann, Christine Wrenzycki. 2018. *Animal Biotechnology 1: Reproductive Biotechnologies*. Springer.
- Heiner Niemann, Christine Wrenzycki. 2018. *Animal Biotechnology 2*. Springer International Publishing AG.
- Troy L Ott, Zhihua Jiang. 2010. *Reproductive Genomics in Domestic Animals*. John Wiley.

- Marcelo Marcondes Seneda, Katia Cristina Silva-Santos LS Rafagnin Marinho. 2016. *Biotechnology of Animal Reproduction*, Nova Science Pub. Inc; UK Ed.
- Tacia Gomes Bergstein-Galan. 2018. *Reproduction Biotechnology in farm animals*. Avid Science.

I. Course Title : Clinical Practice-I

II. Course Code : VGO 507

III. Credit Hours : 0+3

IV. Aim of the course

Hands-on training on diagnosis and treatment of reproductive disorders in animals at VCC.

V. Practical

Clinical examination of animals affected with reproductive disorders, Use of diagnostic techniques for diagnosis and institution of required therapy. Acquaintance with different equipment used for handling reproductive disorders, Client management, Public relations, Code of conduct, Database management, Maintenance of case records.

VI. Suggested Reading

- Morrow DA. 1986. *Current Therapy in Theriogenology*. WB Saunders.
- Zemjanis R 1970. *Diagnostic and Therapeutic Techniques in Animal Reproduction*. Williams and Wilkins; Second Edition.

I. Course Title : Clinical Practice-II

II. Course Code : VGO 508

III. Credit Hours : 0+3

IV. Aim of the course

Hands-on training on diagnosis and treatment of reproductive disorders in animals at VCC.

V. Practical

Clinical examination of animals affected with reproductive disorders, use of diagnostic techniques for diagnosis and institution of required therapy. Acquaintance with different equipment used for handling reproductive disorders, Client management, Public relations, Code of conduct, Database management, Maintenance of case records.

VI. Suggested Reading

- Morrow DA. 1986. *Current Therapy in Theriogenology*. WB Saunders.
- Zemjanis R. 1970. *Diagnostic and Therapeutic Techniques in Animal Reproduction*. Williams and Wilkins; Second Edition.

I. Course Title : Canine and Feline Reproduction

II. Course Code : VGO 509

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training about reproduction in canine and feline.

V. Theory

Unit I

Development of reproductive system. Anatomy of male and female reproductive system. Canine and feline estrous cycle, endocrinology of estrous cycle.

Unit II

Breeding management, pregnancy, pregnancy diagnosis; clinical, ultrasonographic, endocrinological and other diagnostic laboratory tests.

Unit III

Parturition, fetal and maternal dystocia; causes, diagnosis and management. Induction of parturition and caesarean section, periparturient disorders.

Unit IV

Medical termination of pregnancy in dogs and cats, management of psudopregnancy, pyometra and it's management. Infertility and it's management in dogs and cats.

Unit V

Postpartum care of dam and lactation. Neonatal care.

Unit VI

Population control in dogs; surgical and non surgical methods.

Unit VII

Reproductive physiology of male dogs, semen collection techniques, semen evaluation, freezing of semen, artificial insemination techniques, male reproductive disorders and it's management.

VI. Practical

Exfoliative vaginal cytology, determination of ovulation time, demonstration of semen collection and artificial insemination, predicting time of parturition using hormonal assay, management of dystocia using clinical cases, castration, ovariohystrectomy, caesarean section, surgical procedure related to reproductive disorders in both male and female dogs and cats.

VII. Suggested Reading

- Edward C Feldman, Richard William Nelson. 2003. *Canine and Feline Endocrinology and Reproduction*. Elsevier Health Sciences, Saunders.
- Shirley Dianne Johnston, Margaret V Root Kustritz, Patricia Schultz Olson. 2001. *Canine and Feline Theriogenology*. Saunders Publ.
- Margaret V, Root Kustritz. 2009. *Clinical Canine and Feline Reproduction*: Evidence-Based Answers. John Wiley and Sons.
- Phyllis A. Holst MS. 2010. *Canine Reproduction: The Breeder's Guide 3rd Edition*. DOGWISE.
- Cheryl Lopate. 2012. *Management of Pregnant and Neonatal Dogs, Cats, and Exotic Pets*. John Wiley and Sons.
- Jovi R Otite. 2015. *Reproduction in the Dog a Tropical Approach*. Xlibris Corporation.

I. Course Title : Caprine and Ovine Reproduction

II. Course Code : VGO 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training about reproduction in sheep and goat.

V. Theory

Unit I

Caprine and ovine estrous cycle, endocrinology of estrous cycle, Seasonal breeding activity in sheep and goat, Artificial control of oestrus in sheep and goat.

Unit II

Breeding management, methods for advancing sheep breeding season, Induction of multiple births in sheep. Artificial insemination, pregnancy and parturition, Dystocia and it's management.

Unit III

Reproductive disorders and it's management.

Unit IV

Reproductive physiology of males, semen collection techniques, semen evaluation, freezing of semen, male reproductive disorders and it's management.

VI. Practical

Demonstration of semen collection and artificial insemination, management of dystocia using clinical cases, castration, ovariohystrectomy, caesarean section, surgical procedure related to reproductive disorders in both male and females.

VII. Suggested Reading

- Mauricio Pineda and Michael P Dooley. 2008. *McDonald's Veterinary Endocrinology and Reproduction*. Wiley-Blackwell.
- Lindsay DR and Pearce DT. 2011. *Reproduction in Sheep*, Cambridge University Press, Cambridge, London.
- Selected articles from journals.

I. Course Title : Equine Reproduction

II. Course Code : VGO 511

III. Credit Hours : 2+1

IV. Aim of the course

To encompass the fundamentals of equine reproductive anatomy and physiology. This will help in understanding the care and management of the breeding stallion and the broodmare.

V. Theory

Unit I

Anatomy and physiology of the mare and stallion.

Unit II

Manipulation of estrus in the mare, estrous cycle, broodmare management, Use of ultrasound in breeding management.

Unit III

Infertility and it's management.

Unit IV

Pregnancy diagnosis and management of the pregnant mare. Fetal development, abortion, induced parturition and dystocia.

Unit V

Neonatal management and common neonatal diseases, orphan foal management, foal management during the first six months.

Unit VII

Semen collection, semen preservation, artificial insemination and embryo transfer.

VI. Practical

Visit of equine/ stud farm, overall management of an equine breeding program, handling the cases of reproductive disorders, artificial insemination, semen collection, semen preservation, breeding record keeping and analysis.

VII. Suggested Reading

- Mauricio Pineda and Michael P Dooley. 2008. *McDonald's Veterinary Endocrinology and Reproduction*. Wiley-Blackwell.
- McKinnon, Squires, Vaala and verner. 2011. *Equine Reproduction* (2nd Ed). Wiley- Blackwell.
- Juan Samper, Jonathan Pyocock and Angus McKinnon. 2007. *Current Therapy in Equine Reproduction*. Saunders.
- Steven Brinsko Terry Blanchard Dickson Varner James Schumacher Charles Love. 2010. *Manual of Equine Reproduction* (3rd Ed). CV Mosby.
- John Dascanio and Patrick McCue. 2014. *Equine Reproductive procedures.* John Wiley and Sons, Inc.
- Selected articles from journals.

I. Course Title : Camel Reproduction
II. Course Code : VGO 512
III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training about reproduction in camels.

V. Theory

Unit I

Male reproductive organs, male reproductive physiology and sexual behavior, puberty and sexual maturity, seasonal changes, copulation, semen collection and it's characteristics.

Unit II

Female reproductive organs, female reproductive physiology and sexual behavior, oestrous cycle, external signs of oestrus, pregnancy and foetal development, pregnancy diagnosis and parturition.

Unit III

Age of sexual maturity, breeding season, conception rate, calving interval, reproductive longevity.

Unit IV

Early embryonic mortality, reproductive problems in the female, reproductive problems in the male.

Unit V

Artificial insemination, nutrition and reproduction, embryo transfer in camel.

VI. Practical

Management of dystocia in clinical cases, castration, ovariohystrectomy, caesarean section, surgical procedure related to reproductive disorders in both male and females.

VII. Suggested Reading

- H Merkt, D Rath, B Musa, MA El-Naggar. 1990. *Reproduction in Camels*. FAO.
- Muhammad Jamshed Khan. 2011. *Equine and Camel Production: An Approach towards Better Management*. LAP LAMBERT Academic Pub.
- Selected articles from journals.

I. Course Title : Elephant Reproduction

II. Course Code : VGO 513

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training about reproduction in elephant.

V. Theory

Unit I

General introduction, Elephas maximus, domestic and wild elephants.

Unit II

Male genital system, Accessory sex glands, Hormonal control and semenology.

Unit III

Female reproductive system, Ovaries, fallopian tubes, Uterus, vagina and external genitalia. Oestrous cycle, Hormonal regulation of estrous cycle, Mating behaviour and act of copulation.

Unit IV

Pregnancy, Gestation length and parturition. Neonatal care of elephant calves.

Unit V

Musth in elephants, behavioral patterns, pre-musth, violent- musth and post-musth phases, controlling elephants in musth using drugs/ hormones, anti androgens. Artificial insemination and cryopreservation of gametes.

VI. Practical

Management of dystocia in clinical cases, surgical procedure related to reproductive disorders in both male and females.

VII. Suggested Reading

- Brown JL, Paris S, Prado-Oviedo NA, Meehan CL, Hogan JN, Morfeld KA and Carlstead KA. 2016. *Reproductive Health Assessment of Female Elephants in North American Zoos and Association of Husbandry Practices with Reproductive Dysfunction in African Elephants* (Loxodonta africana). PLOS ONE | DOI:10.1371 journal pone 014573.
- Ortolani A, Leong K, Graham L, Savage A. 2005. *Behavioral indices of estrus in a group of captive African Elephants* (Loxodonta africana). Zoo Biol. 24:311-329.
- Rasmussen LE, Schmidt MJ, Henneous R, Groves D, Daves GD. Jr. 1982. *Asian bull elephants: flehmen-like responses to extractable components in female elephant estrous urine*. Science. 217: 159-162.
- Sukumar R. 2006. *A brief review of the status, distribution and bioilogy of wild Asian elephants Elephas maximus*. Int. Zoo Yb. 40: 1-8.
- Thitaram C. 2009. *Elephant reproduction: Improvement of breeding efficiency and development*

of a breeding strategy. Ph.D. Thesis, Utrecht University, The Netherlands
- Vidya TNC and Sukumar R. 2005. *Social and reproductive behaviour in elephants. Current sci*. **89**: 1200-1207.
- Selected articles from journals.

I. Course Title : Wild and Zoo Animal Reproduction
II. Course Code : VGO 514
III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and training about reproduction in Wild and zoo animals.

V. Theory

Unit I

Introduction to reproduction, Pattern of estrous cycle, Optimal breeding time with emphasis on tiger, deer, monkey and crocodile.

Unit II

Gestational length, parturition and pregnancy diagnosis.

Unit III

Sexual behavior and major reproductive disorders in wild and zoo animals, contraception techniques for deer.

VI. Practical

Management of dystocia in clinical cases, castration, observation of estrus behavior, pregnancy diagnosis, surgical procedure related to reproductive disorders in both male and females.

VII. Suggested Reading

- GR Smith, JP Hearn and Wellcome Trust (London, England). 1988. *Reproduction and disease in captive and wild animals*, New York: Oxford University Press.
- Ian Gordon. 1997. *Controlled reproduction in horses, deer and camelids*. CAB International.
- Mauricio Pineda and Michael P Dooley. 2008. *McDonald's Veterinary Endocrinology and Reproduction*. Wiley-Blackwell.
- Paul A Rees. 2011. *An Introduction to Zoo Biology and Management*. Wiley-Blackwell.
- R Eric Miller, Murray E Fowler. 2014. *Fowler's Zoo and Wild Animal Medicine*. Saunders.
- Selected articles from journals.

I. Course Title : Porcine Reproduction
II. Course Code : VGO 515
III. Credit Hours : 2+1

IV. Aim of the course

To acquire knowledge about the fundamentals of reproductive anatomy, physiology and advances in fertility management in swine.

V. Theory

Unit I

Anatomy and physiology of boar and sow.

Unit II

Oestrus cycle in sow, manipulation of oestrus cycle, methods for detection of oestrus, endocrinology of pregnancy and parturition.

Unit III

Infertility in sow and its management.

Unit IV

Pregnancy diagnosis and management of pregnant sow.

Unit V

Fetal development, abortion, induced parturition, dystocia, stages of parturition and mastitis-metritis complex in sow.

Unit VI

Neonatal management and common neonatal diseases, care of piglets.

Unit VII

Breeding boar selection and management, semen collection, semen preservation, natural service, artificial insemination, embryo transfer and IVF.

VI. Practical

Visit of swine farm, breeding management in sows, handling the cases of reproductive disorders, caesarean section, castration, sexual behaviour, vaginal cytology, pregnancy diagnosis, dystocia, semen collection, semen preservation, artificial insemination, embryo transfer and record keeping.

VII. Suggested Reading

- Colin T Whittemore, Ilias Kyriazakis. 2008. *Whittemore's Science and Practice of Pig Production*. John Wiley and Sons Press.
- *Control of Pig Reproduction*. Proceedings of the Eighth International Conference on Pig Reproduction, Alberta, Canada, June 2009 by Heriberto Rodríguez Martínez, Jeff L Vallet, Adam J Ziecik, Nottingham University Press. 2009.
- DJA Cole, GR Foxcroft, Butterworth-Heinemann. 2013. *Control of Pig Reproduction*. Technology and Engineering Press.
- Mauricio Pineda and Michael P Dooley. 2008. *McDonald's Veterinary Endocrinology and Reproduction*. Wiley-Blackwell.
- *Pig Reproduction: Problems, Practices and Principles*. Proceedings of a Conference Held at Christ Church, Oxford University, 16-18 December, 1998.
- Sergi Bonet, Isabel Casas, William V Holt, Marc Yeste. 2013. *Boar Reproduction: Fundamentals and New Biotechnological Trends*. Springer Science and Business Media.
- Selected articles from journals.

I. Course Title : Ultrasonography in Animal Reproduction

II. Course Code : VGO 516

III. Credit Hours : 1+2

IV. Aim of the course

To impart knowledge and training about application of ultrasonography in diagnosis of conditions associated with animal reproduction.

V. Theory

Unit I

Basic principle of ultrasonography, physics of ultrasonography, A-mode, B-mode and M-mode ultrasonography, artifacts, principle of Doppler ultrasonography.

Unit II

Trans-abdominal ultrasonography, transrectal ultrasonography, follicular dynamics and luteal characteristics in large and small ruminants, luteal blood flow studies.

Unit III

Use of ultrasonography in pregnancy diagnosis, infertility management, uterine involution, luteal cyst and follicular cyst, blood flow studies in uterine and foetal arteries. Determination of gestational age in small animals by measuring gestational sac diameter, crown rump length and body diameter. Detection of foetal resorption and mummification. Prediction of parturition time, fetal viability by detecting fetal heart rate, foetal number and sex determination.

Unit IV

Testicular and male accessory sex gland ultrasonography.

VI. Practical

Use of ultrasonography in different stages of reproductive cycle. Use of ultrasonography in diagnosis of clinical cases associated with reproductive disorders in both male and females.

VII. Suggested Reading

- MAM Taverne and AH Willemse. 1989. *Diagnostic ultrasound and animal reproduction*. Dordrecht; Boston: Kluwer Academic.
- J Ginther. 1998. *Ultrasonic imaging and animal reproduction*. Cross Plains, Wis.: Equiservices Pub.
- Selected articles from journals.

I. Course Title : Special Problem
II. Course Code : VGO 590
III. Credit Hours : 0+1

IV. Aim of the course

To expose students to research techniques related to sub discipline of the subject and submission of written project with references.

V. Practical

Student will carry out research on allotted project and submit the project report.

VGO 591 Master's Seminar 1+0
VGO 599 Master's Research 30

Course Outline: Lecture wise

VGO 501: General Gynaecology (2+1)

Theory Lectures

1. Functional anatomy reproductive organs, puberty and sexual maturity in farm animals.
2. Endocrine regulation of estrous cycle in farm animals.
3. Role of hypothalamic-pituitary-gonadal axis in attainment of puberty.
4. Role of pineal gland, endogenous opioids and neuropeptides in reproduction.
5. Folliculogenesis, follicular waves and its manipulation, oogenesis and ovulation.
6. Synchronization of estrus and ovulation in farm animals.
7. Artificial induction of ovarian activity.
8. Transport of gametes in the reproductive tract, fertilization and implantation.
9. Maternal recognition of pregnancy in farm animals.
10. Embryonic and fetal development during gestation.
11. Placentation and fetal circulation.
12. Gestational changes in the fetus w.r.t. to position in the uterus, age, etc.
13. Pregnancy diagnosis in farm animals. Pregnancy diagnosis using clinical method.
14. Pregnancy diagnosis using endocrinological and other diagnostic laboratory methods.
15. Pregnancy diagnosis using ultrasonographic method.
16. Lactation and artificial induction of lactation in cattle and buffaloes.

Practicals

1. Clinical examination of female genitalia.
2. Biometry of female genital organs using slaughter house specimen.
3. Rectal and vaginal examination to diagnose cyclic phases of estrous cycle.
4. Fern pattern of cervical mucus and exfoliated vaginal cytology.
5. Pregnancy diagnosis in large and small animals by various methods.
6. Estimation of age of the fetus.
7. Pregnancy diagnosis using Ultrasonography method.
8. Pregnancy diagnosis using endocrinological method.
9. Synchronization of estrus and ovulation in farm animals.

VGO 502: Female Infertility In Farm Animals (2+1)

Theory Lectures

1. Infertility, its classification and economic impact.
2. Anatomical, congenital/ hereditary and acquired causes of infertility.
3. Nutritional causes of infertility.
4. Importance of body condition score. Negative energy balance, its prevention and amelioration.
5. Managemental and environmental causes of infertility.
6. Out of season breeding.
7. Infectious causes of female infertility, specific and non-specific infections; it's diagnosis, treatment, prevention and control.

8. Anoestrus; causes, diagnosis and treatment.
9. Cystic ovarian degeneration; causes, diagnosis and treatment.
10. Anovulation and delayed ovulation; causes, diagnosis and treatment.
11. Luteal insufficiency; causes, diagnosis and treatment.
12. Repeat breeding; its causes, diagnosis and treatment.
13. Early embryonic death (EED); it's causes, diagnosis and therapeutic management.
14. Abortion; Infectious and non infectious causes of abortion.
15. Diagnosis and prevention of abortion.
16. Immunological mechanisms leading to infertility.

Practicals

1. Record keeping w.r.t. herd fertility assessment and management.
2. Diagnosis and treatment of infertility in female animals.
3. Uterine swabbing for bacterial and fungal culture.
4. Histo-pathological evaluation of uterine biopsy.
5. White side test, endometrial cytology and hormone assay.
6. Use of ultrasonography in diagnosis of infertility.
7. Immuno- diagnostic techniques.

VOG 503: Veterinary Obstetrics (2+1)

Theory Lectures

1. Parturition; stages of parturition.
2. Mechanism of initiation of parturition, hormonal profiles associated with parturition.
3. Transition cow, onset of postpartum ovarian activity.
4. Dystocia and principles of handling of dystocia.
5. Obstetrical procedures: mutations, fetotomy, caesarean section.
6. Obstetrical anesthesia and analgesia, epidural anesthesia.
7. Fetal dystocia; causes, diagnosis and management.
8. Maternal dystocia; causes, diagnosis and management.
9. Uterine torsion; causes, diagnosis and its correction.
10. Caesarean section and ovariohysterectomy.
11. Diseases and accidents during gestation
12. Diseases and accidents around parturition.
13. Etiology, diagnosis and treatment of ante-partum vagino-cervical prolapse.
14. Etiology, diagnosis and treatment of post-partum uterine and vaginal prolapse.
15. Induction of parturition and elective termination of pregnancy.
16. Involution of uterus following normal and abnormal parturition.
17. Care of dam and the newborn.

Practicals

1. Pelvimetry of different species of farm animals.
2. Diagnosis and correction of abnormal fetal presentation, position and posture in phantom box.
3. Epidural anesthesia, episiotomy, ovariohysterectomy.
4. Caesarean operation.
5. Management of incomplete cervical dilation.
6. Fetotomy operations.
7. Detorsion of uterus.
8. Management of cervico-vaginal and uterine prolapse.
9. Handling of clinical cases of dystocia.

VGO 504: Andrology and Male Infertility (2+1)

Theory Lectures

1. Structure and function of reproductive tract of male.
2. Sexual behavior in males.
3. Examination of bulls for breeding soundness.
4. Spermatogenesis, seminiferous epithelial cycle and spermatogonial wave.
5. Structure of spermatozoa, semen and its composition.
6. Mechanism of sperm motility.
7. Diseases transmitted through semen.
8. Factors affecting semen quality.
9. Tests for assessment of sperm motility, sperm survival and fertilizing capacity of spermatozoa.
10. Causes of male infertility; hereditary, congenital, infectious, nutritional and hormonal.
11. Pathological and functional disturbances of epididymis, vas deferens and accessory sex glands.
12. Impotentia cocundi and impotentia generandi.
13. Testicular hypoplasia and degeneration; causes and affect on semen and fertility.
14. Coital injuries and vices of male animals.
15. Influence of seminal plasma proteins in modulating fertility.
16. Heat stress and its effect on sperm production.
17. Screening of the breeding bulls to be selected for semen collection.

Practicals

1. General and per-rectal examination for biometrics of male genitalia and accessory sex glands.
2. Breeding soundness evaluation of male animals.
3. Semen evaluation for sperm abnormalities, fertility.
4. Determination of biochemical constituents of seminal plasma.
5. Microbiological load assessment of semen.
6. Examination, diagnosis and treatment of infertile male animals.

VGO 505: Semen Preservation and Artificial Insemination (2+1)

Theory Lectures

1. History of artificial insemination.
2. Methods of semen collection.
3. Semen evaluation; macroscopic and microscopic examination.
4. Biochemical and microbiological tests of semen.
5. Semen dilution and preservation.
6. Extenders for preservation of semen at different temperatures.
7. Semen additives for enhancement of motility and fertilizing capacity of spermatozoa.
8. Cryopreservation of semen.
9. Effect of cryopreservation on spermatozoa, semen quality and fertility.
10. Liquid Nitrogen (LN2) cylinders; its handling, care and maintenance.
11. Thawing protocols of frozen semen.
12. Factors affecting post-thaw semen quality.
13. Ideal protocol for AI in different species of animals. Factors affecting success of AI.
14. Biosecurity and biosafety guidelines for frozen semen stations, semen processing laboratories and quarantine stations.

15. Minimum standards and standard operating procedures for artificial insemination.
16. Quality testing of straws and sheath for use in artificial insemination.

Practicals

1. Instrumentation in semen laboratory.
2. Minimum standards of protocols of semen laboratory.
3. Standard operating procedures for semen production.
4. Computer assisted semen analysis.
5. Collection and evaluation of semen for its quality.
6. Preparation of semen extenders.
7. Preservation of semen; room temperature, refrigeration and cryopreservation.
8. Handling and evaluation of processed semen.
9. Practice of AI techniques.

VGO 506: Basics of Reproductive Biotechnology (2+1)

Theory Lectures

1. Embryo transfer technology: selection of donors and recipients.
2. Synchronization of estrus in donors and recipients.
3. Super-ovulation, surgical and non-surgical collection of embryos.
4. Evaluation and cryopreservation of embryos.
5. Transfer of embryos to donors.
6. Sexed semen production.
7. Sexing of embryos.
8. Guidelines for export and import of bovine germplasm.
9. Guidelines and standards regarding embryo production.
10. *In-vitro* culture of granulosa cells, cumulus cells, luteal cells and oviductal cells.
11. Recovery of bovine oocytes; from abattoir ovaries and live animals.
12. *In-vitro* maturation, *in-vitro* fertilization and micromanipulation of embryos.
13. Immuno-neutralization and immunomodulation of fertility.

Practicals

1. Synchronization of estrus in donors and recipients.
2. Superovulation, surgical and non-surgical collection and transfer of embryos.
3. Collection of oocytes from slaughter house genitalia.
4. *In-vitro* maturation and *in-vitro* fertilization of embryos.
5. Sexing of embryos.

VGO 509: Canine and Feline Reproduction (2+1)

Theory Lectures

1. Development of reproductive system. Anatomy of male and female reproductive system.
2. Canine and feline estrous cycle, endocrinology of estrous cycle.
3. Breeding management.
4. Pregnancy and pregnancy diagnosis; clinical method of pregnancy diagnosis.
5. Ultrasonographic, endocrinological and other diagnostic laboratory tests of pregnancy diagnosis.
6. Parturition and periparturient disorders in dogs and cats.
7. Dystocia; fetal and maternal causes, diagnosis and management.
8. Induction of parturition and caesarean section.
9. Medical termination of pregnancy in dogs and cats.

10. Management of psudopregnancy and pyometra.
11. Infertility and it's management in dogs and cats.
12. Postpartum care of dam and lactation. Neonatal care.
13. Population control in dogs; surgical and non surgical methods.
14. Reproductive physiology of male dogs.
15. Semen collection techniques and semen evaluation.
16. Freezing of semen and artificial insemination techniques.
17. Male reproductive disorders and its management.

Practicals

1. Exfoliative vaginal cytology.
2. Determination of ovulation time.
3. Demonstration of semen collection and artificial insemination.
4. Predicting time of parturition using hormonal assay.
5. Management of dystocia in clinical cases.
6. Castration, ovariohystrectomy and caesarean section.
7. Surgical procedure related to reproductive disorders in both male and female dogs and cats.

VGO 510: Caprine and Ovine Reproduction (2+1)

Theory Lectures

1. Caprine and ovine estrous cycle.
2. Endocrinology of estrous cycle.
3. Seasonal breeding activity in sheep and goat.
4. Artificial control of oestrus in sheep and goat.
5. Breeding management.
6. Methods for advancing sheep breeding season, induction of multiple births in sheep.
7. Artificial insemination.
8. Pregnancy and parturition.
9. Dystocia and its management.
10. Reproductive disorders and its management.
11. Reproductive physiology of males.
12. Semen collection techniques and semen evaluation.
13. Freezing of semen.
14. Male reproductive disorders and its management.

Practicals

1. Demonstration of semen collection.
2. Demonstration of artificial insemination.
3. Management of dystocia in clinical cases.
4. Castration.
5. Ovariohystrectomy and caesarean section.
6. Surgical procedure related to reproductive disorders in both male and females.

VGO 511: Equine Reproduction (2+1)

Theory Lectures

1. Reproductive anatomy and physiology of Mare.
2. Reproductive anatomy and physiology Stallion.
3. Estrous cycle, manipulation of estrus in Mare.
4. Broodmare management.

5. Use of ultrasound in breeding management.
6. Infertility in Mare and it's management.
7. Pregnancy diagnosis.
8. Management of the pregnant mare.
9. Fetal development.
10. Abortion.
11. Parturition, induced parturition.
12. Management of dystocia.
13. Neonatal management.
14. Common neonatal diseases, orphan foal management.
15. Foal management during the first six months.
16. Semen collection.
17. Semen preservation.
18. Artificial insemination.
19. Embryo transfer.

Practicals

1. Visit of equine/ stud farm.
2. Overall management of an equine breeding program.
3. Handling the cases of reproductive disorders.
4. Artificial insemination.
5. Semen collection.
6. Semen preservation.
7. Breeding record keeping and analysis.

VGO 512: Camel Reproduction (2+1)

Theory Lectures

1. Male reproductive organs, male reproductive physiology.
2. Sexual behavior, puberty and sexual mamturity.
3. Seasonal changes and copulation.
4. Semen collection and it's characteristics.
5. Female reproductive organs, female reproductive physiology.
6. Sexual behavior, oestrous cycle, signs of oestrus.
7. Pregnancy and foetal development.
8. Pregnancy diagnosis.
9. Parturition.
10. Age of sexual maturity, breeding season.
11. Conception rate, calving interval, reproductive longevity.
12. Early embryonic mortality, reproductive problems in the female.
13. Reproductive problems in the male.
14. Artificial insemination.
15. Nutrition and reproduction.
16. Embryo transfer in camel.

Practicals

1. Management of dystocia in clinical cases.
2. Castration and ovariohystrectomy.
3. Caesarean section.
4. Surgical procedure related to reproductive disorders in both male and females.

VGO 513: Elephant Reproduction (2+1)

Theory Lectures

1. General introduction, Elephas maximus, domestic and wild elephants.
2. Male genital system, accessory sex glands.
3. Spermatogenesis and hormonal control.
4. Semen characteristics.
5. Female reproductive system, ovaries, fallopian tubes, uterus, vagina and external genitalia.
6. Oestrous cycle, hormonal regulation of estrous cycle.
7. Mating behaviour and act of copulation.
8. Pregnancy, gestation length.
9. Parturition.
10. Neonatal care of elephant calves.
11. Musth in elephants, bahavioural patterns, pre-musth, violent- musth and post-musth phases.
12. Controlling elephants in musth using drugs/ hormones, anti androgens.
13. Artificial insemination.
14. Cryopreservation of gametes.

Practicals

1. Management of dystocia in clinical cases.
2. Surgical procedure related to reproductive disorders in both male and females.

VGO 514: Wild and Zoo Animal Reproduction (2+1)

Theory Lectures

1. Introduction to reproduction in wild animals.
2. Pattern of estrous cycle in tiger, deer, monkey and crocodile.
3. Optimal breeding time with emphasis on tiger, deer, monkey and crocodile.
4. Gestational length and pregnancy diagnosis in wild and zoo animals.
5. Parturition in wild and zoo animals.
6. Sexual behavior in wild and zoo animals.
7. Major reproductive disorders in wild and zoo animals.
8. Contraception techniques for deer.

Practicals

1. Management of dystocia in clinical cases.
2. Castration in wild and zoo animals.
3. Observation of estrus behavior.
4. Pregnancy diagnosis.
5. Surgical procedure related to reproductive disorders in both male and females.

VGO 515: Porcine Reproduction (2+1)

Theory Lectures

1. Anatomy and physiology of Boar
2. Anatomy and physiology of Sow.
3. Oestrus cycle, manipulation of oestrus cycle in sow.
4. Methods for detection of oestrus.
5. Endocrinology of pregnancy.
6. Endocrinology of parturition.

7. Infertility in sow and its management.
8. Pregnancy diagnosis and management of pregnant sow.
9. Fetal development.
10. Abortion and induced parturition.
11. Parturition and its stages.
12. Dystocia in Sow.
13. Mastitis-metritis complex in sow.
14. Neonatal management and common neonatal diseases, care of piglets.
15. Breeding boar selection and management.
16. Semen collection and preservation.
17. Natural service and artificial insemination.
18. Embryo transfer and IVF.

Practicals

1. Visit and record keeping of swine farm.
2. Breeding management in sows.
3. Handling the cases of reproductive disorders.
4. Caesarean section and castration.
5. Sexual behaviour and vaginal cytology.
6. Pregnancy diagnosis in Sow.
7. Semen collection, semen preservation and artificial insemination.
8. Embryo transfer in Sow.

VGO 516: Ultrasonography in Animal Reproduction (1+2)

Theory Lectures

1. Basic principle of ultrasonography, physics of ultrasonography, A-mode, B-mode and M-mode Ultrasonography. Artifacts and principle of Doppler ultrasonography.
2. Trans-abdominal and transrectal ultrasonography.
3. Follicular dynamics and luteal characteristics in large and small ruminants, luteal blood flow studies.
4. Use of ultrasonography in pregnancy diagnosis and infertility management.
5. Studies on uterine involution, luteal cyst and follicular cyst, blood flow studies in uterine and foetal arteries ultrasonography.
6. Determination of gestational age in small animals by measuring gestational sac diameter, crown rump length and body diameter. Detection of foetal resorption and mummification.
7. Prediction of parturition time, fetal viability by detecting fetal heart rate, foetal number and sex determination.
8. Testicular and male accessory sex gland ultrasonography.

Practicals

1. Practicing trans-abdominal and trans-rectal ultrasonography.
2. Use of ultrasonography in follicular dynamics study.
3. Use of ultrasonography in luteal characteristics study.
4. Use of ultrasonography in pregnancy diagnosis.
5. Prediction of parturition time using ultrasonography.
6. Use of ultrasonography in diagnosis of clinical cases associated with reproductive disorders in females.
7. Testicular studies using ultrasonography.
8. Male accessory sex gland studies using ultrasonography

9. Use of ultrasonography in diagnosis of clinical cases associated with reproductive disorders in male.

Minor Courses for M.V.Sc. Degree programme

Courses of any one department/ discipline from the list given below:

- Veterinary Pathology
- Veterinary Pharmacology
- Veterinary Physiology
- Veterinary Biochemistry
- Veterinary Bacteriology
- Veterinary Immunology

Supporting Courses

It could be any subject considered relevant for student's research work. This will be decided by Advisor/ guide concerned.

Common Courses

The following courses (one credit each) will be offered to all students undergoing Master's degree programme.

- Library and Information Services
- Technical Writing and Communications Skills
- Intellectual Property and its management in Agriculture
- Basic Concepts in Laboratory Techniques
- Agricultural Research, Research Ethics and Rural Development Programmes

Course Title with Credit Load
Ph.D. in Animal Reproduction Gynaecology and Obstetrics

Course Code	Course Title	Credit Hours
VGO 601	Advances in Gynaecology and Infertility* Management	2+1
VGO 602	Advances in Veterinary Obstetrics	1+1
VGO 603	Advances in Andrology and Male Infertility*	2+1
VGO 604	Reproductive Biotechnology	1+1
VGO 605	Semenology	1+1
VGO 606	Clinical Practice-I*	0+3
VGO 607	Clinical Practice-II*	0+3
VGO 690	Special Problem	0+2
VGO 691	Doctoral Seminar-I	1+0
VGO 692	Doctoral Seminar-II	1+0
VGO 699	Doctoral Research	75

*Core Courses

Course Contents
Ph.D. in Animal Reproduction Gynaecology and Obstetrics

I. Course Title : Advances in Gynaecology and Infertility Management

II. Course Code : VGO 601

III. Credit Hours : 2+1

IV. Aim of the course

To learn about advances in endocrine, ovarian and uterine functions and effect of nutrition, season and immunological factors on female fertility.

V. Theory

Unit I

Neuro-endocrine control of reproduction, follicular development, ovulation fertilization and implantation. Embryonic and fetal development.

Unit II

Maternal recognition of pregnancy advances in early diagnosis of pregnancy.

Unit III

Embryonic losses, abortion and their prevention.

Unit IV

Seasonal breeders, Synchronization and induction of estrus and ovulation in seasonal breeders, Assisted Reproductive Technology (ART) to increase reproductive efficiency in farm animals.

Unit V

Effect of stress, nutrition and immunological factors on fertility.

Unit VI

Onset of postpartum ovarian activity and factors affecting it.

Unit VI

Diagnostic and therapeutic approaches in infertility; principles of hormone therapy in reproductive disorders, laparoscopy, ultrasonographic diagnosis of ovarian/ uterine dysfunction, reproductive disorders, vaginal and uterine cytology.

VI. Practical

Clinical examination of female animals. Use of ultrasonography in ovarian function (follicular image pattern, follicular dynamics) and in early pregnancy diagnosis and infertility. Utility of uterine culture, uterine cytology and uterine biopsy (histopathological examination) in infertility investigation. Laparoscopy in diagnosis of ovarian and uterine dysfunction. ELISA/ RIA of hormones and interpretation of results. Use of assisted reproductive technology (ART) to enhance reproductive efficiency in farm animals.

VII. Suggested Reading

- Hafez ESE and B Hafez. 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.

- Mauricio Pineda and Michael P Dooley. 2008. *McDonald's Veterinary Endocrinology* and Wiley-Blackwell.
- David Noakes, Timothy Parkinson and Gary England. 2018. *Veterinary Reproduction and Obstetrics*. Saunders Ltd.
- Roberts SJ. 2005. *Veterinary Obstetrics and Genital Diseases*. Scientific Book Agency.
- Morrow DA. 1986. *Current Therapy in Theriogenology*. WB Saunders.
- Selected articles from journals.

I. Course Title : Advances in Veterinary Obstetrics

II. Course Code : VGO 602

III. Credit Hours : 1+1

IV. Aim of the course

To learn current developments in diagnosis and management of dystocia, accidents of gestation and peri-parturient disorders in domestic animals.

V. Theory

Unit I

Conceptus and its development. Factors influencing gestation period and birth weight.

Unit II

Anomalies of conceptus, teratogens and effect of stress on conceptus development.

Unit III

Mechanism of initiation of parturition. Use of tocolytic drugs.

Unit IV

Induction of parturition and termination of abnormal pregnancies. Obstetrical analgesia and anesthesia.

Unit V

Pre-treatment evaluation of the dam suffering from dystocia. Management of maternal and fetal dystocia, hydrallantois, hydramnion, fetal mummification, fetal maceration, uterine inertia and uterine torsion.

Unit VI

Fetotomy, caesarean section and ovairo-hysterectomy. Retention of fetal membranes and management.

Unit VII

Neo-natal physiology and post-natal adaptations. Assessment of neonatal viability, care of the newborn.

Unit VIII

Involution of uterus, post-partum ovarian dysfunction and their manipulation. Care of the postpartum dam.

VI. Practical

Obstetrical operations in fetal dystocia; mutations, fetotomy, cesarean section, ovario-hysterectomy; induction of parturition, obstetrical analgesia and anaesthesia.

VII. Suggested Reading

- David Noakes, Timothy Parkinson and Gary England. 2018. *Veterinary Reproduction and Obstetrics*. Saunders Ltd.
- Roberts SJ. 2005. *Veterinary Obstetrics and Genital Diseases*. Scientific Book Agency.
- Sloss V and Dufty JH. 1980. *Handbook of Bovine Obstetrics*. Williams and Wilkins.
- Selected articles from journals.

I. Course Title : Advances in Andrology and Male Infertility

II. Course Code : VGO 603

III. Credit Hours : 2+1

IV. Aim of the course

To learn advances in male reproduction and treatment of male infertility in domestic animals.

V. Theory

Unit I

Spermatogenesis, Spermatogenic waves, Sperm passage in male genitalia, biochemical milieu of male genitalia. Correlation between motility and fertilizing capacity of spermatozoa. Seminiferous eipithelial cycle, Theory of sperm motility and ultrastructure of sperm. Sperm passage in female reproductive tract; capacitation and acrosome reaction.

Unit II

Separation of motile and immotile spermatozoa.

Unit III

Sperm plasma membrane and its permeability and binding properties: acrosome and lysosomal enzymes, sperm nucleus and nuclear proteins. Mitochondria and their role in sperm metabolism. Flagellum and the mechanochemical basis of motility and cyclic nucleotides.

Unit IV

Biochemistry of seminal plasma and accessory sex gland secretions. Electrolytes, proteins, Enzymes and amino acids in seminal plasma. Fructose and other sugars, Lipids, Cholesterol, Steroid hormones and Prostaglandins in seminal plasma.

Unit V

Fructolysis index. Aerobic and anaerobic metabolism of spermatozoa.

Unit VI

Markers of fertility in males, sperm chromatin structure assay, Anti-sperm antibodies. Karyotyping to identify sperm defect and DNA mapping for parentage.

VI. Practical

Breeding soundness evaluation of bulls, biochemical tests of semen for evaluation of fertility, semen culture for diagnosis of venereal diseases, diagnosis and treatment of genital pathological condition. Computer assisted semen analysis (CASA), Semen evaluation for assessment of fertilizing capacity of spermatozoa: cervical mucus penetration test, sperm capacitation test, hypo osmotic swelling test and zona free hamster egg penetration test. Anti-sperm antibody assay. Collection of preputial washings and semen for bacterial load and venereal pathogens.

VII. Suggested Reading

- Hafez ESE and B Hafez. 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.
- Enos Johnson Perry. 2013. *Artificial Insemination of Farm Animals*. Jodhpur: Axis Books (India).
- Roberts SJ. 2005. *Veterinary Obstetrics and Genital Diseases*. Scientific Book Agency.
- Selected articles from journals.

I. Course Title : Reproductive Biotechnology

II. Course Code : VGO 604

III. Credit Hours : 1+1

IV. Aim of the course

To learn advances and recent developments in biotechnology in reproduction for the production of desired elite animals.

V. Theory

Unit I

Micromanipulation, Intracytoplasmic Sperm Injection (ICSI), Sexing of embryos.

Unit II

Stem cell biotechnology, Semen sorting for production of sexed semen.

Unit III

Cloning, Biopharming, Transgenic Animals and Chimeras.

Unit IV

Transgenic animals and chimeras. Gene expression in oocyte and embryo, Identification of cellular organelles of Gamete.

Unit V

Principle and application of PCR technique in animal reproduction.

VI. Practical

Micromanipulation of embryos, Sexing of embryos, Stem cell production.

VII. Suggested Reading

- Hafez ESE and B Hafez. 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.
- B Singh, SK Gautam and MS Chauhan. 2012. *Textbook of Animal Biotechnology*, Pearson Education.
- Heiner Niemann, Christine Wrenzycki. 2018. *Animal Biotechnology 1: Reproductive Biotechnologies*. Springer.
- Heiner Niemann, Christine Wrenzycki. 2018. *Animal Biotechnology* 2. Springer International Publishing AG.
- Ian Gordon. 2017. *Reproductive Technologies in Farm Animals*. Wallingford, Oxfordshire CABI.
- Troy L Ott, Zhihua Jiang. 2010. *Reproductive Genomics in Domestic Animals*. John Wiley.
- Marcelo Marcondes Seneda, Katia Cristina Silva-Santos, LS Rafagnin Marinho. 2016. *Biotechnology of Animal Reproduction*, Nova Science Pub. Inc; UK Ed.
- Tacia Gomes Bergstein-Galan. 2018. *Reproduction Biotechnology in farm animals*. Avid Science.
- Selected articles from journals.

I. Course Title : Semenology

II. Course Code : VGO 605

III. Credit Hours : 1+1

IV. Aim of the course

To learn advances in processing and cryopreservation of semen and insemination techniques to obtain high fertility.

V. Theory

Unit I

Contribution of gonads and accessory sex glands to semen ejaculate. Factors affecting semen production. Morphology of sperm and their defects. Biochemical composition of semen.

Unit II

Metabolism of sperm. Role of seminal plasma proteins. Species variation in seminal characteristics. Factors affecting motility and fertilizing capacity of spermatozoa.

Unit III

Use of semen additives and activators. Sperm cryodamage, Commercial extenders used for bovine semen. Microbial contamination of semen and measures for its prevention. Transmission of venereal diseases through semen and their prevention.

Unit IV

Thawing protocols for frozen semen. Post-thaw evaluation of motility and fertilizing capacity of spermatozoa. Quality control and quality assurance of semen, antisperm antibodies. Flow cytometric assessment of sperm quality.

Unit V

Sperm vitrification, freeze drying of sperm and sperm encapsulation.

Unit VI

Criteria for gradation of semen stations.

VI. Practical

Semen evaluation. Estimation of bacterial load and enzymes in semen. Morphological defects of sperm. *In-vitro* tests for sperm function i.e. BCMPT, HOST, etc. Physical and enzymatic changes in semen following cryopreservation. Tests to assess acrosomal integrity, Mitochondrial activity, DNA damage, binding assays, etc. Fluorescent probe based assessment of sperm quality. Comet assay, Sperm chromatin structure assay, TUNEL assay.

VII. Suggested Reading

- Salisbury GW, VanDemark NL and Lodge JR. 1978. *Physiology of Reproduction and Artificial Insemination of Cattle*. WH Freeman and Co.
- Hafez ESE and B Hafez. 2013. *Reproduction in Farm Animals*. Wiley-Blackwell.
- Selected articles from journals.

I. Course Title : Clinical Practice-I

II. Course Code : VGO 606

III. Credit Hours : 0+3

IV. Aim of the course

Hands-on training on diagnosis and treatment of reproductive disorders in animals

V. Practical

Clinical examination of animals affected with reproductive disorders, use of diagnostic techniques for diagnosis and institution of required therapy. Acquaintance with different equipment used for handling reproductive disorders, client management, public relations, code of conduct, database management, Maintenance of case records.

VI. Suggested Reading

- Morrow DA. 1986. *Current Therapy in Theriogenology*. WB Saunders.
- Zemjanis R. 1970. *Diagnostic and Therapeutic Techniques in Animal Reproduction*. Williams and Wilkins; Second Edition.
- Selected articles from journals.

I. Course Title : Clinical Practice-II
II. Course Code : VGO 607
III. Credit Hours : 0+3

IV. Aim of the course

Hands-on training on diagnosis and treatment of reproductive disorders in animals.

V. Practical

Clinical examination of animals affected with reproductive disorders, use of diagnostic techniques for diagnosis and institution of required therapy. Acquaintance with different equipment used for handling reproductive disorders, client management, public relations, code of conduct, database management, Maintenance of case records.

VI. Suggested Reading

- Morrow DA. 1986. *Current Therapy in Theriogenology*. WB Saunders.
- Zemjanis R. 1970. *Diagnostic and Therapeutic Techniques in Animal Reproduction*. Williams and Wilkins; Second Edition.
- Selected articles from journals.

I. Course Code : VGO 690
II. Course Title : Special Problem
III. Credit Hours : 0+2

V. Aim of the course

To expose students to research techniques related to sub discipline of the subject and submission of written project with references.

VI. Practical

Student will carry out research on allotted project and submit the project report.

VGO 691 DOCTORAL SEMINAR-I 1+0
VGO 692 DOCTORAL SEMINAR-II 1+0
VGO 699 DOCTORAL RESEARCH 75

Course Outline: Lecture wise

VGO 601: Advances in Gynaecology and Infertility Management (2+1)

Theory Lectures

1. Neuro-endocrine control of reproduction.
2. Follicular development.
3. Ovulation, fertilization and implantation.
4. Embryonic and fetal development.
5. Maternal recognition of pregnancy.
6. Advances in early diagnosis of pregnancy.
7. Embryonic losses, abortion and their prevention.
8. Seasonal breeders, synchronization and induction of estrus and ovulation in seasonal breeders.
9. Assisted reproductive technology (ART) to increase reproductive efficiency in farm animals.
10. Effect of stress and nutritional factors on fertility.
11. Effect of immunological factors on fertility.
12. Onset of postpartum ovarian activity and factors affecting it.
13. Diagnostic and therapeutic approaches in infertility.
14. Principles of hormone therapy in reproductive disorders.
15. Laproscopy.
16. Ultrasonographic diagnosis of ovarian/ uterine dysfunction.
17. Vaginal and uterine cytology.

Practicals

1. Clinical examination of female animals for reproductive soundness.
2. Use of ultrasonography in ovarian function (follicular image pattern, follicular dynamics).
3. Use of ultrasonography in early pregnancy diagnosis.
4. Use of ultrasonography in infertility management.
5. Uterine culture, uterine cytology and uterine biopsy (histopathological examination) in infertility investigation.
6. Laparoscopy in diagnosis of ovarian and uterine dysfunction.
7. Use of ELISA/ RIA in reproductive parameters study and interpretation of results.
8. Use of Assisted reproductive technology (ART) to enhance reproductive efficiency in farm animals.

VGO 602: Advances in Veterinary Obstetrics (1+1)

Theory Lectures

1. Conceptus and its development.
2. Factors influencing gestation period and birth weight.
3. Anomalies of conceptus, teratogens and effect of stress on conceptus development.
4. Mechanism of initiation of parturition. Use of tocolytic drugs.

5. Induction of parturition and termination of abnormal pregnancies.
6. Pre-treatment evaluation of the dam suffering from dystocia. Obstetrical analgesia and anesthesia.
7. Management of maternal and fetal dystocia, hydrallantois, hydramnion, fetal mummification, fetal maceration, uterine inertia and uterine torsion.
8. Fetotomy, caesarean section and ovaro-hysterectomy.
9. Retention of fetal membranes and management.
10. Neo-natal physiology and post-natal adaptations. Assessment of neonatal viability, care of the newborn.
11. Involution of uterus, post-partum ovarian dysfunction and their manipulation. Care of the postpartum dam.

Practicals

1. Performing obstetrical operations.
2. Performing obstetrical mutations.
3. Fetotomy.
4. Cesarean section and ovario-hysterectomy.
5. Induction of parturition.
6. Obstetrical analgesia and anaesthesia.

VGO 603: Advances in Andrology and Male Infertility (2+1)

Theory Lectures

1. Spermatogenesis and spermatogenic waves.
2. Sperm passage in male genitalia, biochemical milieu of male genitalia.
3. Correlation between motility and fertilizing capacity of spermatozoa.
4. Seminiferous eipithelial cycle, theory of sperm motility and ultrastructure of sperm.
5. Sperm passage in female reproductive tract; capacitation and acrosome reaction.
6. Separation of motile and immotile spermatozoa.
7. Sperm plasma membrane and its permeability and binding properties: acrosome and lysosomal enzymes, sperm nucleus and nuclear proteins.
8. Mitochondria and their role in sperm metabolism.
9. Flagellum and the mechanochemical basis of motility and cyclic nucleotides.
10. Biochemistry of seminal plasma and accessory sex gland secretions.
11. Electrolytes, proteins, enzymes and amino acids in seminal plasma. Fructose and other sugars, lipids, cholesterol, steroid hormones and prostaglandins in seminal plasma.
12. Fructolysis index. Aerobic and anaerobic metabolism of spermatozoa.
13. Markers of fertility in males.
14. Sperm chromatin structure assay.
15. Anti-sperm antibodies.
16. Karyotyping to identify sperm defect and DNA mapping for parentage.

Practicals

1. Breeding soundness evaluation of bulls.
2. Biochemical tests of semen for evaluation of fertility.
3. Semen culture for diagnosis of venereal diseases.
4. Diagnosis and treatment of genital pathological condition.
5. Studies on sperm motility using Computer assisted semen analysis (CASA).
6. Cervical mucus penetration test, sperm capacitation test and hypo-osmotic swelling test.

7. Zona free hamster egg penetration test.
8. Anti-sperm antibody assay.
9. Collection of preputial washings and semen for bacterial load and venereal pathogens.

VGO 604: Reproductive Biotechnology (1+1)

Theory Lectures

1. Micromanipulation and Intracytoplasmic sperm injection (ICSI).
2. Sexing of embryos.
3. Stem cell biotechnology.
4. Semen sorting for production of sexed semen.
5. Cloning and biopharming.
6. Transgenic animals and chimeras.
7. Gene expression in oocyte and embryo, identification of cellular organelles of Gamete.
8. Principle and application of PCR technique in animal reproduction.

Practicals

1. Micromanipulation of embryos.
2. Sexing of embryos.
3. Stem cell production.

VGO 605: Semenology (1+1)

Theory Lectures

1. Contribution of gonads and accessory sex glands to semen ejaculate. Factors affecting semen production.
2. Morphology of sperm and their defects. Biochemical composition of semen.
3. Metabolism of sperm. Role of seminal plasma proteins. Species variation in seminal characteristics.
4. Factors affecting motility and fertilizing capacity of spermatozoa. Commercial extenders used for bovine semen.
5. Use of semen additives and activators. Sperm cryodamage.
6. Microbial contamination of semen and measures for its prevention. Transmission of venereal diseases through semen and their prevention.
7. Thawing protocols for frozen semen. Post-thaw evaluation of motility and fertilizing capacity of spermatozoa.
8. Quality control and quality assurance of semen.
9. Antisperm antibodies assay.
10. Flow cytometric assessment of sperm quality.
11. Sperm vitrification, freeze drying of sperm and sperm encapsulation.
12. Criteria for gradation of semen stations.

Practicals

1. Semen evaluation for its quality.
2. Estimation of bacterial load in semen.
3. Estimation of enzymes in the semen.
4. *In-vitro* tests for sperm function i.e. BCMPT, HOST, etc.
5. Tests to assess acrosomal integrity, mitochondrial activity and DNA damage.
6. Tests to assess binding assays.
7. Fluorescent probe based assessment of sperm quality.
8. Comet assay, Sperm chromatin structure assay, TUNEL assay.

Minor Courses for Ph.D. Degree programme

Courses of any one department/ discipline from the list given below:

- Veterinary Pathology
- Veterinary Pharmacology
- Veterinary Physiology
- Veterinary Biochemistry
- Veterinary Bacteriology
- Veterinary Immunology

Supporting Courses

It could be any subject considered relevant for student's research work. This will be decided by Advisor/ guide concerned.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Clinical Subjects
– Veterinary Surgery and Radiology

Preamble
(Veterinary Surgery and Radiology)

The subjects under surgical discipline have undergone sea change, except for 'Tenets of Halstead', since the introduction of 'Key Hole' surgery and newer imaging techniques. In fact, the technological advancements demand creation of two separate disciplines - Surgery and Imaging. Further, to start with there is need of separate speciality courses involving Imaging, Orthopaedics, Anaesthesia and Ophthalmology. Scope also exists for addition of Avian Surgery, etc. However, in view of BSMA guidelines, efforts have been made to tune the Syllabus as per the existing infrastructure catering futuristic societal needs and to remain relevant and purposeful.

To encourage clinical practice in the veterinary clinics, courses on clinical practice, each at M.V.Sc. and Ph.D. level have been made mandatory. To focus on learning of research methodology, scientific thinking, planning and experimentation, a course on special problems has been introduced.

The new and restructured postgraduate curricula and syllabi in Surgery and Radiology contains several innovative and practically applicable courses. Credit hours for Clinical Practice have been increased from 0+3 to 0+4, as maximum time of the postgraduate scholars of clinical disciplines is spent in clinics. Small animal anaesthesia (2+1) and Large animal anaesthesia (2+1) courses are merged together and a new course on Veterinary Anaesthesia and Analgesia (2+1) is proposed. Small Animal Soft Tissue Surgery (2+1) and Large Animal Soft Tissue Surgery (2+1) courses are merged together and a new course Soft Tissue Surgery (2+1) is proposed. As per the advances in Ophthalmology and Dentistry, Veterinary Ophthalmology and Dentistry (1+1) is bifurcated into two separate courses, Veterinary Ophthalmology (1+1) and Veterinary Dentistry and Oral Surgery (1+1) to give more emphasis in two different distinct subjects.

New Courses were added to M.V.Sc. degree programme to gain thorough knowledge in areas like Anaesthesia of zoo, wild, exotic and laboratory animals (1+1), Urogenital Surgery (1+1), Cardiovascular Surgery (1+1). Clinical Case Conference (0+1) was added to encourage the students to do thorough case study of a single patient. In few states of India, certain species of animals are more prevalent, hence, we have developed species specific courses for those dealing with majority of cases in that particular region. Thus two new courses, viz., Camel surgery (1+1) and Elephant surgery (1+1) are added.

At Ph.D. level, courses on experimental surgical techniques in animals (1+1) is deleted in view of new CPCEA guidelines of unnecessary experimentation on animals to be discouraged and new methods be designed for teaching. Few new courses in Ph.D. degree programme were added, viz., Advances in orthopaedics (2+1), Reconstructive and regenerative surgery (1+1), Cardiovascular surgery (1+1), Special problems in diagnostic imaging (0+2), Advances in soft tissue surgery (2+1), Advances in veterinary ophthalmology (1+1), Veterinary surgical oncology (1+1), Clinical case conference (0+1), Advances in radiology (2+1) and Advances in diagnostic imaging techniques (2+1). These new courses are designed in such a way to keep pace with the development of new technologies and recent advances in these areas.

Under existing clinical ecosystem, the implementation of the new and restructured postgraduate course curricula is expected to build clinical knowledge and skill portfolio of the students so as to enhance their employability and marketability as multi-service providers with hands on skills and comprehensive knowledge of the entire subject after Masters degree. The doctorates should, in turn, prove as specialists, in the field of their specialization.

Course Title with Credit Load
M.V.Sc. in Veterinary Surgery and Radiology

Course Code	Course Title	Credit Hours
VSR 501	Clinical Practice-I*	0+3
VSR 502	Clinical Practice-II*	0+3
VSR 503	Principles of Surgery*	2+1
VSR 504	Anaesthesia And Analgesia*	2+1
VSR 505	Diagnostic Imaging Techniques*	2+1
VSR 506	Soft Tissue Surgery	2+1
VSR 507	Orthopaedic Surgery*	2+1
VSR 508	Anaesthesia of Zoo, Wild, Exotic and Laboratory Animals	1+1
VSR 509	Urogenital Surgery	1+1
VSR 510	Ophthalmology	1+1
VSR 511	Dentistry and Oral Surgery	1+1
VSR 512	Camel Surgery	1+1
VSR 513	Elephant Surgery	1+1
VSR 587	Clinical Case Conference	0+1
VSR 588	Special Problem in Radiology	0+2
VSR 589	Special Problem in Anaesthesia	0+2
VSR 590	Special Problem in Surgery	0+2
VSR 591	Masters Seminar	1+0
VSR 599	Masters Research	0+30

*Core Courses

Course Contents
M.V.Sc. in Veterinary Surgery and Radiology

I. Course Title : Clinical Practice-I
II. Course Code : VSR 501
III. Credit Hours : 0+3
IV. Aim of the course

To learn techniques and procedures in anaesthesia, diagnostic imaging techniques and surgery

V. Practical

Basic requirements and designing surgical and general veterinary hospital, Developing different proformas required in hospital facility, Assessing surgical patients and documentation, Preparation of surgical team and duties of team members, Surgical suite maintenance and sterilization, Acquaintance with different equipment like inhalant anaesthesia machine, Radiography systems, Ultrasonography, Endoscopy, Electro-surgery, Cryosurgery and physiotherapy equipment, Client management, Public relations, code of conduct, Management of surgical affections, Hospital database management, Attending surgical cases, Disaster management.

I. Course Code : VSR 502
II. Course Title : Clinical Practice-II
III. Credit Hours : 0+3
IV. Aim of the course

To learn techniques and procedures in anaesthesia, diagnostic imaging techniques and surgery

V. Practical

Application of different equipment like inhalant anaesthesia machine, Computerized radiography system, Ultrasonography, Electro-surgery, Cryosurgery, Physiotherapy and endoscopy and Physiotherapy equipment, Client management and Counselling, public relations, Code of conduct, Management of surgical affections, Hospital management, Database management, Attending surgical cases, Disaster management.

I. Course Title : Principles of Surgery
II. Course Code : VSR 503
III. Credit Hours : 2+1
IV. Aim of the course

To learn basic and advance principles and standards of practice in veterinary surgery

V. Theory

Unit I

Classification of wounds, wound healing, mechanism of wound repair, local and systemic factors affecting wound healing, current concepts of inflammation and management, thermal, electrical and chemical injuries and their management.

Unit II

Asepsis, sterilization and disinfection and principles and practice of antimicrobial therapy in surgical patients.

Unit III

Shock, classification, pathophysiology, diagnosis, treatment and monitoring, surgical stress and its systemic effects, haemorrhage and haemostasis, acid-base balance, fluid therapy and blood transfusion, metabolism of the surgical patient.

Unit IV

Principles and clinical applications of laser surgery, cryosurgery, electrosurgery, physiotherapy.

Unit V

Minimally invasive surgical procedures which includes laproscopy and endoscopy, principles of microscopic surgery-vessel and nerve anastomosis, application of computers in surgery.

VI. Practical

Identification and handling of surgical instruments, preparation of surgical pack, surgical team and surgical patients, surgical facilities and equipment, introduction to clinical skill laboratory, practice of different suturing patterns and repair of different wounds, using drains, bandages and bandaging techniques, monitoring of traumatized surgical patient, operation theatre conduct.

I. Course Title : Anaesthesia And Analgesia

II. Course Code : VSR 504

III. Credit Hours : 2+1

IV. Aim of the course

To gain the basic and practical knowledge of principals of companion and farm animals anaesthesia and pain management

V. Theory

Unit I

Introduction and history of anaesthesia, General consideration for anaesthesia in animals, Properties of ideal anaesthetic agent, Types of anaesthesia, Anaessthetic triad, Preanaesthetic evaluation of patient and selection of anaesthesia.

Unit II

Preanaesthetic medication (anticholinergics, sedatives, tranquilizers, alpha-2 agonist, narcotics), Muscle relaxants and neuromuscular blocking agents.

Unit III

General anaesthetics and factors affecting their uptake, Distribution and metabolism; Injectable anaesthetic agents (properties, dosage and usage); Combinations of injectable agents and neuroleptanalgesia, Inhalation anaesthetic agents (properties, methods of administration, dosage and usages), Inhalation anaesthesia equipment and breathing circuits, artificial ventilation.

Unit IV

Post-operative care of the surgical patient, operating room emergencies, cardio-pulmonary arrest and resuscitation, monitoring of anaesthetic recovery.

Unit V

Local anaesthetics, their mechanisms, local and regional nerve blocks, spinal analgesia, intravenous regional anaesthesia, peri-operative and post-operative pain and its management.

VI. Practical

Inhalation anaesthesia equipment, circuits and vaporizers, artificial ventilation, use of various pre-anaesthetic and anaesthetic agents in small and large animals, anaesthetic triad, balanced anaesthesia, total intravenous anaesthesia, regional and local nerve blocks using local anaesthetics, alpha-2 agonists and their combinations in domestic animals, monitoring of anaesthesia, reversal of sedation and analgesia induced by alpha-2 agonists, practice of anaesthesia in clinical cases; record keeping in anaesthesia and euthanaia.

I. Course Title : Diagnostic Imaging Techniques

II. Course Code : VSR 505

III. Credit Hours : 2+1

IV. Aim of the course

To learn the basic principles and gain practical knowledge of diagnostic imaging techniques and interpretation

V. Theory

Unit I

Regulations regarding establishment and handling of x-ray units. Requirements for establishment of x-ray units, conventional and digital x-ray machine, x-ray films, Cassettes, screen, x-ray production, Qualities of x-rays, Image formation and dark room procedures, Image plate, Formation of radiograph technique chart, Artifacts and their prevention, Radiographic quality Contrast, Density and details), radiographic accessories, radiographic positioning for different organs/ parts in small and large animals.

Unit II

Plain and contrast radiographic techniques of small and large animals, fluoroscopy/ C-arm, principles of radiographic interpretation,

Unit III

Principles of radiation therapy, medical radioisotope curves, radiation laws and regulations. Radiation hazards and monitoring of radiographic exposure to personnel and protection.

Unit IV

Basic physics of ultrasound waves and image formation, scanning principles of ultrasound, transducers, equipment controls, modes of display, terminology used for echotexture and USG artifacts, application of ultrasound in small and large animals.

Unit V

Doppler techniques echocardiography and its application, introduction to nuclear imaging techniques, computerized tomography, magnetic resonance imaging, positron emission tomography technique.

VI. Practical

Acquaintance with imaging equipment, computed radiography and digital radiography systems, dark room processing techniques and x-ray film handling, formulation of technique chart with fixed kVp and variable mAs, radiographic artefacts and their prevention, basics of radiographic interpretation of diseases, PACS, radiography positioning of different regions in domestic animals, contrast radiographic techniques, interpretation of radiographs, practice of ultrasonographic imaging and report writing.

I. Course Title : Soft Tissue Surgery

II. Course Code : VSR 506

III. Credit Hours : 2+1

IV. Aim of the course

To learn about soft tissue surgical skills and various surgical affections of different body systems in companion and farm animals

V. Theory

Unit I

Skin, adnexa, integument, appendages, horn, tail, sinus affections of equine and bovine, teat affections, principles of plastic and reconstructive surgery, different types of skin grafts.

Unit II

Surgical approaches/ affections of ear, oral cavity, larynx and pharynx, salivary glands, oesophagus, abdomen, rumen, reticulum, omasum, abomasum, stomach, intestines, rectum, anus, liver and biliary system, pancreas and porto-systemic shunts.

Unit III

Abdominal hernia, diaphragmatic hernia, perineal hernia, ventral, femoral and umbilical hernia, ritcher hernia, hiatal hernia, omental hernia, pre-pubic tendon rupture, use of biological and synthetic grafts for hernia repair, laparoscopic repair of hernia.

Unit IV

Principles of thoracic surgery, Functional anatomy of respiratory system, diseases of upper and lower respiratory system, functional anatomy of cardiovascular system and common affections of heart.

Unit V

Affections of pituitary, adrenals, thyroid, parathyroid glands, Principles of neurosurgery and common surgical affections of nervous system and special sense organs.

Unit VI

Haemolymphatic system, bone marrow, spleen, tonsils, lymph nodes and lymphatics, thymus.

VII. Practical

Practice of various surgical techniques of skin and adnexa, alimentary system, hernias, respiratory system, affections of horn, tail and teat, endoscopy techniques, instrumentation, use of rigid/ flexible endoscopes in companion and farm animals.

I. Course Title : Orthopaedic Surgery

II. Course Code : VSR 507

III. Credit Hours : 2+1

IV. Aim of the course

To learn about various affections of bones, joints, tendons, ligaments and foot and their treatment in companion and farm animals.

V. Theory

Unit I

Bone structure and function, growth, Response to injury, Fractures and luxations, classification of fracture, Fracture healing.

Unit II

Biomechanics of fracture healing, Considerations for selection of fixation techniques, Treatment of fractures of different bones in companion and farm animals, Diseases of bone.

Unit III

Various affections of the joints, ligaments and tendons and their treatment.

Unit IV

Spinal affections and injury to axial skeleton.

Unit V

Conformation of the limb, anatomy of hoof, anatomical, conformational and pathological causes of lameness and allied surgical conditions of fore and hind limbs, rehabilitation of orthopaedic patient.

VI. Practical

Application of Plaster of Paris cast, fiberglass cast, Roberts Jones bandage, modified Schroeder Thomas splint, Coaptation splint, sling application, practice of IM pinning, wiring, bone plating, inter locking nailing, external skeletal fixation, arthrotomy, tenotomy, examination of limbs for lameness, desmotomy, nerve blocks, injections in joints, operations for arthritis, hoof surgery and corrective shoeing.

I. Course Title : Anaesthesia of Zoo, Wild, Exotic and Laboratory Animals

II. Course Code : VSR 508

III. Credit Hours : 1+1

IV. Aim of the course

To learn about basic and practical knowledge of chemical immobilization, sedation and anaesthesia of laboratory animals, exotic, captive and free ranging wild animals.

V. Theory

Unit I

General consideration in chemical restraint of captive and free ranging wild animals, handling of birds with minimum stress, physical examination, blood sampling, crop washes, faecal sampling.

Unit II

Methods of administration of anaesthesia in captive, free ranging animals, birds and laboratory animals.

Unit III

Local and general anaesthesia in exotic species, wild animals, birds, zoo animals and laboratory animals.

Unit IV

Anaesthetic emergencies and complications.

Unit V

Diagnostic interpretation, haematology and biochemistry analysis, avian diagnostic endoscopy

VI. Practical

Familiarization with capture and anaesthetic equipments, local anaesthetic techniques, use of various preanaesthetic and anaesthetic agents in laboratory animals, birds, monitoring of patient during general anaesthesia, familiarization of various diseases in exotic birds like tumours, foreign body, crop stasis, crop tear, crop fistula, toe necrosis, feather cyst, excision of uropygieal gland, rhinolith, pharyngostomy, ingluviotomy, ventriculotomy and orthopedic injuries, visits to zoos and wild life sanctuaries for practical on wild and zoo animals.

I. Course Title : Urogenital Surgery

II. Course Code : VSR 509

III. Credit Hours : 1+1

IV. Aim of the course

To learn about various surgical affections of urinary and genital tract and their treatment in companion and farm animals.

V. Theory

Unit I

Surgical anatomy of urinary and reproductive tract in male and female animals, Congenital anomalies of organs of male and female urinary and reproductive system.

Unit II

Principals of urinary tract surgery, Pathophysiology, Diagnosis and surgical management of affections of kidney, ureter, urinary bladder and urethra, Medical dissolution and prevention of Canine uroliths, Feline urologic syndrome, Surgical management of urolithiais in ruminants and its prevention, management of uroperitoneum and renal failure.

Unit III

Pathogenesis, Clinical symptoms, Diagnosis and surgical management of vaginal and uterine prolapse, Rectovaginal fistula, Pneumovagina, Vaginal tumours, pyometra, Cysts of Gartner's canal and vestibular glands.

Unit IV

Surgical conditions of penis, Prepuce, Prostate and testicles, Cryptorchidism, Inguinal and scrotal hernia, Affections of teat and udder.

Unit V

Indications, Techniques and postoperative complications of episiotomy, Ovariectomy, ovariohysterectomy and caesarean section, Pyomerta and its surgical treatment.

Unit VI

Castration, Vasectomy, Cauda epididymectomy and penile deviation.

VI. Practical

Hands-on-training of techniques of centesis of urinary bladder in companion and farm animals, Different types of catheters used in urogenital surgery, Retrograde catheterization of urethra and urinary bladder, Normograde catheterization of urethra on clinical cases of urinary retention, Pudendal nerve block for penis examination in ruminants, Diagnostic techniques and surgical management of the affections of kidney, Ureters, Urinary bladder, Urethra, Uro-hydropropulsion, Restraint and anaesthesia for urogenital tract surgery, Cystotomy, Tube cystostomy, Nephrotomy, Ureterocolostomy, Urethrotomy, Urethrostomy, Castration, Vasectomy, Penile deviation, Epididymectomy, Amputation of penis, Episiotomy, Ovariohysterectomy, Tubectomy, Caesarean section, Management of phimosis, Paraphimosis, Venereal granuloma, Vaginal and uterine prolapse, Rectovaginal fistula and pneumovagina, Bladder and uterine marsupialization.

I. Course Title : Ophthalmology

II. Course Code : VSR 510

III. Credit Hours : 1+1

IV. Aim of the course

To learn basic principles and gain practical knowledge of diagnosis and treatment of diseases of eye.

V. Theory

Unit I

Anatomy and physiology of eye and its adnexa, Ophthalmic examination and diagnosis, Diagnostic instrumentation, Anaesthesia and surgery.

Unit II

General consideration for eye surgery in companion and farm animals, Therapeutic agents for eye diseases and surgery of eye lids, lacrimal apparatus, naso-lacrimal duct.

Unit III

Diseases of conjunctiva, cornea, sclera, iris, orbit, lens, vitreous and aqueous humor, retina and optic nerve, eye tumours, enucleation, exenteration.

Unit IV

Ocular manifestations of systemic diseases.

Unit V

Neuro-ophthalmology and ocular emergencies

VI. Practical

Ophthalmic instrumentation, examination of the eye and its adnexa, anaesthesia, preparation of patient, suture materials for eye surgery, canthotomy, tarsorrhaphy, keratoplasty, anterior chamber paracentesis, flushing of naso-lacrimal duct, iridectomy, phacoemulsification and implantation of foldable lens, surgical treatment of entropion and ectropion, cherry eye, Schirmer tear test, use of fluorescein dye in corneal ulcer, glaucoma surgery, eye worm removal.

I. Course Title : Dentistry and Oral Surgery

II. Course Code : VSR 511

III. Credit Hours : 1+1

IV. Aim of the course

To learn the basic and practical knowledge of diagnosis and treatment of diseases of teeth and oral cavity.

V. Theory

Unit I

Anatomy, development of teeth (odontogenesis), dentition and ageing of different species.

Unit II

Clinical examination of oral cavity, Dental anesthesia and pain management, Dental radiography.

Unit III

Diseases of oral cavity and teeth, Congenital and developmental anomalies of oral cavity, Abnormal tooth eruption, Irregular wear of teeth in companion and farm animals, occlusion and malocclusion, Mandibular fracture, Malformation of mandible, maxilla (cleft palate).

Unit IV

Acquired diseases of teeth (halitosis, dental caries, fracture of teeth, dental materials and dental radiography), Oronasal fistula, Maxilla and mandibular fractures repair, Orthodontics, Tumors and Other acquired condition of oral cavity.

Unit V

Exodontics, Restorative dentistry, Periodontal disease, Tooth extraction, Gum diseases. Endodontics, Pulpectomy, Root Canal therapy (RCT), Current techniques in dentistry.

VI. Practical

Oral examination, Modified triadian system of tooth numbering in various species, Dental chart for companion and farm animals, Dentistry instrumentation, Dental radiography procedure, Periodontal probing, Scaling/ teeth cleaning, Tooth extraction, Malpractices in equine dentistry, Periodical maintenance of oral hygiene, Corrective procedures, Malocclusion, Treatment strategies congenital malformations of maxilla and mandible, oral surgery.

I. Course Title : Camel Surgery

II. Course Code : VSR 512

III. Credit Hours : 1+1

IV. Aim of the course

To learn the basic principles and gain practical knowledge of diagnosis and treatment of surgical diseases of camel.

V. Theory

Unit I

Introduction to special surgical anatomy of important parts, i.e. Mandible, Soft palate, Chest pad, saddle region, Male urinary system, tail, etc., Restraint and positioning for various surgical procedures and radiography of different parts.

Unit II

Use of local anaesthesia, Various nerve blocks and regional anaesthesia used to treat diverse surgical disorders, Preanaesthetics, Tranquilizers, Sedatives and general anaesthetics used for camel surgery.

Unit III

Surgical affections of head and neck region: Laceration and infected wounds of nostril skin, Infection of turbinate, Actinobacillosis, Dental affections, Removal of canines in furious camels, Torticollis, Fracture of mandible and maxilla, Soft palate injuries, Ophthalmic affections, Salivary fistula, Stenson's duct ligation, Oesophageal obstruction.

Unit IV

Surgical affections of thorax and abdominal region: Saddle gall, Hernia, Chest pad wounds and enlargements, Foreign bodies in compartment, Intestinal obstruction, Obstructive urolithiasis, Rupture of urethra, Subcutaneous infiltration of urine, Cystorrhexis.

Unit V

Surgical affections of musculo-skeletal system: diagnosis of lameness in camels, management of long bone and digital fractures, upward fixation of patella, sprains, arthritis.

Unit VI

Sheath abscess, Necrosis of penis, Phimosis, Paraphimosis, Preputial prolapse, Various types of tumours, Gangrene and tumours of udder, Necrosis of tail, Punctured foot, prolapse of digital cushion, Foot injuries, Kumri, Kapali, etc.

VI. Practical

Restraint and anaesthesia (Local, regional, sedation and general anaesthesia), Preparation of sites, Surgical anatomy of important surgical affections, Special instruments used for camel restraining and surgery, Observing and assisting in diverse surgical procedures on clinical cases in camels, Practice of interdental wiring for repair of mandibular fractures in specimen mandibles, Clinical and radiographic diagnosis of lameness, Protection of wounds of chest pad and foot using special bandages, Radiography of different part of camels and postoperative care of diverse surgical affections of camels.

I. Course Title : Elephant Surgery
II. Course Code : VSR 513
III. Credit Hours : 1+1
IV. Aim of the course

To learn the basic principles and gain practical knowledge of diagnosis and treatment of surgical diseases of elephant.

V. Theory

Unit I

Basic surgical anatomy of Asian elephants and comparison with other farm animals.

Unit II

Drug administration techniques in captive and wild elephants, Anaesthetic management of captive and wild elephants for various surgical and managerial conditions.

Unit III

Principles of soft tissue surgery in elephants, Cyst, Bursitis, Gall, Haematoma, Abscess, etc.

Unit IV

Management and treatment of fractures and arthritis in elephants.

Unit V

Pedicure, corrective foot care and maintenance of healthy feet of captive elephants housed in different establishments in different seasons.

Unit VI

Hoisting of recumbent elephants, Surgical methods of birth control in elephants, limitations and risks of abdominal surgery in elephants (eg. Caesarian section, Castration, Hernia, etc., Soft tissue surgery like episiotomy, vestibulotomy, etc.)

VI. Practical

Familiarity with clinical examination procedures, Body weight estimation, Signs of health and diseases, Signs of localized lesions, etc., Familiarity with physical and chemical restraint procedures, Drug administrations by various routes-IM, IV, SC, sub-conjuctival, oral, per rectal, etc., foot examination and foot care procedures, visit to elephant camps and attending clinical procedures, surgeries, etc.

I. Course Title : Clinical Case Conference
II. Course Code : VSR 587
III. Credit Hours : 0+1
IV. Practical

Present seminar on unusual/ interesting clinical cases done in the semester. Compile them from presentation to follow up and also submit the write up in soft or hard copy.

I. Course Title : Special Problem in Radiology
II. Course Code : VSR 588
III. Credit Hours : 0+2

IV. Practical

Investigative radiological problems in clinical or experimental models, didactic and interpersonal learning-teaching, problem solving self-learning strategies in problems related to radiology.

I. Course Title : Special Problem in Anaesthesia
II. Course Code : VSR 589
III. Credit Hours : 0+2

IV. Practical

Investigative anesthetic problems in clinical or experimental models, Didactic and interpersonal learning-teaching, Problem solving self-learning strategies in problems related to anaesthesia.

I. Course Title : Special Problem in Surgery
II. Course Code : VSR 690
III. Credit Hours : 0+2

IV. Practical

Investigative surgical problems in clinical or experimental models, Didactic and interpersonal learning-teaching, Problem solving self-learning strategies in problems related to surgery.

VSR 591 MASTERS SEMINAR (1+0)
VSR 599 MASTERS RESEARCH (0+30)

Course Outline: Lecture wise

VSR 503: Principles of Surgery (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Classification of wounds	1
2.	Wound healing, mechanism of wound repair	2
3.	Local and systemic factors affecting wound healing	1
4.	Current concepts of inflammation and management	1
5.	Thermal, electrical and chemical injuries and their management	3
	Unit II	
6.	Asepsis, sterilization and disinfection	1
7.	Principles and practice of antimicrobial therapy in surgical patients	2
	Unit III	
8.	Shock, classification, pathophysiology, diagnosis, treatment and monitoring	4
9.	Surgical stress and its systemic effects	1
10.	Haemorrhage and haemostasis	1
11.	Acid-base balance	1
12.	Fluid therapy	2
13.	Blood transfusion	1
14.	Metabolism of the surgical patient	2
	Unit IV	
15.	Principles and clinical applications of laser surgery, cryosurgery, electrosurgery, physiotherapy	4
	Unit V	
16.	Minimally invasive surgical procedures which includes laproscopy and endoscopy	2
17.	Principles of microscopic surgery-vessel and nerve anastomosis	1
18.	Application of computers in surgery	1
Practical		
1.	Identification and handling of surgical instruments	3
2.	Preparation of surgical pack	1
3.	Preparation of surgical team	1
4.	Preparation of surgical patients	1
5.	Surgical facilities and equipment	2
6.	Introduction to clinical skill laboratory	1
7.	Practice of different suturing patterns	2
8.	Repair of different wounds, using drains, bandages and bandaging techniques	2
9.	Monitoring of traumatized surgical patient	2
10.	Operation theatre conduct	1

Suggested Reading

- Fossum TW. (Ed.). 2018. *Small Animal Surgery*. Mosby.
- Slatter DH. 2003. 3rd ed. *Textbook of Small Animal Surgery*. WB Saunders.
- Hendrickson DA and Baird AN. 2013. *Turner and McIlwraiths Techniques in Large Animal Surgery* 4th ed. Wiley Black Well.
- AK Gangwar, Naveen Kumar and Kh. Sangeeta Devi. 2010. *General Animal Surgery and Anesthesiology* (With Theory and Practicals) New India Publishing Agency, New Delhi (ISBN: 9789-38-0235-172).

VSR 504: Anaesthesia and Analgesia (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Introduction and history of anaesthesia	1
2.	General consideration for anaesthesia in animals	1
3.	Properties of ideal anaesthetic agent, types of anaesthesia	1
4.	Anaesthetic triad, preanaesthetic evaluation of patient and selection of anaesthesia	1
5.	Preanaesthetic evaluation of patient and selection of anaesthesia	2
	Unit II	
6.	Preanaesthetic medication (anticholinergics, sedatives, tranquilizers, alpha-2 agonist, narcotics)	5
7.	Muscle relaxants and neuromuscular blocking agents	1
	Unit III	
8.	General anaesthetics and factors affecting their uptake, distribution and metabolism	2
9.	Injectable anaesthetic agents (properties, dosage and usage)	3
10.	Combinations of injectable agents and neuroleptanalgesia	1
11.	Inhalation anaesthetic agents (properties, methods of administration, dosage and usages)	2
12.	Inhalation anaesthesia equipment and breathing circuits	1
13.	Artificial ventilation	1
	Unit IV	
14.	Post-operative care of the surgical patient	1
15.	Operating room emergencies	1
16.	Cardio-pulmonary arrest and resuscitation	1
17.	Monitoring of anaesthetic recovery	1
	Unit V	
18.	Local anaesthetics, their mechanisms	1
19.	Local and regional nerve blocks	1
20.	Spinal analgesia, intravenous regional anaesthesia	1
21.	Peri-operative and post-operative pain and its management	2
Practical		
1.	Inhalation anaesthesia equipment, circuits and vaporizers	2
2.	Artificial ventilation	1
3.	Use of various pre-anaesthetic and anaesthetic agents in small and large animals	3
4.	Anaesthetic triad	1
5.	Balanced anaesthesia	1

S. No.	Topics	No. of Lectures/ Practicals
6.	Total intravenous anaesthesia	1
7.	Regional and local nerve blocks using local anaesthetics	1
8.	Repair of different wounds, using drains, bandages and bandaging techniques	1
9.	Alpha-2 agonists and their combinations in domestic animals	1
10.	Monitoring of anaesthesia	1
11.	Reversal of sedation and analgesia induced by alpha-2 agonists	1
12.	Practice of anaesthesia in clinical cases	1
13.	Record keeping in anaesthesia and euthanaia	1

Suggested Reading

- AK Gangwar, Naveen Kumar and Kh. Sangeeta Devi. 2010. *General Animal Surgery and Anesthesiology (With Theory and Practicals)* New India Publishing Agency, New Delhi (ISBN: 9789-38-0235-172).
- Clarke KW, Trim CM and Hall LW. 2013. *Veterinary Anaesthesia*. 11th ed. WB Saunders.
- Grim KA, Lamont LA, Tranquilli WJ, Greene SA and Robertson SA. 2015. *Veterinary Anaesthesia and Analgesia*, The 5th ed. Lumb and Jones. Wiley Blackwell.
- Grim KA, Tranquilli WJ and Lamont LA. 2011. *Essentials of Small Animal Anesthesia and Analgesia*. 2nd ed. Wiley Blackwell.
- Paddleford RR. 1999. *Manual of Small Animal Anesthesia*. 2nd ed. WB Saunders.

VSR 505: Diagnostic Imaging Techniques (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Regulations regarding establishment and handling of x-ray units, requirements for establishment of x-ray units	1
2.	Conventional and digital X-ray machine	1
3.	X-ray films, cassettes, screen	1
4.	X-ray production, qualities of x-rays	1
5.	Image formation and dark room procedures	1
6.	Image plate, formation of radiograph technique chart, artifacts and their prevention	1
7.	Radiographic quality (Contrast, density and details)	1
8.	Radiographic accessories	1
9.	Radiographic positioning for different organs/ parts in small and large animals	1
	Unit II	
10.	Plain and contrast radiographic techniques of small and large animals	3
11.	Fluoroscopy/ C-arm	1
12.	Principles of radiographic interpretation	1
	Unit III	
13.	Principles of radiation therapy, medical radioisotope curves, radiation laws and regulations	2
14.	Radiation hazards and monitoring of radiographic exposure to personnel and pretection	2
	Unit IV	
15.	Basic physics of ultrasound waves and image formation	2

S. No.	Topics	No. of Lectures/ Practicals
16.	Scanning principles of ultrasound	1
17.	Transducers, equipment controls, modes of display	1
18.	Terminology used for echotexture and USG artifacts	4
	Unit V	
19.	Doppler techniques echocardiography and its application	2
20.	Introduction to nuclear imaging techniques, computerized tomography, magnetic resonance imaging, positron emission tomography techniques	3
Practical		
1.	Acquaintance with imaging equipment, computed radiography and digital radiography systems	3
2.	Dark room processing techniques and X-ray film handling	1
3.	Formulation of technique chart with fixed kVp and variable mAs	1
4.	Radiographic artefacts and their prevention	1
5.	Basics of radiographic interpretation of diseases	2
6.	Radiography positioning of different regions in domestic animals	1
7.	Contrast radiographic techniques	2
8.	Interpretation of radiographs	2
9.	PACS, Practice of ultrasonographic imaging and report writing	3

Suggested Reading

- AK Gangwar, Kh. Sangeeta Devi and Naveen Kumar. 2015. *Radiography in Veterinary Practice at a glance (Including Diagnostic Imaging techniques*) Astral International Pvt. Limited, New Delhi (ISBN: 978-93-5124-335-9).
- Barr FJ and Gaschen L. 2011. *BSAVA Manual of Canine and Feline Ultrasonography*. British Small Animal Veterinary Association
- Boon JA. 2011. *Veterinary Echocardiography*. 2nd ed. Wiley-Blackwell.
- Bushong SC. 2017. *Radiologic Science for Technologists*. 11th ed. CV Mosby.
- Gillette EL, Thrall DE and Lebel JL. (Eds.). 1977. *Carlson's Veterinary Radiology*. Lea and Febiger.
- Goddard PJ. 1995. *Veterinary Ultrasonography*. CABI.
- Kealy JK, McAllister H and Graham JP. (Eds.). 2011. *Diagnostic Radiology and Ultrasonography of the Dog and Cat*. 5th ed. WB Saunders, Philadelphia.
- Mannion P. 2006. *Diagnostic Ultrasound in Small Animal practice*. Blackwell Science.
- Kirberger RM and McEvoy FJ 2016. *BASAVA Manual of Canine and Feline Musculoskeltal Imaging*. 2nd BASAVA Gloucester.
- Morgan JP. 1972. *Radiology in Veterinary Orthopaedics*. Lea and Febiger.
- Nyland TG and Mattoon JS. 2002. *Small Animal Diagnostic Ultrasound*. WB Saunders.
- Thrall DE. 2017. *Textbook of Veterinary Diagnostic Radiology*. 7th ed. Saunders, Philadelphia.
- Bargai U, Pharr, JW and Morgan JP. 1989. *Bovine Radiology*. Iowa State University Press, Ames.

VSR 506: Soft Tissue Surgery (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Skin, adnexa, integument, appendages, horn, tail, sinus affections of equine and bovine	3

S. No.	Topics	No. of Lectures/ Practicals
2.	Principles of plastic and reconstructive surgery, different types of skin grafts	2
	Unit II	
3.	Surgical approaches/ affections of ear	1
4.	Surgical approaches/ affections of oral cavity	1
5.	Surgical approaches/ affections of larynx, pharynx, salivary glands and oesophagus	1
6.	Surgical approaches/ affections of abdomen	1
7.	Surgical approaches/ affections of rumen and reticulum	1
8.	Surgical approaches/ affections of omasum and abomasum	1
9.	Surgical approaches/ affections of stomach, intestines, rectum, anus	3
10.	Surgical approaches/ affections of liver and biliary system, pancreas and porto-systemic shunts	1
	Unit III	
11.	Abdominal hernia	1
12.	Diaphragmatic hernia	1
13.	Perineal hernia, ventral, femoral and umbilical hernia	1
14.	Ritcher hernia, hiatal hernia, omental hernia, pre-pubic tendon rupture	1
15.	Use of biological and synthetic grafts for hernia repair, laparoscopic repair of hernia	1
	Unit IV	
16.	Principles of thoracic surgery, functional anatomy of respiratory system	1
17.	Diseases of upper and lower respiratory system	4
18.	Functional anatomy of cardiovascular system and common affections of heart	3
	Unit V	
19.	Affections of pituitary, adrenals, thyroid, parathyroid glands	1
20.	Principles of neurosurgery and common surgical affections of nervous system and special sense organs	1
	Unit VI	
21.	Haemolymphatic system, bone marrow, spleen, tonsils, lymph nodes and lymphatics, thymus	2
Practical		
1.	Practice of various surgical techniques of skin and adnexa	2
2.	Practice of various surgical techniques of alimentary system	5
3.	Practice of various surgical techniques of hernias	2
4.	Practice of various surgical techniques of respiratory system	2
5.	Affections of horn, tail and teat	2
6.	Endoscopy techniques, instrumentation, use of rigid/ flexible endoscopes in companion and farm animals	1
7.	Use of rigid/ flexible endoscopes in companion animals	1
8.	Use of rigid/ flexible endoscopes in farm animals	1

Suggested Reading

- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders
- Slatter DH. 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.
- Yool DA. 2012. *Small Animal Soft Tissue Surgery*. CABI.
- Tobia KM. 2010. *Manual of Small Animal Soft Tissue Surgery*. Wiley Black Well.

VSR 507: Orthopaedic Surgery (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Bone structure and function, growth, response to injury, fractures and luxations	1
2.	Classification of fracture	1
3.	Fracture healing, Biological osteosynthesis	1
	Unit II	
4.	Biomechanics of fracture healing	1
5.	Considerations for selection of fixation techniques	1
6.	Current trends in treatment of fractures of different bones in companion and farm animals	4
7.	Diseases of bone	2
	Unit III	
8.	Various affections of the joints and their treatment	3
9.	Various affections of the ligaments and tendons and their treatment	3
	Unit IV	
10.	Spinal affections and injury to axial skeleton	3
	Unit V	
11.	Conformation of the limb	3
12.	Anatomy of hoof	1
13.	Anatomical, conformational and pathological causes of lameness and allied surgical conditions of fore and hind limbs	6
Practical		
1.	Application of Plaster of Paris cast	1
2.	Application of fiberglass cast	1
3.	Application of Roberts Jones bandage	1
4.	Application of modified Schroeder Thomas splint	1
5.	Application of Coaptation splint, sling application	1
6.	Practice of IM pinning, wiring	2
8.	Practice of bone plating	1
9.	Practice of inter locking nailing	1
10.	Practice of external skeletal fixation	1
11.	Practice of arthrotomy	1
12.	Practice of tenotomy	1
13.	Examination of limbs for lameness	1
14.	Desmotomy, nerve blocks, injections in joints	1
15.	Operations for arthritis and hoof surgery	1
16.	Corrective shoeing	1

Suggested Reading

- AK Gangwar, Khangembam Sangeeta Devi, Ajit Kumar Singh and Naveen Kumar (2018) *Veterinary Orthopaedics and Lameness*, Kalyani Publishers, New Delhi (ISBN 978-93-272-8837-7).
- Auer JA. 2006. *Equine Surgery*. WB Saunders.
- Baxter GM. (Ed.). 2011. *Adams and Stashak's Lameness in Horses*. 6th ed. Wiley-Blackwell.
- Decamp CE, Johnston, SA, Dejardin LM and Schaefer SL. 2016. *Handbook of Small Animal Othopaedics and Fracture Repair*, 5th ed., Elsevier.

- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders.
- Greenough PR. 2007. *Bovine Laminitis and Lameness*. WB Saunders.
- Millis DL and Levine D 2014. *Canine Rehabilitation and Physical Therapy*, 2nd ed., Elsevier.
- Newton CD and Nunamaker DM. (Eds.). 1985. *Textbook of Small Animal Orthopaedics*. JB Lippincott.
- Oehme FW and Prier JE. (Eds.). 1974. *Textbook of Large Animal Surgery*. Williams and Wilkins.
- Tyagi RPS and Singh J. (Eds.). 1993. *Ruminant Surgery*. CBS.
- Weaver AD, Jean GS and Steiner A. 2007. *Bovine Surgery and Lameness*. 2nd ed. Wiley-Blackwell.

VSR 508: Anaesthesia of Zoo, Wild, Exotic and Laboratory Animals (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	General consideration in chemical restraint of captive wild animals	1
2.	General consideration in chemical restraint of free ranging wild animals	1
3.	Handling of birds with minimum stress	1
4.	Physical examination, blood sampling, crop washes, faecal sampling	1
	Unit II	
5.	Methods of administration of anaesthesia in captive animals	1
6.	Methods of administration of anaesthesia in free ranging animals	1
7.	Methods of administration of anaesthesia in birds	1
8.	Methods of administration of anaesthesia in laboratory animals	1
	Unit III	
9.	Local and general anaesthesia in exotic species	1
10.	Local and general anaesthesia in wild animals	1
11.	Local and general anaesthesia in birds	1
12.	Local and general anaesthesia in zoo animals	1
13.	Local and general anaesthesia in laboratory animals	1
	Unit IV	
14.	Anaesthetic emergencies and complications	1
	Unit V	
15.	Diagnostic interpretation, haematology and biochemistry analysis	2
16.	Avian diagnostic endoscopy	1
Practical		
1.	Familiarization with capture and anaesthetic equipments	1
2.	Local anaesthetic techniques	1
3.	Use of various preanaesthetic and anaesthetic agents in laboratory animals	1
4.	Use of various preanaesthetic and anaesthetic agents in birds	1
5.	Monitoring of patient during general anaesthesia	1
6.	Familiarization of various diseases in exotic birds like tumours, foreign body, crop stasis, crop tear, crop fistula, toe necrosis, feather cyst	2
8.	Excision of uropygieal gland	1
9.	Excision of rhinolith	1
10.	Pharyngostomy	1
11.	Ingluviotomy	1
12.	Ventriculotomy	1

S. No.	Topics	No. of Lectures/ Practicals
13.	Orthopedic injuries	2
15.	Visits to zoos for practical on zoo animals	1
16.	Visits to wild life sanctuaries for practical on wild animals	1

Suggested Reading

- Coles BH. 2007. *Essentials of Avian Medicine and Surgery*. 3rd ed. Blackwell Publishing
- Donely B. 2010. *Avian Medicine and Surgery in Practice*. Manson Publishing Ltd.
- Grim KA, Lamont LA, Tranquilli WJ, Greene SA and Robertson SA. 2015. *Veterinary Anaesthesia and Analgesia*. 5th ed. Lumb and Jones. Wiley Blackwell.
- Mader DR. 2005. *Reptile Medicine and Surgery*. 2nd ed. WB Saunders
- Miller RE and Fowler M. 2014. *Fowler's Zoo and Wild Animal Medicine*. 1st ed. Saunders
- Wobeser GA. 2007. *Disease in Wild Animals: Investigation and Management*. 2nd ed. Springer

VSR 509: Urogenital Surgery (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Surgical anatomy of urinary tract in male and female animals	1
2.	Surgical anatomy of reproductive tract in male and female animals	1
3.	Congenital anomalies of organs of male and female urinary system	1
4.	Congenital anomalies of organs of male and female reproductive system	1
	Unit II	
5.	Principels of urinary tract surgery, pathophysiology, diagnosis and surgical management of affections of kidney	1
6.	Pathophysiology, diagnosis and surgical management of affections of ureter and urinary bladder	2
7.	Medical dissolution and prevention of canine uroliths	1
8.	Feline urologic syndrome	1
9.	Surgical management of urolithiais in ruminants and its prevention	1
10.	Management of uroperitoneum and renal failure	1
	Unit III	
11.	Pathogenesis, clinical symptoms, diagnosis and surgical management of vaginal and uterine prolapse, rectovaginal fistula, pneumovagina	1
12.	Pathogenesis, clinical symptoms, diagnosis and surgical management of vaginal tumours, pyometra, cysts of Gartner's canal and vestibular glands	1
	Unit IV	
13.	Surgical conditions of penis, prepuce, prostate and testicles, cryptorchidism, inguinal and scrotal hernia	1
14.	Affections of teat and udder	1
	Unit V	
15.	Indications, techniques and postoperative complications of episiotomy, ovariectomy, ovariohysterectomy and caesarean section, pyomerta and its surgical treatment	1
	Unit VI	
16.	Castration, vasectomy, cauda epididymectomy and penile deviation	1

S. No.	Topics	No. of Lectures/ Practicals
Practical		
1.	Hand-on-training of techniques of centesis of urinary bladder in companion and farm animals	1
2.	Different types of catheters used in urogenital surgery, retrograde catheterization of urethra and urinary bladder	1
3.	Normograde catheterization of urethra on clinical cases of urinary retention	1
4.	Pudendal nerve block for penis examination in ruminants	1
5.	Diagnostic techniques and surgical management of the affections of kidney and ureters	2
6.	Uro-hydropropulsion	1
7.	Restraint and anaesthesia for urogenital tract surgery	1
8.	Cystotomy, tube cystostomy	1
9.	Nephrotomy, ureterocolostomy	1
10.	Urethrotomy, urethrostomy	1
11.	Castration, vasectomy, penile deviation, epididymectomy, amputation of penis, episiotomy	1
12.	Ovariohysterectomy, tubectomy	1
13.	Caesarean section	1
14.	Management of phimosis, paraphimosis, venereal granuloma	1
15.	Vaginal and uterine prolapse, rectovaginal fistula and pneumovagina	1
16.	Bladder and uterine marsupialization	1

Suggested Reading

- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders
- Slatter DH. 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.
- Wolfe DF and Moll HD. *Large Animal Urogenital Surgery* 1999. 2nd ed., Williams and Wilkins, Tokyo.
- Yool DA. 2012. *Small Animal Soft Tissue Surgery*. CABI.

VSR 510: Ophthalmology (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Anatomy and physiology of eye and its adnexa	1
2.	Ophthalmic examination and diagnosis, diagnostic instrumentation	1
3.	Anaesthesia and surgery	1
	Unit II	
4.	General consideration for eye surgery in companion and farm animals	1
5.	Therapeutic agents for eye diseases and surgery of eye lids, lacrimal apparatus, naso-lacrimal duct	1
	Unit III	
6.	Diseases of conjunctiva	1
7.	Diseases of cornea, sclera, iris, orbit	1
8.	Diseases of lens	1
9.	Diseases of vitreous and aqueous humor	1

S. No.	Topics	No. of Lectures/ Practicals
10.	Diseases of retina and optic nerve	1
11.	Eye tumours, enucleation, exenteration	1
	Unit IV	
12.	Ocular manifestations of systemic diseases	2
	Unit V	
13.	Neuro-ophthalmology and ocular emergencies	3
Practical		
1.	Ophthalmic instrumentation	1
2.	Examination of the eye and its adnexa	2
3.	Anaesthesia, preparation of patient, suture materials for eye surgery	1
4.	Canthotomy, tarsorrhaphy	1
5.	Keratoplasty, anterior chamber paracentesis	1
6.	Flushing of naso-lacrimal duct	1
7.	Iridectomy	1
8.	Phacoemulsification and implantation of foldable lens	1
9.	Surgical treatment of entropion	2
10.	Surgical treatment of cherry eye	1
11.	Schirmer tear test	1
12.	Use of fluorescein dye in corneal ulcer	1
13.	Glaucoma surgery	1
14.	Eye worm removal	1

Suggested Reading

- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders
- Gelatt KN. 2014. *Essentials of Veterinary Ophthalmology*. 3rd ed. Wiley Blackwell. US.
- Gilger BC. 2017. *Equine Ophthalmology*, 3rd ed. Wiley Blackwell.
- Maggs DJ, Miller PE and Ofri R. 2017. *Slatter's Fundamentals of Veterinary Ophthalmology*. 6th ed. Saunders.
- Slatter DH 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.

VSR 511: Dentistry and Oral Surgery (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Anatomy, development of teeth (odontogenesis)	1
2.	Dentition and ageing of different species	1
	Unit II	
3.	Clinical examination of oral cavity, dental anesthesia and pain management	1
4.	Dental anaesthesia and pain management	1
5.	Dental radiography	1
	Unit III	
6.	Diseases of oral cavity and teeth, congenital and developmental anomalies of oral cavity	1

S. No.	Topics	No. of Lectures/ Practicals
7.	Abnormal tooth eruption, irregular wear of teeth in companion and farm animals, occlusion and malocclusion	1
8.	Mandibular fracture, malformation of mandible, maxilla (cleft palate)	1
	Unit IV	
9.	Acquired diseases of teeth (halitosis, dental caries, fracture of teeth, dental materials and dental radiography), oronasal fistula	1
10.	Maxilla and mandibular fractures repair	1
11.	Orthodontics	1
12.	Tumors and other acquired condition of oral cavity	1
	Unit V	
13.	Exodontics, restorative dentistry	1
14.	Periodontal disease, tooth extraction, gum diseases	1
15.	Endodontics, pulpectomy, root canal therapy, current techniques in dentistry	2
Practical		
1.	Oral examination	1
2.	Modified triadian system of tooth numbering in various species	1
3.	Dental chart for companion and farm animals	1
4.	Dentistry instrumentation	1
5.	Dental radiography procedure	1
6.	Periodontal probing, scaling/ teeth cleaning	1
7.	Tooth extraction	1
8.	Malpractices in equine dentistry	1
9.	Periodical maintenance of oral hygiene	1
10.	Corrective procedures, malocclusion	1
11.	Treatment strategies congenital malformations of maxilla	2
12.	Oral surgery	4

Suggested Reading

- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders
- Holmstrom SE. 2013. *Veterinary Dentistry - A Team Approach*. 2nd ed. Elsevier.
- Slatter DH. 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.
- Soto JC. 2015. *Visual Atlas of Dental Pathologies in Dogs*. SERVET, Spain.

VSR 512: Camel Surgery (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Introduction to special surgical anatomy of important parts, i.e. mandible, soft palate, chest pad, saddle region, male urinary system, tail, etc.	1
2.	Restraint and positioning for various surgical procedures and radiography of different parts	1

S. No.	Topics	No. of Lectures/ Practicals
	Unit II	
3.	Use of local anaesthesia, various nerve blocks and regional anaesthesia used to treat diverse surgical disorders	1
4.	Preanaesthetics, tranquilizers, sedatives and general anaesthetics used for camel surgery	1
	Unit III	
5.	Surgical affections of head and neck region: laceration and infected wounds of nostril skin, infection of turbinate, actinobacillosis, dental affections	1
6.	Surgical affections of head and neck region: removal of canines in furious camels, torticollis, fracture of mandible and maxilla, soft palate injuries	1
7.	Surgical affections of head and neck region: ophthalmic affections, salivary fistula, Stenson's duct ligation, oesophageal obstruction	1
	Unit IV	
8.	Surgical affections of thorax and abdominal region: saddle gall, hernia, chest pad wounds and enlargements	1
9.	Surgical affections of thorax and abdominal region: foreign bodies in compartment, intestinal obstruction	1
10.	Surgical affections of thorax and abdominal region: obstructive urolithiasis, rupture of urethra, subcutaneous infiltration of urine, cystorrhexis	1
	Unit V	
11.	Surgical affections of musculo-skeletal system: diagnosis of lameness in camels	1
12.	Surgical affections of musculo-skeletal system: management of long bone and digital fractures	1
13.	Surgical affections of musculo-skeletal system: upward fixation of patella, sprains, arthritis	1
	Unit VI	
14.	Sheath abscess, necrosis of penis, phimosis, paraphimosis, preputial prolapse	1
15.	Various types of tumours, gangrene and tumours of udder, necrosis of tail	1
16.	Punctured foot, prolapse of digital cushion, foot injuries, Kumri, Kapali etc	1
Practical		
1.	Restraint and anaesthesia (Local, regional, sedation and general anaesthesia)	2
2.	Preparation of sites	1
3.	Surgical anatomy of important surgical affections	1
4.	Special instruments used for camel restraining and surgery	1
5.	Observing and assisting in diverse surgical procedures on clinical cases in camels	5
6.	Practice of interdental wiring for repair of mandibular fractures in specimen mandibles	1
7.	Clinical and radiographic diagnosis of lameness	2
8.	Protection of wounds of chest pad and foot using special bandages	1
9.	Radiography of different part of camels	1

Suggested Reading

- *Selected Topics on Camelids*, Ed-TK Gahlot, The Camelid Publishers, Bikaner and now marketed by Camel Publishing House, Edition 2000.
- *Medicine and Surgery of Camelids*. Ed-Murray E. Fowler, Wiley-Blackwell, Edition 2010.
- *Advances in Surgery and Diagnostic Imaging of the Dromedary Camel*, Ed- RO Ramadan, King Faisal University, Edition 2016.

VSR 513: Elephant Surgery (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Basic surgical anatomy of Asian elephants and comparison with other farm animals	4
	Unit II	
2.	Drug administration techniques in captive and wild elephants, anaesthetic management of captive and wild elephants for various surgical and managerial conditions	1
3.	Drug administration techniques in captive and wild elephants, anaesthetic management of captive and wild elephants for various surgical and managerial conditions	1
	Unit III	
4.	Principles of soft tissue surgery in elephants, cyst, bursitis, gall, haematoma, abscess, etc.	2
	Unit IV	
5.	Management and treatment of fractures and arthritis in elephants	2
	Unit V	
6.	Pedicure, corrective foot care and maintenance of healthy feet of captive elephants housed in different establishments in different seasons	2
	Unit VI	
7.	Hoisting of recumbent elephants, surgical methods of birth control in elephants	1
8.	Limitations and risks of abdominal surgery in elephants (eg. caesarian section, castration, hernia, etc., soft tissue surgery like episiotomy, vestibulotomy, etc.)	2
Practical		
1.	Familiarity with clinical examination procedures	1
2.	Body weight estimation	1
3.	Signs of health and diseases	1
4.	Signs of localized lesions, etc.	1
5.	Familiarity with physical and chemical restraint procedures	1
6.	Drug administrations by various routes-IM, IV, SC, sub-conjuctival, oral, per rectal, etc.	1
7.	Foot examination and foot care procedures	1
8.	Visit to elephant camps	1
9.	Attending clinical procedures, surgeries etc	7

Suggested Reading

- Fowler ME and Mikota SK. 2006. *Biology, Medicine, and Surgery of Elephants*. Blackwell Publishing

Minor Courses for M.V.Sc. Degree programme

Courses of any one department/ discipline from the list given below or as considered relevant by the Advisory Committee from the BSMA approved subjects:

- Veterinary Physiology
- Veterinary Biochemistry
- Veterinary Biotechnology
- Veterinary Anatomy
- Veterinary Medicine
- Veterinary Pathology
- Animal Reproduction, Gynaecology and Obstetrics

Supporting Courses

It could be any subject considered relevant for student's research work. This will be decided by Advisor/ Guide concerned.

Common Courses

The following courses (one credit each) will be offered to all students undergoing Master's degree programme.

- Library and Information Services
- Technical Writing and Communications Skills
- Intellectual Property and its management in Agriculture
- Basic Concepts in Laboratory Techniques
- Agricultural Research, Research Ethics and Rural Development Programmes

Course Title with Credit Load
Ph.D. in Veterinary Surgery and Radiology

Course Code	Course Title	Credit Hours
VSR 601	Clinical Practice-I*	0+2
VSR 602	Clinical Practice-II*	0+2
VSR 603	Clinical Practice-III*	0+2
VSR 604	Cardiovascular Surgery	2+1
VSR 605	Advances in Anaesthesiology	2+1
VSR 606	Advances in Radiology	2+1
VSR 607	Advances in Diagnostic Imaging Techniques	2+1
VSR 608	Advances in Orthopaedics	2+1
VSR 609	Neurosurgery	2+1
VSR 610	Reconstructive and Regenerative Surgery	1+1
VSR 611	Advances in Soft Tissue Surgery	2+1
VSR 612	Advances in Ophthalmology	1+1
VSR 613	Surgical Oncology	1+1
VSR 687	Clinical Case Conference*	0+1
VSR 688	Special Problem in Diagnostic Imaging	0+2
VSR 689	Special Problem in Anaesthesia	0+2
VSR 690	Special Problem in Surgery	0+2
VSR 691	Doctoral Seminar-I	2+0
VSR 692	Doctoral Seminar-II	2+0
VSR 699	Doctoral Research	0+75

*Core Courses

Course Contents
Ph.D. in Veterinary Surgery and Radiology

I. Course Title : Clinical Practice-I
II. Course Code : VSR 601
III. Credit Hours : 0+2

IV. Aim of the course

To learn clinical techniques and procedures in anaesthesia, diagnostic imaging and surgery

V. Practical

Application of different equipment like inhalant anaesthesia machine, Computerized or digital radiography system, Ultrasonography, Endoscopy, Electro-surgery, Cryosurgery, Operating microscope, Phacoemulsification and physiotherapy, Client management and counseling, Treating surgical cases using advances techniques, managing surgical facilities, ICU equipment and personnel, Planning and formulating clinical research projects using the clinical data and facilities, Data analysis and writing of clinical case reports and success stories about the clinical achievements.

I. Course Title : Clinical Practice-II
II. Course Code : VSR 602
III. Credit Hours : 0+2

IV. Aim of the course

To learn clinical techniques and procedures in anaesthesia, Diagnostic imaging and surgery

V. Practical

Application of different equipment like inhalant anaesthesia machine, Computerized or digital Radiography system, Ultrasonography, Endoscopy, Electro-surgery, Cryosurgery, Operating microscope, Phacoemulsification and physiotherapy, Client management and counseling, Treating surgical cases using advances techniques, managing surgical facilities, ICU equipment and personnel, Planning and formulating clinical research projects using the clinical data and facilities, Data analysis and writing of clinical case reports and success stories about the clinical achievements.

I. Course Title : Clinical Practice-III
II. Course Code : VSR 603
III. Credit Hours : 0+2

IV. Aim of the course

To learn clinical techniques and procedures in anaesthesia, Diagnostic imaging and surgery

V. Practical

Application of different equipment like inhalant anaesthesia machine, Computerized or digital radiography system, Ultrasonography, Endoscopy, Electro-surgery, Cryosurgery, Operating microscope, Phacoemulsification and physiotherapy, Client management and counseling, Treating surgical cases using advances techniques, Managing surgical facilities, ICU equipment and personnel, Planning and formulating clinical research projects using the clinical data and facilities, Data analysis and writing of clinical case reports and success stories about the clinical achievements.

I. Course Title : Cardiovascular Surgery

II. Course Code : VSR 604

III. Credit Hours : 2+1

IV. Aim of the course

To learn the basic principles and and gain practical knowledge of diagnosis and treatment of diseases of cardiovascular system.

V. Theory

Unit I

Surgical anatomy, Pathophysiology, Systolic and diastolic functions, Heart failure.

Unit II

Physical examination, Electrocardiography, Cardiac catheterization.

Unit III

Special preoperative considerations for patients undergoing cardiovascular surgery, Surgical approaches to thorax, Different techniques of thoracotomy. Special instruments required in cardio-thoracic surgery, Defibrillator, Heart lung machine

Unit IV

Surgical management of congenital cardiac disorders: Malpositioning, Atrial septal defect, Endocardial cushion defect, Tricuspid valve disorder, Ventricular septal defect, Pulmonic stenosis, Teratology of fallot, Eisenmenger's complex, Anomalous pulmonary venous return, Mitral valve abnormalities, Aortic stenosis, Aortic regurgitation, transposition of the great vessels, Aortic pulmonary window, Persistent arteriosus, Patent ductus arteriosus, Coarctation of aorta, Persistent right aortic arch, Pericardial diaphragmatic hernia

Unit V

Acquired cardiac disorders: Mitral regurgitation, Tricuspid regurgitation, Dirofilariasis, Acquired aortic regurgitation, Endocarditis, Heart block, Cardiomyopathy, Pericarditis, Heart tumours, Hypothermia, Extracorporeal circulatory support, Cardiopulmonary bypass, Artificial heart transplant, Post operative management, Basic peripheral vascular procedures arteriotomy, Venotomy, anastomosis, Portocaval shunts and anomalies

VI. Practical

Instrumentation and suture techniques for cardiovascular surgery, Vascular prostheses, Anticoagulants, Surgical approaches to thorax, Different techniques of thoracotomy, Hand-on-training of different techniques of centesis of thoracic cavity on cadavers, Thoracic drain placement, Demonstration of basic Cardiac procedures, Pericardiocentesis, Pericardiotomy, Cardiac catheterization, and various surgical conditions, Pericardiectomy, on cadaver and clinical cases of constructive pericarditis, Biopsy techniques, Use of IPPV in thoracic surgery.

I. Course Title : Advances in Anaesthesiology
II. Course Code : VSR 605
III. Credit Hours : 2+1
IV. Aim of the course

To learn advance concepts and techniques of veterinary anaeathesia.

V. Theory

Unit I

Cellular and molecular mechanisms of anaesthesia, Effects of anaesthesia on different systems.

Unit II

Drug interactions with anaesthetics, Pharmacokinetics and pharmacodynamics of anaesthetics, CRI and TCI, Computer assisted anaesthesia.

Unit III

Opioids, alpha-2 agonists and ketamine for epidural anaesthesia, Acupuncture and electroanaesthesia.

Unit IV

Critical acre in ICU, Pain transmission and processing, Methods for pain assessment in animals, Multimodal and preemptive analgesia, Techniques and drugs for pain managements.

Unit V

Anaesthesia for selected diseases (cardiovascular dysfunction, pulmonary dysfunction, Neurologic diseases, Renal diseases, Hepatic diseases, Gastrointestinal diseases, Endocrine diseases, Airway diseases).

Unit VI

Anaesthesia for special patients (ocular patients, heart patients, caesarian section patients, trauma patients, neonatal and geriatric patients).

VI. Practical

Various procedures for catheterization of heart and great vessels, Central venous line, Haemodynamic changes and pulmonary function tests during trials of anaesthetics, Electrocardiographic, Encephalographic evaluation of central nervous system activity, Cybernetics, Data acquisition and retrieval, Administration and monitoring of newer anaesthetics combinations.

I. Course Title : Advances in Radiology
II. Course Code : VSR 606
III. Credit Hours : 2+1
IV. Aim of the course

To learn advance theoretical and practical knowledge in radiology.

V. Theory

Unit I

Biological effects of radiations (alpha, beta, X-ray and gamma rays) in vivo and *in-vitro* cellular response following radiation as an immunosuppressive agent.

Unit II

Different kind of projections and positioning, Contrast material, Different contrast techniques, PACS.

Unit III

Radiography of head and neck region, Radiography of thorax, Lung patterns, Radiography of abdominal and pelvic region

Unit IV

Radiography of limbs for lameness and fracture diagnosis, Application of image intensifiers in veterinary practice, Different types of screens.

Unit V

Computerized radiography (CR), Digital radiography (DR), Contrast CT and contrast MRI, PETCT, Advances in scintigraphy.

Unit VI

Radiation therapy in cancer patients, Biological effects of radiation physics, Physics of radiation, Electromagnetic radiations, Hazards of electromagnetic Radiations and protection and bio-safety.

VI. Practical

Radiographic positioning, Radiation safety measures, Handling radioactive material, Clinical radiological diagnosis at Radiology Unit, Demonstration of advanced radiological techniques.

I. Course Title : Advances in Diagnostic Imaging Techniques
II. Course Code : VSR 607
III. Credit Hours : 2+1

IV. Aim of the course

To learn advance theoretical and practical knowledge of ultrasonography, Diagnostic imaging techniques and their interpretations.

V. Theory

Unit I

Techniques of ultrasonography for diagnosis of different affections of neck, thorax (echocardiography, Doppler techniques), Abdomen and pelvis (Urinary bladder and prostrate), Synovial joints, Muscle and tendons, Eye.

Unit II

Interpretation of ultrasonogram of different body organs/ vessels (normal and abnormal), Therapeutic applications of ultrasonography for physiotherapy.

Unit III

Imaging modalities like, MRI, CT scan, Nuclear medicine, Positron emission tomography technique, Single-photon emission computed tomography, etc.

Unit IV

Nuclear Scintigraphy-isotopes (natural and man-made); Cyclotron reactor, Half-life, decay pattern, Storage and handling of radioactive material,

Unit V

Methods in the detection of isotopes, Geiger-Mullar tubes, Photo-multiplier tube, medical use of isotope, Dosimetry, Nuclear medicine and its use in diagnosis of thyroid, Kidney, bone and liver function studies, Labelling of isotope and biological uses, Detonation and fission products, Image storage and transfer, DICOM, PACS and teleinterpretation.

VI. Practical

Hands-on-practice on different visceral organs collected from slaughter house for ultrasonographic scanning in water tub, dry and wet lab training, Demonstration and practice on different clinical cases reported for ultrasonography, Visit to places with facility of other alternate imaging techniques.

I. Course Title : Advances in Orthopaedics

II. Course Code : VSR 608

III. Credit Hours : 2+1

IV. Aim of the course

To learn advance concepts and techniques of treatment of various affections of bones, joints, tendons, ligaments and foot in companion and farm animals.

V. Theory

Unit I

Biomechanics of bone, Fracture etiology, Fracture reduction and different fracture fixation techniques like IM pinning, plating, nailing (inter locking nailing) and external skeletal fixation.

Unit II

Types, Properties, Biomechanics and use of different orthopaedic Implants, Bone grafts and their collection, Preservation, Indications and limitations, Bone graft substitutes like ceramics and composites, Their usage and limitations.

Unit III

Principles of osteogenesis, Osteoinduction and Osteoconduction.

Unit IV

Advances in internal fixation and external skeletal fixation techniques in veterinary orthopaedics.

Unit V

Metabolic bone diseases like rickets, osteomalacia, osteodystrophy and secondary hyperparathyroidism, etc. Classification, diagnosis and treatment of arthritis.

Unit VI

Advances in the management of congenital and acquired disorders of joints like traumatic dislocations, luxations and dysplasia. etiopathology and management of equine lameness including Laminitis, Navicular disease, Quitter, Canker and thrush, Sand cracks, Ring bone, Hygromas, Bursitis, Spavin and Splint.

Unit VII

Affections of muscles, tendons and ligaments, joint prosthesis and transplantation.

Unit VIII

Postoperative management of orthopaedic patients including the role of movement restriction, Weight bearing, Nutritional therapy, Physiotherapy and rehabilitation, Introduction to recovery assessment using lameness score, Gait analysis using computerized software.

VI. Practical

Hands on practice for different internal fixation techniques on cadaver, Management of different types of long bone fractures in different species of domestic animals, with special reference to practice of bone plating, Interlocking nailing and external skeletal fixation, Treatment of metabolic bone diseases in growing animals, Correction of antebrachial deformities including osteotomies and limb lengthening procedures, preservation of bone grafts, practice of bone grafting and use of osteoinducers in Clinical situation, Clinical and radiographic evaluation of various joint affections, Reduction and fixation of different joint luxations like coxo-femoral, Patellar, femoro-tibial, hock, scapulo-humeral, elbow and temporomandibular, Techniques of osteotomy, arthrodesis and joint replacement, Repair of tendon and ligament injuries, Diagnosis and treatment of various conditions causing lameness in equines and bovines.

I. Course Title : Neurosurgery
II. Course Code : VSR 609
III. Credit Hours : 2+1

IV. Aim of the course

To learn principles and techniques of treatment of surgical affections of nervous system in animals

V. Theory

Unit I

Nervous system – anatomy, physiology and pathological manifestations.

Unit II

Clinical neurology, Therapeutic Neurectomy, Nerve anastomosis, Pathogenesis of disease of the central nervous system.

Unit III

Diagnostic methods – Electrodiagnostic methods, Neuro radiology.

Unit IV

Fundamentals of neurosurgery, Surgical approaches to brain, Surgical diseases of peripheral nerves, Surgical affections and approaches to the spine, Diseases of the spinal column, Intervertebral disc diseases.

Unit V

Surgical approaches to brain and intracranial surgery.

VI. Practical

Methods for clinical and neurological examination including electro-encephalography, electromyography and electro-diagnostic testing, Collection of CSF and its evaluation, Techniques of myelography, Vertebral venography, Pneumoventriculography, Cerebral arteriography and cavernus sinus venography, Management of vertebral fractures and luxations with stabilization, Treatment of spinal cord compression, viz., Disc fenestration, Hemilaminectomy, Dorsal laminectomy and ventral slot, Techniques of peripheral nerve anastomosis and reconstruction of peripheral nerves.

I. Course Title : Reconstructive And Regenerative Surgery

II. Course Code : VSR 610

III. Credit Hours : 1+1

IV. Aim of the course

To learn principles and techniques of reconstructive and regenerative surgery.

V. Theory

Unit I

Principles of regenerative medicine, Tissue homeostasis, Tissue and organ transplantation, Histo-compatibility matching, Transplantation immunity and host graft reaction, Immunosuppression

Unit II

Classification, Isolation, Characterization, Storage and application of stem cells, Extracellular matrix, Microenvironment and growth factors for tissue repair and regeneration.

Unit III

Synthetic and biological scaffols, Preparation of biological scaffold and its role in Tissue regeneration, Whole organ decellularization and its application, Biomimetic scaffolds.

Unit IV

Designing for 3D printing, Bio-fabrication of organ and Tissue substitutes and its applications, Ethical concerns in regenerative medicine, GMP protocols and its applications in regenerative medicine

Unit V

Current techniques in designing and clinical application of biomaterials, Mechanical and functional testing of biomaterials, Biocompatibility testing

VI. Practical

Collection of bone marrow derived stem cells from different species of animals, Growth and differentiation of stem cells in different lineages, Decellularization of different tissues and organs, cell growth on different scaffolds, Clinical application of stem cells

I. Course Title : Advances in Soft Tissue Surgery

II. Course Code : VSR 611

III. Credit Hours : 2+1

IV. Aim of the course

To learn advanced concepts and practical techniques of treatment of soft tissue surgery, laparoscopic and minimally invasive surgery

V. Theory

Unit I

Advances in surgeries of ENT affections of small and large animals, Rhinoscopy-rhinotomy, Tumors of turbinates, Cheiloplasty, Hare lip correction, Salivary duct ligation, Parotid gland abalation, Bullaosteotomy, Buccotomy procedures, Glossophagia, Self suck correction.

Unit II

Upper respiratory tract affection in small and large animals, Barchiochephalic air way syndrome, Laryngeal paralysis, Tracheal collapse, Tracheostomy (temporary/ permanent), Chest trauma, Chest tube placement, Thoracocentesis, Pneumectomy, (partial/ unilateral), Heart lung transplant, Thoracic duct ligation, Trans tracheal intubation, Thoracoscopic procedure.

Unit III

Esophageal affections in small and large animals, Dilatation, Diverticulum, PRAA-Mullers surgery, Gastroesophageal intussception, Short bowel syndrome, Colostomy, megacolon, Rectal tube placement, Rectal diverticulum, Gastroscopy techniques

Unit IV

Pyelolithotomy, Lithotripsy, Renal transplantation, Ectopic ureter, Prostatectomy, Urinary incontinence, Penile urethosotomy, Urethroscopic retrival of urolith, Endoscopic ureter stunt placement.

Unit V

Thyroidectomy in cats, Liver lobectomy, Cholelithiasis, Cholecystectomy, Cholecystoduo denostomy, Porto caval shunt, Adrenalectomy.

Unit VI

Skin grafting, Subdermal, Axial skeletal, Omocervical axial pattern flap, Thoracodorsal axial pattern flap, Superficial brachial axial pattern flap, Caudal superficial epigastric axial pattern flap, Cranial superficial epigastric axial pattern flap, Deep circumflex iliac dorsal axial pattern flap, Deep circumflex iliac ventral axial pattern flap, Genicular axial pattern flap, Reverse saphenous conduit flap, Caudal auricular axial pattern flap, Split thickness and full thickness grafts, Reconstructive surgical procedures.

VI. Practical

Endoscopic surgical procedures in small and large animals, Chest tube placement, Rhinoscopy, Thoracoscopy, Broncoscopy, Gastroscopy, Colonoscopy, Urethrocystoscopy, Laproscopic surgical techniques, Skin flap and grafting techniques, Tracheaostomy, Renal graft cystoplasty.

I. Course Title : Advances in Ophthalmology

II. Course Code : VSR 612

III. Credit Hours : 1+1

IV. Aim of the course

To learn advanced concepts and practical techniques in ophthalmology.

V. Theory

Unit I

Embryology of the eye, study of ocular physiology and biochemistry, structure and function of eye and adenexa, Physiology of vision, Electrophysiology of visual system

Unit II

Advances in diagnosis and diseases of the eye and adnexia.

Unit III

Ocular neoplasia, advances in neuro ophthalmology, Advances in ophthalmic pharmacology, microbiology and nutrition

Unit IV

Advances in ocular imaging, Advances in ocular anaesthesia and analgesia

Unit V

Advances in ocular emergencies, Opthalmology of exotic species and lab animals, ocular toxicology

Unit VI

Corneal grafting, application of nanotechnology and stem cell therapy in veterinary ophthalmology.

VI. Practical

Exposure to latest ophthalmic instrumentation like phaco, ultrasound, cataract surgery and lens implantation, corneal transplantation.

I. Course Title : Surgical Oncology

II. Course Code : VSR-613

III. Credit Hours : 1+1

IV. Aim of the course

To learn about tumor genesis and treatment in animals.

V. Theory

Unit I

Biology of neoplastic disease: etiology, cellular mechanism, principles of surgical oncology.

Unit II

Diagnosis, classification and clinical staging of tumors and decision making for therapy, metastasis.

Unit III

Surgical management: Surgical excision of tumors, Cytoreductive surgery, Surgery for metastatic disease, Palliative surgery, Evaluation and interpretation of surgical margins.

Unit IV

Clinical signs, Diagnosis and treatment options of tumors of skin, Soft tissues, skeletal system, Head and neck, Gastro-intestinal tract, Respiratory tract, Urinary tract, Genital tract, Mammary gland, Nervous system, Endocrine system, haematopoietic system, the eye and orbit and miscellaneous tumours.

Unit V

Radiation therapy, Chemotherapy, Electrochemotherapy, Cryotherapy and targeted therapy. Side effects of radio and chemotherapy, Nutritional management of cancer patients, Basics of immunotherapy in cancer management.

VI. Practical

General approaches to the diagnosis of neoplasia: Fine needle aspiration biopsy, needle core biopsy, excisional and incisional biopsy, bone marrow biopsy, lymph node biopsy, percutaneous lung biopsy, bone biopsy, ultrasound/ laparoscope guided biopsy.

I. Course Title : Clinical Case Conference
II. Course Code : VSR 687
III. Credit Hours : 0+1

IV. Practical

Present seminar on unusual/ interesting clinical cases done in the semester. Compile them from presentation to follow up and also submit the write up in soft or hard copy.

I. Course Title : Special Problem in Diagnostic Imaging
II. Course Code : VSR 688
III. Credit Hours : 0+2

IV. Practical

Investigative diagnosing imaging problems in clinical models, didactic and interpersonal learning-teaching, problem solving self-learning strategies in problems related to surgery

I. Course Title : Special Problem in Anaesthesia
II. Course Code : VSR 689
III. Credit Hours : 0+2

IV. Practical

Investigative anaesthetic problems in clinical models, didactic and interpersonal learning-teaching, problem solving self-learning strategies in problems related to anaesthesia

I. Course Title : Special Problem in Surgery
II. Course Code : VSR 690
III. Credit Hours : 0+2

IV. Practical

Investigative surgical problems in clinical models, didactic and interpersonal learning-teaching, problem solving self-learning strategies in problems related to surgery

VSR 691 Doctoral Seminar-I (2+0)
VSR 692 Doctoral Seminar-II (2+0)
VSR 699 Doctoral Research (0+75)

Course Outline: Lecture wise

VSR 604: Cardiovascular Surgery (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Surgical anatomy, pathophysiology	1
2.	Systolic and diastolic functions	1
3.	Heart failure	1
	Unit II	
4.	Physical examination	1
5.	Electrocardiography	1
6.	Cardiac catheterization	1
	Unit III	
7.	Special preoperative considerations for patients undergoing cardiovascular surgery, surgical approaches to thorax	1
8.	Different techniques of thoracotomy	1
9.	Special instruments required in cardio-thoracic surgery, defibrillator, heart lung machine	1
	Unit IV	
10.	Surgical management of congenital cardiac disorders: malpositioning, atrial septal defect, endocardial cushion defect	1
11.	Surgical management of congenital cardiac disorders: tricuspid valve disorder, ventricular septal defect	1
12.	Surgical management of congenital cardiac disorders: pulmonic stenosis, teratology of fallot	1
13.	Surgical management of congenital cardiac disorders: eisenmenger's complex, anomalous pulmonary venous return	1
14.	Surgical management of congenital cardiac disorders: mitral valve abnormalities, aortic stenosis, aortic regurgitation	1
15.	Surgical management of congenital cardiac disorders: transposition of the great vessels, aortic pulmonary window, persistent arteriosus	1
16.	Surgical management of congenital cardiac disorders: patent ductus arteriosus, coarctation of aorta, persistent right aortic arch	1
17.	Surgical management of congenital cardiac disorders: pericardial diaphragmatic hernia	1
	Unit V	
18.	Acquired cardiac disorders: mitral regurgitation, tricuspid regurgitation	1
19.	Acquired cardiac disorders: dirofilariasis	1
20.	Acquired cardiac disorders: acquired aortic regurgitation, endocarditis	1
21.	Acquired cardiac disorders: heart block	1
22.	Acquired cardiac disorders: cardiomyopathy, pericarditis, heart tumours	1
23.	Acquired cardiac disorders: hypothermia, extracorporeal circulatory support	1

S. No.	Topics	No. of Lectures/ Practicals
24.	Acquired cardiac disorders: cardiopulmonary bypass	1
25.	Acquired cardiac disorders: artificial heart transplant, post operative management	1
26.	Acquired cardiac disorders: basic peripheral vascular procedures arteriotomy, venotomy, anastomosis	1
27.	Acquired cardiac disorders: portocaval shunts and anomalies	1
Practical		
1.	Instrumentation and suture techniques for cardiovascular surgery	2
2.	Vascular prostheses	1
3.	Anticoagulants	1
4.	Surgical approaches to thorax	1
5.	Different techniques of thoracotomy	1
6.	Hand-on-training of techniques of centesis of thoracic cavity on cadavers	1
7.	Hand-on-training of thoracic drain placement	1
8.	Demonstration of pericardiocentesis	1
9.	Demonstration of pericardiotomy	1
10.	Demonstration of cardiac catheterization	1
11.	Demonstration of pericardiectomy on cadaver and clinical cases of constructive pericarditis	1
12.	Demonstration of cardiac biopsy techniques	1
13.	Demonstration of use of IPPV in thoracic surgery	1

Suggested Reading

- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Slatter DH. 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.

VSR 605: Advances in Anaesthesiology (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Cellular and molecular mechanisms of anaesthesia	1
2.	Effects of anaesthesia on different systems	3
	Unit II	
3.	Drug interactions with anaesthetics	1
4.	Pharmacokinetics and pharmacodynamics of anaesthetics	2
5.	CRI and TCI, computer assisted anaesthesia	1
	Unit III	
6.	Opioids, alpha-2 agonists and ketamine for epidural anaesthesia	2
7.	Acupuncture and electroanaesthesia	
	Unit IV	
8.	Critical acre in ICU	1
9.	Pain transmission and processing, methods for pain assessment in animals	1
10.	Multimodal and preemptive analgesia	1
11.	Techniques and drugs for pain managements	1

S. No.	Topics	No. of Lectures/ Practicals
	Unit V	
12.	Anaesthesia for selected diseases (cardiovascular dysfunction)	1
13.	Anaesthesia for selected diseases (pulmonary dysfunction)	1
14.	Anaesthesia for selected diseases (neurologic diseases)	1
15.	Anaesthesia for selected diseases (renal diseases)	1
16.	Anaesthesia for selected diseases (hepatic diseases)	1
17.	Anaesthesia for selected diseases (gastrointestinal diseases)	1
18.	Anaesthesia for selected diseases (endocrine diseases, airway diseases)	1
	Unit VI	
19.	Anaesthesia for special patients (ocular patients)	1
20.	Anaesthesia for special patients (heart patients)	1
21.	Anaesthesia for special patients (caesarian section patients)	1
22.	Anaesthesia for special patients (trauma patients)	1
23.	Anaesthesia for special patients (neonatal patients)	1
24.	Anaesthesia for special patients (geriatric patients)	1
Practical		
1.	Various procedures for catheterization of heart and great vessels	2
2.	Central venous line	1
3.	Haemodynamic changes during trials of anaesthetics	2
4.	Electrocardiography	1
5.	Encephalographic evaluation of central nervous system activity	1
6.	Cybernetics	1
7.	Data acquisition and retrieval	1
8.	Administration and monitoring of newer anaesthetics combinations	6

Suggested Reading

- Aronson LR. 2016. *Small Animal Surgical Emergencies*. Wiley Blackwell.
- Clarke KW, Trim CM and Hall LW. 2013. *Veterinary Anaesthesia*. 11th ed. WB Saunders.
- Grim KA, Lamont LA, Tranquilli WJ, Greene SA and Robertson SA. 2015. *Veterinary Anaesthesia and Analgesia*. 5th ed. Lumb and Jones. Wiley Blackwell.
- Grim KA, Tranquilli WJ and Lamont LA. 2011. *Essentials of Small Animal Anesthesia and Analgesia*. 2nd ed. Wiley Blackwell.
- Paddleford RR. 1999. *Manual of Small Animal Anesthesia*. 2nd ed. WB Saunders.

VSR 606: Advances in Radiology (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Biological effects of radiations (alpha, beta, X-ray and gamma rays) *in vivo* and *in-vitro* cellular response following radiation as an immunosuppressive agent	4
	Unit II	
2.	Different kind of projections and positioning, contrast material, different contrast techniques, PACS	4
	Unit III	
3.	Radiography of head region	1

S. No.	Topics	No. of Lectures/ Practicals
4.	Radiography of neck region	1
5.	Radiography of thorax	1
6.	Lung patterns	1
7.	Radiography of abdominal region	1
8.	Radiography of pelvic region	1
	Unit IV	
9.	Radiography of limbs for lameness and fracture diagnosis	1
10.	Application of image intensifiers in veterinary practice	1
11.	Different types of screens	1
	Unit V	
12.	Computerized radiography (CR)	1
13.	Digital radiography (DR)	1
14.	Contrast CT	1
15.	Contrast MRI	1
16.	PETCT	1
17.	Advances in scintigraphy	1
18.	Radiation therapy in cancer patients	1
19.	Biological effects of radiation physics	1
20.	Physics of radiation, electromagnetic radiations	1
21.	Hazards of electromagnetic radiations and protection and bio-safety	2
Practical		
1.	Radiographic positioning	3
2.	Radiation safety measures	1
3.	Handling radioactive material	1
4.	Clinical radiological diagnosis at Radiology Unit	8
5.	Demonstration of advanced radiological techniques	2

Suggested Reading

- Bargai U, Pharr, JW and Morgan JP. 1989. *Bovine Radiology*. Lowa State University Press, Ames.
- Bushong SC. 2017. *Radiologic Science for Technologists*. 11th ed. CV Mosby.
- Gillette EL, Thrall DE and Lebel JL. (Eds.). 1977. *Carlson's Veterinary Radiology*. Lea and Febiger.
- Kealy JK, McAllister H and Graham JP. (Eds.). 2011. *Diagnostic Radiology and Ultrasonography of the Dog and Cat*. 5th ed. WB Saunders, Philadelphia.
- Morgan JP. 1972. *Radiology in Veterinary Orthopaedics*. Lea and Febiger.
- Thrall DE. 2017. *Textbook of Veterinary Diagnostic Radiology*. 7th ed. Saunders, Philadelphia.

VSR 607: Advances in Diagnostic Imaging Techniques (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Techniques of ultrasonography for diagnosis of different affections of neck	1
2.	Techniques of ultrasonography for diagnosis of different affections of thorax (echocardiography, Doppler techniques)	3

S. No.	Topics	No. of Lectures/ Practicals
3.	Techniques of ultrasonography for diagnosis of different affections of abdomen and pelvis (Urinary bladder and prostrate)	1
4.	Techniques of ultrasonography for diagnosis of different affections of synovial joints	1
5.	Techniques of ultrasonography for diagnosis of different affections of muscle and tendons.	1
6.	Techniques of ultrasonography for diagnosis of different affections of eye.	1
	Unit II	
7.	Interpretation of ultrasonogram of different body organs/ vessels (normal and abnormal)	3
8.	Therapeutic applications of ultrasonography for physiotherapy	1
	Unit III	
9.	Imaging modalities like, MRI, CT scan, nuclear medicine, positron emission tomography technique, single-photon emission computed tomography etc	4
10.	Nuclear Scintigraphy-isotopes (natural and man-made); cyclotron reactor, half-life, decay pattern, storage and handling of radioactive material	4
	Unit IV	
11.	Methods in the detection of isotopes, Geiger-Mullar tubes, photo-multiplier tube, medical use of isotope, dosimetry	2
12.	Nuclear medicine and its use in diagnosis of thyroid	1
13.	Nuclear medicine and its use in diagnosis of kidney	1
14.	Nuclear medicine and its use in diagnosis of bone	1
15.	Nuclear medicine and its use in diagnosis of liver function studies	1
16.	Labelling of isotope and biological uses, detonation and fission products, image storage and transfer, DICOM, PACKS and teleinterpretation	3
Practical		
1.	Hands-on-practice on different visceral organs collected from slaughter house for ultrasonographic scanning in water tub, dry and wet lab training	6
2.	Demonstration and practice on different clinical cases reported for ultrasonography	7
3.	Visit to places with facility of other alternate imaging techniques	2

Suggested Reading

- Bargai U, Pharr, JW and Morgan JP. 1989. *Bovine Radiology*. Lowa State University Press, Ames.
- Barr FJ and Gaschen L. 2011. *BSAVA Manual of Canine and Feline Ultrasonography*. British Small Animal Veterinary Association.
- Boon JA. 2011. *Veterinary Echocardiography*. 2nd ed. Wiley-Blackwell.
- Bushong SC. 2017. *Radiologic Science for Technologists*. 11th ed. CV Mosby.
- Butler JA, Colles CM, Dyson SJ, Kold SE and Poulos PW. 2017. *Clinical Radiology of the Horse*. 4th ed. Wiley Blackwell.
- Gillette EL, Thrall DE and Lebel JL. (Eds.). 1977. *Carlson's Veterinary Radiology*. Lea and Febiger.
- Goddard PJ. 1995. *Veterinary Ultrasonography*. CABI.

- Kealy JK, McAllister H and Graham JP. (Eds.). 2011. *Diagnostic Radiology and Ultrasonography of the Dog and Cat*. 5th ed. WB Saunders, Philadelphia.
- Mannion P. 2006. *Diagnostic Ultrasound in Small Animal Practice*. Blackwell Science.
- Mantis P. 2016. *Practical Small Animal Ultrasonography Abdomen*. SERVET, Spain.
- Morgan JP@. 1972. *Radiology in Veterinary Orthopaedics*. Lea and Febiger.
- Nyland TG and Mattoon JS. 2002. *Small Animal Diagnostic Ultrasound*. WB Saunders.
- Thrall DE. 2017. *Text book of Veterinary Diagnostic Radiology*. 7th ed. Saunders, Philadelphia.
- Weisse C and Berent A (Eds.) 2015. *Veterinary Image Guided Interventions*. Wiley Blackwell.

VSR 608: Advances in Orthopaedics (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Biomechanics of bone, fracture etiology	1
2.	Fracture reduction and different fracture fixation techniques like IM pinning	1
3.	Fracture reduction and different fracture fixation techniques like plating	1
4.	Fracture reduction and different fracture fixation techniques like nailing (inter locking nailing) and external skeletal fixation	1
5.	Fracture reduction and different fracture fixation techniques like external skeletal fixation	1
	Unit II	
6.	Types, properties, biomechanics and use of different orthopaedic implants	1
7.	Bone grafts and their collection, preservation, indications and limitations	1
8.	Bone graft substitutes like ceramics and composites, their usage and limitations	1
	Unit III	
9.	Principles of osteogenesis, osteoinduction and osteoconduction	2
	Unit IV	
10.	Advances in internal fixation techniques in veterinary orthopaedics	2
11.	Advances in internal fixation techniques in veterinary orthopaedics	
12.	Advances in external skeletal fixation techniques in veterinary orthopaedics	2
13.	Metabolic bone diseases like rickets, osteomalacia, osteodystrophy and secondary hyperparathyroidism, etc.	2
14.	Classification, diagnosis and treatment of arthritis.	3
15.	Advances in the management of congenital and acquired disorders of joints like traumatic dislocations, luxations and dysplasia.	2
16.	Etiopathology and management of equine lameness including laminitis, navicular disease, quitter, canker and thrush, sand cracks, ring bone, hygromas, bursitis, spavin and splint.	5
17.	Affections of muscles, tendons and ligaments	1
18.	Joint prosthesis and transplantation	1
	Unit V	
19.	Postoperative management of orthopaedic patients including the role of movement restriction, weight bearing, nutritional therapy, physiotherapy and rehabilitation	2
20.	Introduction to recovery assessment using lameness score, gait analysis using computerized software	2

S. No.	Topics	No. of Lectures/ Practicals
Practical		
1.	Hands on practice for different internal fixation techniques on cadaver	4
2.	Management of different types of long bone fractures in different species of domestic animals, with special reference to practice of bone plating	1
3.	Management of different types of long bone fractures in different species of domestic animals, with special reference to practice of interlocking nailing	1
4.	Management of different types of long bone fractures in different species of domestic animals, with special reference to practice of external skeletal fixation	1
5.	Treatment of metabolic bone diseases in growing animals	1
6.	Correction of antebrachial deformities including osteotomies and limb lengthening procedures	1
7.	Preservation of bone grafts	1
8.	Practice of bone grafting and use of osteoinducers in clinical situation	1
9.	Clinical and radiographic evaluation of various joint affections	1
10.	Reduction and fixation of different joint luxations like coxo-femoral, patellar, femoro-tibial, hock, scapulo-humeral, elbow and temporomandibular	1
11.	Techniques of osteotomy, arthrodesis and joint replacement	1
12.	Repair of tendon and ligament injuries	1
13.	Diagnosis and treatment of various conditions causing lameness in equines	1
14.	Diagnosis and treatment of various conditions causing lameness in bovines	1

Suggested Reading

- Auer JA and Stick JA. 2017. *Equine Surgery*. 4th ed. Elesvier Saunders.
- Baxter GM. (Ed.). 2011. *Adams and Stashak's Lameness in Horses*. 6th ed. Wiley-Blackwell
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders.
- Greenough PR. 2007. *Bovine Laminitis and Lameness*. WB Saunders.
- Newton CD and Nunamaber DM. (Eds.). 1985. *Textbook of Small Animal Orthopaedics*. JB Lippincott.
- Oehme FW and Prier JE. (Eds.). 1974. *Textbook of Large Animal Surgery*. Williams and Wilkins.
- Ross MW and Dyson SJ. 2011. *Diagnosis and Management of Lameness in the Horse*. 2nd ed. Elsevier Saunders.
- Tyagi RPS and Singh J. (Eds.). 1993. *Ruminant Surgery*. CBS
- Weaver AD, Jean GS and Steiner A. 2007. *Bovine Surgery and Lameness*. 2nd ed. Wiley-Blackwell.

VSR 609: Neurosurgery (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Nervous system – anatomy, physiology and pathological manifestations	5

S. No.	Topics	No. of Lectures/ Practicals
	Unit II	
2.	Clinical neurology	1
3.	Therapeutic neurectomy	1
4.	Nerve anastomosis	1
5.	Pathogenesis of disease of the central nervous system	1
	Unit III	
6.	Diagnostic methods – electrodiagnostic methods, neuro radiology	4
	Unit IV	
7.	Fundamentals of neurosurgery	1
8.	Surgical approaches to brain	1
9.	Surgical diseases of peripheral nerves	1
10.	Surgical approaches to brain and intracranial surgery	1
11.	Surgical affections and approaches to the spine	2
12.	Diseases of the spinal column	1
13.	Intervertebral disc diseases	1
	Unit V	
14.	Surgical approaches to brain and intracranial surgery	3
Practical		
1.	Methods for clinical and neurological examination	1
2.	Electro-encephalography	1
3.	Electromyography and electro-diagnostic testing	2
5.	Collection of CSF and its evaluation	2
7.	Techniques of myelography	1
8.	Vertebral venography	1
9.	Pneumoventriculography	1
10.	Cerebral arteriography	1
11.	Cavernus sinus venography	1
12.	Management of vertebral fractures and luxations with stabilization	1
13.	Treatment of spinal cord compression, viz., disc fenestration, hemilaminectomy, dorsal laminectomy and ventral slot	2
15.	Techniques of peripheral nerve anastomosis and reconstruction of peripheral nerves	2

Suggested Reading

- Dewey CW and C da Costa R. 2016. *Practical Guide to Canine and Feline Neurology*, 3rd ed. Wiley Blackwell.
- Lorenz MD, Coastes JR and Kent M. 2011. *Handbook of Veterinary Neurology*, 5th ed. Elsevier.

VSR 610: Reconstructive and Regenerative Surgery (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Principles of regenerative medicine, tissue homeostasis	1
2.	Tissue and organ transplantation, histo-compatibility matching	1

S. No.	Topics	No. of Lectures/ Practicals
3.	Transplantation immunity and host graft reaction, immunosuppression	1
	Unit II	
4.	Classification, isolation, characterization, storage and application of stem cells, extracellular matrix,	3
5.	Microenvironment and growth factors for tissue repair and regeneration	1
	Unit III	
6.	Synthetic and biological scaffols	1
7.	Preparation of biological scaffold and its role in tissue regeneration	1
8.	Whole organ decellularization and its application, biomimetic scaffolds	1
	Unit IV	
9.	Designing for 3D printing, bio-fabrication of organ and tissue substitutes and its applications	1
10.	Ethical concerns in regenerative medicine	1
11.	GMP protocols and its applications in regenerative medicine	1
	Unit V	
12.	Current techniques in designing and clinical application of biomaterials,	2
13.	Mechanical and functional testing of biomaterials	1
14.	Biocompatibility testing	1
Practical		
1.	Collection of bone marrow derived stem cells from different species of animals	3
2.	Growth and differentiation of stem cells in different lineages	1
3.	Decellularization of different tissues and organs	6
4.	Cell growth on different scaffolds	3
5.	Clinical application of stem cells	3

Suggested Reading

- Bojrab Joseph M, Monnet Eric. 2010. *Mechanisms of Disease in Small Animal Surgery*, 3rd Teton New Media, U.S.
- Griffers D and Hamaide A. (Eds.). 2016. *Complications in Small Animal Surgery*. Wiley Blackwell.
- Theoret C and Schumacher J. 2017. *Equine Wound Management*. Griffon, D and Hamaide A 2016. *Complications in Small Animal Surgery*, Wiley Blackwell.

VSR 611: Advances in Soft Tissue Surgery (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Advances in surgeries of ENT affections of small and large animals-rhinoscopy, rhinotomy, tumors of turbinates	1
2.	Advances in surgeries of ENT affections of small and large animals-cheiloplasty, hare lip correction, salivary duct ligation, parotid gland abalation	1
3.	Advances in surgeries of ENT affections of small and large animals-bullaosteotomy, buccotomy procedures, glossoplagia, self suck correction	1

S. No.	Topics	No. of Lectures/ Practicals
	Unit II	
4.	Upper respiratory tract affection in small and large animals- barchiochephalic air way syndrome, laryngeal paralysis	1
5.	Upper respiratory tract affection in small and large animals- tracheal collapse, tracheostomy (temporary/ permanent)	1
6.	Upper respiratory tract affection in small and large animals- chest trauma, chest tube placement, thoracocentesis	1
7.	Upper respiratory tract affection in small and large animals- pneumectomy, (partial/ unilateral), heart lung transplant, thoracic duct ligation	1
8.	Upper respiratory tract affection in small and large animals- thoracic duct ligation, trans tracheal intubation, thoracoscopic procedure	1
	Unit III	
9.	Esophageal affections in small and large animals- dilatation, diverticulum, PRAA- Mullers surgery	1
10.	Esophageal affections in small and large animals- gastroesophageal intussception, short bowel syndrome	1
11.	Esophageal affections in small and large animals- colostomy, megacolon, rectal tube placement	1
12.	Esophageal affections in small and large animals- rectal diverticulum, gastroscopy techniques	1
	Unit IV	
13.	Pyelolithotomy, lithotripsy	1
14.	Renal transplantation	1
15.	Ectopic ureter, prostatectomy, urinary incontinence	1
16.	Penile urethosotomy, urethroscopic retrival of urolith, endoscopic ureter stunt placement	1
	Unit V	
17.	Thyroidectomy in cats, liver lobectomy	1
18.	Cholelithiasis, cholecystectomy, cholecystoduo denostomy	1
19.	Porto caval shunt, adrenalectomy	1
	Unit VI	
20.	Skin grafting, subdermal, axial skeletal, omocervical axial pattern flap	1
21.	Thoracodorsal axial pattern flap, superficial brachial axial pattern flap, caudal superficial epigastric axial pattern flap	1
22.	Cranial superficial epigastric axial pattern flap, deep circumflex iliac dorsal axial pattern flap	1
23.	Deep circumflex iliac ventral axial pattern flap, genicular axial pattern flap	1
24.	Reverse saphenous conduit flap, caudal auricular axial pattern flap,	1
25.	Split thickness and full thickness grafts	1
26.	Reconstructive surgical procedures	1

Practical

1.	Endoscopic surgical procedures in small and large animals	1
2.	Chest tube placement	1
3.	Rhinoscopy	1
4.	Thoracoscopy	1
5.	Bronchoscopy	1
6.	Gastroscopy	1
7.	Colonoscopy	1

S. No.	Topics	No. of Lectures/ Practicals
8.	Urethrocystoscopy	1
9.	Laparoscopic surgical techniques	2
10.	Skin flap and grafting techniques	3
11.	Tracheaostomy	1
12.	Renal graft cystoplasty	1

Suggested Reading

- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders
- Slatter DH. 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.
- Yool DA. 2012. *Small Animal Soft Tissue Surgery*. CABI

VSR 612: Advances in Ophthalmology (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Embryology of the eye, study of ocular physiology and biochemistry	1
2.	Structure and function of eye and adenexa, physiology of vision, electrophysiology of visual system	1
	Unit II	
3.	Advances in diagnosis and diseases of the eye and adnexia	2
	Unit III	
4.	Ocular neoplasia, advances in neuro ophthalmology	1
5.	Advances in ophthalmic pharmacology, microbiology and nutrition	1
	Unit IV	
6.	Advances in ocular imaging	1
7.	Advances in ocular anaesthesia and analgesia	1
	Unit V	
8.	Advances in ocular emergencies	1
9.	Opthalmology of exotic species	1
10.	Opthalmology of lab animals	1
11.	Ocular toxicology	1
	Unit VI	
12.	Corneal grafting	1
13.	Application of nanotechnology in veterinary ophthalmology	1
14.	Application of stem cell therapy in veterinary ophthalmology	1
Practical		
1.	Exposure to latest ophthalmic instrumentation like phaco	1
2.	Exposure to latest ophthalmic instrumentation like ultrasound	1
3.	Exposure to cataract surgery and lens implantation	10
4.	Corneal transplantation	3

Suggested Reading

- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders
- Gelatt KN. 2014. *Essentials of Veterinary Ophthalmology*. 3rd ed. Wiley Blackwell. US.
- Gilger BC. 2017. *Equine Ophthalmology*, 3rd ed. Wiley Blackwell.
- Maggs DJ, Miller PE and Ofri R. 2017. *Slatter's Fundamentals of Veterinary Ophthalmology*. 6th ed. Saunders.
- Slatter DH. 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.

VSR 613: Surgical Oncology (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
	Unit I	
1.	Biology of neoplastic disease: etiology, cellular mechanism	1
2.	Principles of surgical oncology	1
	Unit II	
3.	Diagnosis, classification and clinical staging of tumors and decision making for therapy, metastasis	2
	Unit III	
4.	Surgical management: surgical excision of tumors, cytoreductive surgery	1
5.	Surgical management: surgery for metastatic disease, palliative surgery, evaluation and interpretation of surgical margins	1
	Unit IV	
6.	Clinical signs, diagnosis and treatment options of tumors of skin, soft tissues	1
7.	Clinical signs, diagnosis and treatment options of tumors of skeletal system, head and neck	1
8.	Clinical signs, diagnosis and treatment options of tumors of gastro-intestinal tract, respiratory tract	1
9.	Clinical signs, diagnosis and treatment options of tumors of urinary tract, genital tract, mammary gland	1
10.	Clinical signs, diagnosis and treatment options of tumors of nervous system, endocrine system, haematopoietic system	1
11.	Clinical signs, diagnosis and treatment options of tumors of the eye and orbit and miscellaneous tumours	1
	Unit V	
12.	Radiation therapy, chemotherapy	1
13.	Electrochemotherapy, cryotherapy and targeted therapy	1
14.	Side effects of radio and chemotherapy	1
15.	Nutritional management of cancer patients, basics of immunotherapy in cancer management	1
Practical		
1.	Fine needle aspiration biopsy	1
2.	Needle core biopsy	1
3.	Excisional biopsy	1
4.	Incisional biopsy	1
5.	Bone marrow biopsy	1
6.	Lymph node biopsy	1

S. No.	Topics	No. of Lectures/ Practicals
7.	Percutaneous lung biopsy	1
8.	Bone biopsy	1
9.	Ultrasound guided biopsy	1
10.	Laparoscope guided biopsy	1

Suggested Reading

- Kudnig ST and Sequin B. 2012. *Veterinary Surgical Oncology*, Wiley Blackwell.
- Fossum TW. 2018. *Small Animal Surgery*. 5th ed. Mosby.
- Fubini SL and Ducharme NG. 2016. *Farm Animal Surgery*. 2nd ed. Saunders.
- Maggs DJ, Miller PE and Ofri R. 2017. *Slatter's Fundamentals of Veterinary Ophthalmology*. 6th ed. Saunders.
- Slatter DH. 2003. *Textbook of Small Animal Surgery*. 3rd ed. WB Saunders.

Minor Courses for Ph.D. Degree programme

Courses of any one department/ discipline from the list given below:

- Veterinary Physiology
- Veterinary Biochemistry
- Veterinary Biotechnology
- Veterinary Anatomy
- Veterinary Medicine
- Veterinary Pathology
- Animal Reproduction, Gynaecology and Obstetrics
- Animal Biotechnology

Supporting Courses

It could be any subject considered relevant for student's research work. This will be decided by Advisor/ Guide concerned.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Clinical Subjects
– Veterinary Medicine

Preamble
(Veterinary Medicine)

Presently, the veterinary education at undergraduate level is regulated by Veterinary Council of India. Two separate departments of Veterinary Clinical Medicine, Ethics and Jurisprudence and Veterinary Epidemiology and Preventive Medicine were merged in 2008 following implementation of VCI norms as per Minimum Standards of Veterinary Education-2008 (MSVE-2008) and also being followed and strictly implemented as per revised VCI norms (MSVE-2016) issued by The Gazette of India Notification. Single department of Veterinary Medicine is functional in most of the colleges and universities of Veterinary Sciences including Indian Veterinary Research Institute (IVRI), Izatnagar, Bareilly. Therefore, the courses in clinical and preventive medicine have been redesigned under the subject of veterinary medicine. The national eligibility test (NET), being conducted by ICAR, New Delhi, in the subject of veterinary medicine includes syllabus for both clinical and infectious diseases. Course curriculum related to Epidemiology will be covered by the Department of Veterinary Public Health and Epidemiology as per the mandate of the BSMA Committee constituted by ICAR on the recommendation by National Core Group.

The Master's and Doctoral courses and the contents were critically examined for revisions in the light of advances transpired in the discipline of veterinary medicine during the last ten years. Precedence has been given to important species, viz., cattle, buffalo, sheep, goat, pig, canine, feline and equine in the course curriculum for M.V.Sc. programme. The courses have been reorganized with respect to species, viz., ruminant, canine and feline and equine, etc. and attempt has been made to cover all the systemic diseases in a comprehensive manner. Contents of the courses have been revised by including newer trends in diagnosis, treatment, management and prevention of various diseases. Different disease conditions have been listed precisely in ruminant and equine medicine courses so as to remove ambiguity in covering of the various topics.

Small animal practice has grown exponentially in last decade. Accordingly, courses in small animal have been recasted by giving emphasis on diseases of gastro-intestinal, respiratory, cardiovascular system. Endocrine disorders, coagulopathies, immune mediated diseases and neoplastic diseases have been given special emphasis. Problem oriented approach to common disease manifestations for better understanding and applications has been added in canine and feline courses for improving diagnostic skills of the students. In recent times, small animals are also frequently presented for behavior disorders. Therefore, topics on pet psychology, pet behavior, adaptation needs and behavioral medicine have been incorporated.

Two separate courses on clinical diagnostic techniques and emergency medicine have been designed to provide hands on training on diagnostic procedures and practical training. Topics have been included to train the students for special examination of different body systems. Emerging diseases have been added to the course curriculum. Two new courses, viz., Geriatrics and Paediatrics, Oncology and Ethno-Veterinary Medicine have been added. To provide practical approach to the diagnosis and investigation of infectious diseases, a special course on investigation of disease outbreaks has been included in the revised curriculum.

Ph.D. courses have been designed according to body systems. This approach will help students in better comprehension of the diseases as already being followed in all veterinary colleges of countries with very high standards of veterinary education and research (USA, Canada and Europe). The doctorates, following new restructured Ph.D. curricula should, in future, manifest as specialists in the field of their specialization.

Management of emergency cases and critically ill patients is an upcoming challenge for practicing veterinarians. Special training is required for monitoring and resuscitation of critically ill patients as well as diagnosis, management and emergency care procedures for common emergencies. Therefore, a special course on 'Veterinary Emergency and Critical Care Medicine, has been designed for Ph.D. programme. Similarly, a new course on 'Advances in Veterinary Diagnostics' has been added to enhance the diagnosis skills and hands on training on the use of ophthalmoscopy, ultrasonography, endoscopy, pulse-oximetry electrocardiography, echocardiography and their interpretations.

The revision of courses has been given due importance in consonance with the national initiatives and key Central Government policies to improve productivity and livestock health. The course contents have been revised comprehensively to cover syllabi, which will be immensely helpful in introducing and exploring new insights and improving clinical knowledge and skill competency of the students, keeping in view the global trends and developments in veterinary clinical diagnosis, education and research.

Course Title with Credit Load
M.V.Sc. in Veterinary Medicine

Course Code	Course Title	Credit Hours
VMD 501*	Ruminant Medicine-internal	3+0
VMD 502*	Ruminant Medicine-infectious	3+0
VMD 503	Equine Medicine	2+0
VMD 504*	Canine and Feline Medicine-I	2+0
VMD 505*	Canine and Feline Medicine-II	2+0
VMD 506	Metabolic and Endocrine Diseases, Nutritional Deficiencies and Diseases of Mammary Gland	2+0
VMD 507	Paediatrics and Geriatrics	2+0
VMD 508	Avian and Swine Medicine	2+0
VMD 509	Zoo, Wild and Laboratory Animal Medicine	1+0
VMD 510	Toxicology and Forensic Medicine	1+0
VMD 511*	Clinical Diagnostic Techniques	0+2
VMD 512	Emergency Medicine	0+2
VMD 513*	Diagnosis of Veterinary Infectious Diseases	0+1
VMD 514	Oncology and Ethno-veterinary Medicine	1+0
VMD 515	Animal Disease Investigation and Biosecurity	1+1
VMD 516*	Clinical Practice-I	0+3
VMD 517*	Clinical Practice-II	0+3
VMD 591	Master’s Seminar	1+0
VMD 599	Master’s Research	0+30

Course Contents
M.V.Sc. in Veterinary Medicine

I. Course Title : Ruminant Medicine - Internal
II. Course Code : VMD 501
III. Credit Hours : 3+0
IV. Aim of the course

Internal diseases of Digestive, Respiratory, Urinary, Cardiovascular, Blood and blood forming organs, Nervous, Musculoskeletal system, Skin, eye and ear of bovine, Sheep, and goat.

V. Theory

Unit I

Examination of alimentary tract and abdomen; Diseases of the buccal cavity and related organs including pharynx, Oesophagus. Reticulo-ruminal fermentative disorders (simple indigestion, impaction, ruminal lactic acidosis), Primary and secondary bloat, Diaphragmatic hernia, Traumatic reticulo-peritonitis and Omasal impaction.

Unit II

Diseases of abomasum (impaction, displacements, ulcers, bloat), Acute and chronic diarrhoea, Intestinal obstructive disorders (intussusception, volvulus), Peritonitis, caecal dilatation and hemorrhagic bowel syndrome.

Unit III

Manifestations of liver and biliary diseases, Focal and diffuse diseases of liver. Disease of nasal cavity, sinuses, disease of larynx and trachea, pneumonias, pleuritis, manifestations Principles of treatment in uro-genital system; Rupture, Paralysis and infections of urinary bladder, Urolithiasis, Nephritis and renal failure, Nephrosis, renal ischemia, Hemolytic uremic like syndrome, Uremia and neoplasms of urinary tract.

Unit IV

Examination of cardiac system and Special examination of heart (ECG, echocardiography, Markers for diagnosis of cardiac disorders. Principal manifestations of cardiovascular diseases, congenital cardiac diseases, myocarditis), cardiomyopathy, endocarditis, pericarditis, phelebitis, thrombosis, anemia, lymphangitis, lymphadenopathies and thrombocytopenia.

Unit V

Principles of nervous dysfunction, Clinical manifestation and special examination, Localization of lesion in brain and spinal cord, Cortical diseases, Brain abscess, Meningitis, Diseases of brainstem, Cerebellar diseases, Spinal cord compression and peripheral nerve paralysis. Principal manifestations and special examination of musculoskeletal system, Myositis, Myopathies, Foot lameness, Arthritis, Osteodystrophies, Degenerative joint disease and nutritional deficiency diseases affecting musculoskeletal system; conjunctivitis, Keratitis, uveitis, Horner syndrome, neoplasms of eye, otits media, otitis externa; Skin diseases: folliculitis, furunculosis and skin neoplasms.

I. Course Title : Ruminant Medicine-infectious

II. Course Code : VMD 502

III. Credit Hours : 3+0

IV. Aim of the course

Bacterial, fungal, chlamydial, viral, parasitic, mycoplasmal, prions and rickettsial diseases of bovine, sheep, and goat.

V. Theory

Unit I

Clostridial diseases-black quarter, Botulism, Bacillary hemoglobinuria, Braxy, Enterotoxemia, Malignant edema, Pulpy kidney disease, Tetanus, Collibacilosis, Salmonellosis, Compylobacteriosis, Listeriosis, Actinobacillosis, Actinomycosis, Anthrax, Tuberculosis, Johne's disease, Leptospirosis, Pasteurellosis, Ulcerative lymphangitis, Infectious bovine keratoconjuctivitis, Chlamydiosis infections, Dermatophytosis, Cutaneous streptothricosis, Candidiasis and Rhinosporidiosis.

Unit II

Foot and mouth disease, Vesicular stomatitis, Vesicular exanthema, Rinderpest, PPR, Bovine viral diarrhea, Mucosal disease, Ephemeral fever, Bovine herpes viral diseases, Leucosis, Viral pneumonia, Pox diseases, Infectious gastroenteritis of viral etiology. Malignant catarrh fever, Rabies, Bluetongue, Louping ill, Papillomatosis, Contagious ecthyma (orf), Caprine arthritis and Encephalopathy(CAE), Contagious bovine pleuropneumonia and Contagious caprine pleuropneumonia.

Unit III

Bovine spongiform Encephalopathy, Scarpie, Bovine Anaplasmosis, Theileriasis, Babesiosis, Fascioliosis, Amphistomiosis, Gastrointestinal nematodiosis, Schistosomiosis, Lung worm infection, Echinococcosis, Coenurosis and Tapeworm infections, Coccidiosis, Thelaziasis, parasitic dermatitis (scabies, psoroptes).

I. Course Title : Equine Medicine

II. Course Code : VMD 503

III. Credit Hours : 2+0

IV. Aim of the course

Internal and infectious diseases of Equines

V. Theory

Unit I

Diseases of buccal cavity (dental diseases, stomatitis), Oesophagus, Gastric dilatation, gastro-duodenal ulceration, Acute and chronic diarrhea, Colic, Acute and chronic hepatitis.

Unit II

Diseases of cardio-vascular system and blood forming organs; Manifestations and principles of treatment in respiratory disorders, Epistaxis, Ethmoidal hematoma, pharyngitis, sinusitis, Guttural pouch diseases, Tracheal collapse, Adult pneumonia, foal pneumonia, Recurrent air way obstruction, Inflammatory airway disease, Pleura-pneumonia, Pulmonary congestion and edema; Manifestations and principles of treatment of urinary system diseases, Rupture of urinary bladder, Paralysis, urolithiasis, Urinary tract infections, Acute and chronic renal failure and Neoplasms of urinary tract.

Unit III

Principal manifestations of musculoskeletal diseases, Laminitis, Inflammatory Myopathy, Exertional Myopathies, Myotonia, Hyperkalemic periodic paralysis and Nutritional deficiency diseases affecting musculoskeletal system.

Nervous diseases, Viral encephalitis, Intracarotid drug injection, Trauma to brain and cranial nerves, Brain abscess, Peripheral vestibular disease, Temporo-hyoid osteoarthropathy, Ataxia (sorghum toxicity, spinal abscesses), Peripheral facial nerve paralysis, Peripheral nerve disorders; Skin diseases, bacterial, fungal, parasitic and allergic dermatitis (culicoides hypersensitivity), Cutaneous eczema, Cutaneous acne, Cutaneous pustular dermatitis, Candidasis, Histoplasmosis, Coccidiodomycosis and dermatophytosis.

Unit IV

Bacterial, fungal and viral keratitis, Equine recurrent uveitis, Uveitis, Ocular neoplasia. Trypanosomiasis/ dourine, Babesiosis, Parasitic pneumonia, Strangles, equine influenza, Equine herpes virus infection, Potomac horse fever, Equine infectious anaemia and setariasis.

I. Course Title : Canine and Feline Medicine-I

II. Course Code : VMD 504

III. Credit Hours : 2+0

IV. Aim of the course

Internal (digestive, liver, pancreas, cardiovascular, blood and blood forming organs) and infectious (bacterial, parasitic and protozoal) diseases of dogs and cats.

V. Theory

Unit I

Diagnostic approach to common manifestations of disease: Vomiting, acute diarrhea, Chronic diarrhea, Syncope, Anemia, Jaundice, Fever, Weight loss, Edema, Dyspnoea, coughing and nasal discharge.

Unit II

Etiology, pathogenesis, clinical signs, clinical pathology, diagnosis, Differential diagnosis and treatment of diseases of the oral cavity, oesophagus, acute gastritis, chronic gastritis, Gastric dilatation, Volvulus, Tumors of the stomach, Intussusception, Acute enteritis, Chronic enteritis, Inflammatory bowel disease, Colitis, Gastric and Intestinal foreign bodies, Diseases of rectum and anal sac, Peritonitis, Acute hepatitis, Chronic hepatitis, Diseases of gall bladder, Cholangitis, Vascular liver diseases, Extra hepatic biliary system, Acute pancreatitis and Exocrine pancreatic insufficiency.

Unit III

Anemia, Lymphangitis, Lymphadinopathies, Coagulopathies, Immune mediated diseases, Neoplastic diseases of hemo-lymphatic system; Examination of cardiac system and special examination of heart (ECG, Echocardiography, Holter and markers for diagnosis of cardiac disorders), Congenital heart diseases, Dilated cardiomyopathy, Endocardiosis, Cardiac arrhythmias, Pericardial disorders. Pet psychology, Pet behaviour, Adaptation needs and Behavioural medicine

Unit IV

Leptospirosis, Tetanus, Brucellosis, Lyme disease, Rocky mountain spotted fever, Kennel cough, Trypanosomiasis, Ehrlichiosis, Ancylostomiasis, Dirofilariasis, Giardiasis, Coccidiosis/ Isosporosis, Toxoplasmosis, Babesiosis, Neosporosis, Hepatozonoosis and Tape worm infections.

I. Course Title : Canine and Feline Medicine-II

II. Course Code : VMD 505

III. Credit Hours : 2+0

IV. Aim of the course

Internal (respiratory, nervous, urogenital, musculoskeletal, eye, ear and skin) and infectious (viral and fungal) diseases of dogs and cats.

V. Theory

Unit I

Principles of treatment in respiratory disorders, Diseases of nasal cavity, Tracheo-bronchitis, Chronic bronchitis, Pulmonary congestion and edema, Acute pneumonia, Chronic pneumonia, Feline asthma, Pleural effusions and Neoplasms of respiratory tract.

Diagnostic approach to common manifestations of disease: Seizures, Coma, Monoparesis, Pelvic limb paralysis, Pruritis, alopecia, Obesity, Urinary incontinence, Hematuria; Focal, diffuse and multifocal diseases of brain. Diseases of spinal cord and Peripheral nervous system, Vestibular diseases and toxins affecting nervous system.

Unit II

Diseases of muscles- congenital and inherited diseases of muscles, bone and joints, Myasthenia, Myopathy; Nutritional deficiency diseases- Rickets, Primary and Secondary Hyperparathyroidism, Osteodystrophy and Osteomyelitis.

Diseases of eyelids, Epiphora, Keratitis, Conjunctivitis, Uveitis, Glaucoma, Acute blindness and Neoplasms of eye.

Unit III

Skin diseases, Common pyodermas, Atopy, Dermatophytosis and Dermatomycosis, Demodicosis, Scabies, Myiasis, and Nutritional disorders related to skin and its therapeutic management, Flea allergy and its treatment and control measures, Alopecia. Cutaneous manifestations of hormonal imbalances and systemic disorders, Auto immune diseases of skin, Diseases of the pinna, Otitis and principles of treatment in otic infections.

Manifestations and principles of treatment of urinary system diseases, Urinary tract infections, Urolithiasis, Nephritis, Nephrosis, Pyelonephritis, Renal failure and neoplasms of urinary tract.

Unit IV

Viral diseases: Canine parvovirus, Canine distemper, Corona viral gastroenteritis, Infectious hepatitis, Infectious tracheobronchitis, Canine herpes virus, Rabies, Feline Panleukopenia, Infectious peritonitis (FIP), Feline leukemia virus infection, Feline immunodeficiency virus, Vaccination schedule for canine and feline diseases, Dermatophytosis, Blastomycosis, Histoplasmosis, Sporotrichosis, and coccidioidomycosis.

I. Course Title : Metabolic and Endocrine Diseases, Nutritional Deficiencies and Diseases of Mammary Gland

II. Course Code : VMD 506

III. Credit Hours : 2+0

IV. Aim of the course

Study of diagnosis, management and control of metabolic, endocrine, nutritional and mammary gland diseases.

V. Theory

Unit I

Metabolic profile test parturient paresis, Downer cow syndrome, Acute hypokalemia in cattle, Transit recumbency, Lactation tetany of mares, Hypomagnesemia, Tetany of calves, Ketosis, sub-clinical ketosis, Pregnancy toxemia, Fatty liver syndrome, Equine hyperlipidemia, Steatitis, Neonatal hypoglycemia, low milk fat syndrome, Peri-parturient hemoglobinuria and Eclampsia in bitches.

Unit II

Deficiency of energy and protein, Deficiency of fat and water soluble vitamins and deficiency of macro- micro minerals.

Unit III

Mastitis, Diseases of teats and udder in ruminants, “mastitis-metritis-agalactia” in sow and congenital abnormalities of udder and teats.

Unit IV

Diabetes mellitus, Diabetes insipidus, Hypothyroidism, Obesity, Hypo- and hyperadrenocorticism.

I. Course Title : Paediatrics and Geriatrics

II. Course Code : VMD 507

III. Credit Hours : 2+0

IV. Aim of the course

Study of non-infectious and infectious diseases of neonates and geriatric animals.

V. Theory

Unit I

Perinatal management, Perinatal adaptation, Neonatal health, Asphyxia and Resuscitation; Physical examination of the neonate, perinatal and neonatal mortality, Colostrum and its substitutes, Manifestations of disease.

Unit II

Immunization of neonates, Fluid replacement therapy, Nutritional support, Blood and Serum transfusion, Antimicrobial therapy and neonatal diarrhoea.

Unit III

Non-infectious and infectious diseases of viral, bacterial, mycoplasma and parasitic origin of neonates, Young and aged farm and companion animals; Diseases acquired from dam, Congenital disorders, Metabolic disorders, Nutritional deficiencies, Miscellaneous conditions (hypothermia, hyperthermia, starvation, arthritis), Management of shock and other emergencies, Detection and correction of failure of passive transfer of immunity.

Unit IV

Geriatric diseases: Senility, Dental diseases, Glaucoma, Cataract, Keratitis sicca, Urinary incontinence, Renal insufficiency, Cardiac diseases, Pulmonary diseases, Neoplasia, Bone and joint diseases, Neurologic disorders, Otologic disorders, Endocrine diseases (diabetes mellitus, cushing's disease, hypothyroidism), Liver diseases, Psychological and behaviour disorders.

I. Course Title : Avian and Swine Medicine

II. Course Code : VMD 508

III. Credit Hours : 2+0

IV. Aim of the course

Recent concepts in non-infectious and infectious diseases of avian species and pigs.

V. Theory

Unit I

Specific needs of avian species; Diseases due to deficiency of vitamins (vitamins A, B complex, C, D, E, K); minerals (calcium, phosphorus, manganese, zinc, etc.) and sodium chloride.

Unit II

Miscellaneous diseases/ conditions/ vices (cage layer fatigue, beak necrosis, blue comb disease, round heart disease, kerato- conjunctivitis, ascites, urolithiasis, fatty liver, kidney hemorrhagic syndrome, heat stroke, cannabalism, vent picking), egg bound peritonitis, diseases of feather, skin, beak and foot, bumble foot, gout, infectious diseases of poultry (marek's disease, lymphoid leukosis, new castle disease, infectious coryza, fowl typhoid, CRD, pullorum disease, cocciodiosis, chlamydiasis, avian pox, infectious bursal disease, infectious bronchitis, infectious laryngo-tracheitis, etc.)

Unit III

Nutritional deficiency diseases of pigs, swine influenza, hog cholera, african swine fever, swine pox, vesicular exanthema, vesicular stomatitis, rabies. porcine enteroviruses, pseudorabies, listeriosis, leptospirosis, brucellosis, anthrax, salmonellosis, swine erysipelas, pasteurellosis, tuberculosis, mange, etc.

Unit IV

Handling, physical examination, sampling, diagnostic techniques and medication.

I. **Course Title** : **Zoo, Wild and Laboratory Animal Medicine**
II. **Course Code** : **VMD 509**
III. **Credit Hours** : **1+0**

IV. **Aim of the course**

Study of diagnosis, management and control of Zoo, wild and laboratory animals.

V. **Theory**

Unit I

Study of diseases and health management of zoo, Wild and laboratory animals; Etiology, Clinical signs, Diagnosis and management of various diseases of zoo, wild and laboratory animals. Restraint, Feeding, Diseases and health management of exotic animals kept as pets.

Unit II

Specific diseases of laboratory animals caused by bacteria, viruses, fungi and parasites.
Specific diseases of zoo (captive) animals caused by bacteria, viruses, fungi and parasites.

I. **Course Title** : **Toxicology and Forensic Medicine**
II. **Course Code** : **VMD 510**
III. **Credit Hours** : **1+0**

IV. **Aim of the course**

Study of diseases caused by physical, chemical, other toxicants in domestic animals and animal welfare issues.

V. **Theory**

Unit I

Diseases caused by physical agents and poisoning of organic and inorganic compounds. Diseases caused by farm chemicals and phytotoxins. Diseases caused by mycotoxins and zootoxins.

Unit II

Collection, Dispatch and Examination of vetro-legal samples. Examination of wounds, blood, offenses and frauds in animal sales. Animal cruelty and welfare related issues. Study of common laws related to vetro-legal aspects.

I. **Course Title** : **Clinical Diagnostic Techniques**
II. **Course Code** : **VMD 511**
III. **Credit Hours** : **0+2**

IV. **Aim of the course**

To impart training on diagnostic procedures for various diseases of farm and companion animals and their interpretations.

V. **Theory**

Unit I

Peritoneal fluid analysis, Gastrointestinal endoscopy, Colonoscopy, Proctoscopy, Ultrasonography, Liver biopsy, Interventional imaging, Rhinoscopy, Brochoscopy, Transtracheal lavage, Endotracheal lavage, Broncho-alveolar lavage, Thoracocentesis, Pericardiocentesis, Interpretation of hemogram, Renal and Hepatic function tests. Neurological examination.

Unit II

Electrocardiography, Echocardiography, Pulse oximetry, Blood and blood component therapy, Bone marrow biopsy, Arterial blood gas analysis, Cerebrospinal fluid analysis, Cystocentesis, Urinary catheterization, Renal function tests, Specific gravity of urine by refractometer, Skin-biopsy, Cytology- scrapings, Otoscopy, Direct and indirect ophthalmoscopy, Shirmer tear test, Tonometry. Diagnosis tests in mastitis. Assay for $T_{3,}$ $T_{4,}$ lipase, Amylase, Radio immunoassay and indications of CT, MRI, nuclear medicine.

I. Course Title : Emergency Medicine
II. Course Code : VMD 512
III. Credit Hours : 0+2

IV. Aim of the course

Diagnosis and management of common emergencies in animals.

V. Practical

- Diagnosis and therapeutic management of various emergencies of cardiovascular, respiratory, gastrointestinal, urinary and nervous systems.
- Diagnosis and therapeutic management of various emergencies of toxicities, sting bites, snake bite and burns in farm and companion animals.
- Monitoring critical ill patient, application of emergency care procedures for resuscitation of critically ill patients.
- Placement of central venous catheters, introsseous fluid administration, endotracheal intubation, gastric lavage, decompression of guttural pouch, stomach, cecum, ventilation, nebulization, fluid therapy, CPR, oxygen therapy, enteral nutrition, nasogastric intubation, Blood transfusion

I. Course Title : Diagnosis of Veterinary Infectious Diseases
II. Course Code : VMD 513
III. Credit Hours : 0+1

IV. Aim of the course

Concepts and diagnostic tests in veterinary infectious diseases.

V. Practical

- Sampling techniques for collection of samples during research;
- Sensitivity and specificity of diagnostic tests including false positive and false negative tests. Mastitis diagnostic tests;
- Culture and staining techniques;
- Diagnosis of fungal diseases, protozoan and rickettsial diseases, fecal examination for endoparasites, skin scrapping examination for mites, fleas and lice;
- ELISA, PCR, culture sensitivity tests on milk and other body fluids, molecular techniques and types of PCR, Molecular epidemiology tools including RFLP, etc.

I. Course Title : Oncology and Ethno-veterinary Medicine

II. Course Code : VMD 514

III. Credit Hours : 1+0

IV. Aim of the course

Study of diagnosis and management of tumors, natural remedies and alternative systems of medicine.

V. Theory

Unit I

Tumors related to different systems - biology and pathogenesis of cancer, diagnostic procedures, oncology medicine, chemotherapy, radiation therapy, immuno-therapy and miscellaneous therapeutic measures, including advancements of therapeutic approaches, supportive care for the cancer patient.

Unit II

Natural remedies and products for use towards therapy in animal ailments.

Unit III

Acupuncture, physiotherapy, laser therapy, nutraceuticals and dietary supplements.

I. Course Title : Animal Disease Investigation and Biosecurity

II. Course Code : VMD 515

III. Credit Hours : 1+1

IV. Aim of the course

Concepts in investigation of infectious diseases and their prevention.

V. Theory

Unit I

Investigation and diagnosis on dead and live diseased animal (s) and poultry. Point source epidemics and propagating epidemics, Collection, Preservation and transport of material in the face of disease outbreak, and processing of material in the laboratory for diagnosis; Recording and analysis of epidemiological data. Establishing working hypothesis and formulating and advising and/ or implementing treatment, control and prevention measures.

Unit II

Biosecurity definition, Related concepts, Principles and basic components of biosecurity, Physical and operational elements of biosecurity. Routes of entry and transmission dynamics of pathogens. Shedding pattern of pathogens by infected animals and their survival in the environment. Protection of susceptible animals, interruption of pathways of transmission, role of disinfection to break cycle of infection. Sterilization, fumigation and disinfection methods, disinfectants and its classification, Microbial resistance to disinfectants, Risk assessment and its management. Principles of biosecurity in laboratory animal house, Biosecurity measures for collection of specimen from wild animals. Biosecurity in research laboratories. Vaccines-success stories of disease eradication through vaccination.

VI. Practical

- Isolation and identification of field isolates and vaccine strains by conventional,

immunoassays and molecular techniques.
- To perform an outbreak investigation of infectious diseases and toxicological conditions in livestock and poultry in the field/ organised livestock farms.
- Practical use of disinfectants in destruction of microbes in laboratory and under field conditions. Determination of efficacy/ phenol coefficient of commonly used disinfectants.
- Approaches in animal disease control and eradication. Preliminary steps to control animal disease outbreaks.
- Types of vaccines, vaccination schedule in livestock, pets and poultry

I. Course Title : Clinical Practice-I
II. Course Code : VMD 516
III. Credit Hours : 0+3

IV. Aim of the course

Application of the theoretical concepts in practice.

V. Practical

- Diagnostic and therapeutic protocol application, specimen collection, examination and management of sick farm and companion animals, use of diagnostic techniques for diagnosis of medicinal cases, acquaintance with different equipment, client management, public relations, code of conduct, hospital management, database management and maintenance of case records, disaster management
- Note: This course shall be conducted in Veterinary Clinical Complex (VCC), where students shall participate in diagnosis and treatment of diseased animals.

I. Course Title : Clinical Practice-II
II. Course Code : VMD 517
III. Credit Hours : 0+3

IV. Aim of the course

Application of the theoretical concepts in practice.

V. Practical

- Diagnostic and therapeutic protocol application, specimen collection, examination and management of sick farm and companion animals, use of diagnostic techniques for diagnosis of medicinal cases, acquaintance with different equipment, client management, public relations, code of conduct, hospital management, database management and maintenance of case records, disaster management.
- **Note:** This course shall be conducted in Veterinary Clinical Complex (VCC), where students shall participate in diagnosis and treatment of diseased animals.

Course Outline: Lecture wise

VMD 501: Ruminant Medicine-internal 3+0

S. No.	Topics	No. of Lectures
1.	Examination of alimentary tract and abdomen	1
2.	Diseases of the buccal cavity and related organs including pharynx, oesophagus	2
3.	Reticulo-ruminal fermentative disorders (simple indigestion, impaction, ruminal lactic acidosis, alkalosis)	2
4.	Primary and secondary bloat, diaphragmatic hernia	1
5.	Traumatic reticulo-peritonitis, vagal indigestion syndrome, generalised peritonitis vagal indigestion syndrome, generalised peritonitis and omasal impaction	1
6.	Diseases of abomasum (impaction, displacements)	2
7.	(Acute and chronic diarrhoea), hemorrhagic diarrhea	2
8.	Intestinal obstructive disorders (intussusception, volvulus), strangulation	2
9.	Caecal dilatation and volvulus	1
10.	Manifestations of liver and biliary diseases	1
11.	Focal and diffuse diseases of liver, fatty liver syndrome	1
12.	Principle of treatment of respiratory diseases, respiratory insufficiency, anoxias, diseases of nasal cavity, sinuses, diseases of larynx and trachea	2
13.	Epistaxis, hemoptysis, congestion and edema of lungs, hydro and hemothorax	1
14.	Pneumonias and pleuritis	2
15.	Manifestations and principles of treatment in uro-genital system; rupture, paralysis	1
16.	Infections of urinary bladder	1
17.	Urolithiasis, nephritis and renal failure, nephrosis	2
18.	Hemolytic uremic like syndrome, uremia and neoplasms of urinary tract	1
19.	Examination of cardiac system and special examination of heart (ECG, echocardiography disorders)	1
20.	Principal manifestations of cardiovascular diseases	1
21.	Congenital cardiac diseases, Myocarditis	1
22.	Cardiomyopathy, endocarditis, pericarditis	1
23.	Phlebitis, thrombosis, anemia, lymphangitis, lymphadenopathies and thrombocytopenia, lymphosarcoma	2
24.	Principles of nervous dysfunctions, clinical manifestation SOL special examination	1
25.	Localization of lesion in brain and spinal cord	2
26.	Cortical diseases, brain abscess, SOL, meningitis, diseases of brainstem, cerebellar diseases	2
27.	Spinal cord compression, peripheral nerve paralysis, Horner Syndrome, facial nerve paralysis	2
28.	Principle manifestations and special examination of musculoskeletal system	1

S. No.	Topics	No. of Lectures
29.	Foot lameness, arthritis, osteodystrophies, degenerative joint disease and nutritional deficiency diseases affecting musculoskeletal system	3
30.	Diseases of eyes, neoplasms of eyes	1
31.	Conjunctivitis, keratitis, uveitis	1
32.	Diseases of pinna, otits media, otitis externa	2
33.	Skin diseases: folliculitis, furunculosis, and skin neoplasms, skin tumors	1

Suggested Books

- Bradford Smith, David Van Metre, Nicola Pusterla. 2019. *Large Animal Internal Medicine.* 6th Edition, Mosby.
- Neil V Anderson, 1992. *Veterinary Gastroenterology*. 2nd Revised edition, Lea and Febiger, USA.
- Simon F Peek, Thomas J Divers. 2018. *Rebhun's Diseases of Dairy Cattle*. 3rd Edition, Elseviers.
- Research and Review Papers in Current Journals.

VMD 502: Ruminant Medicine-infectious 3+0

S. No.	Topics	No. of Lectures
1.	Principles of prevention and control of infectious diseases	1
2.	Anthrax	1
3.	Brucellosis	1
4.	Mastitis	1
5.	Foot rot/ Joint ill	1
6.	Black quarter/ Braxy	1
7.	Tetanus	1
8.	Enterotoxemia	1
9.	Bacillary haemoglobinuria	1
10.	Botulism	1
11.	Colibacillosis	1
12.	Pasteurellosis/ Hemorrhagic septicemia	1
13.	Tuberculosis	1
14.	Paratuberculosis	1
15.	Listeriosis	1
16.	Leptospirosis	1
17.	Acitnomycosis/ Actinobacillosis	1
18.	Ringworm	1
19.	Systemic mycotic infections (Aspergillosis, candidiasis, histoplasmosis, sporotrichosis, coccidiodomycosis, mycotoxicosis)	1
20.	Dermatophilosis	1
21.	Campylobacteriosis	1
22.	Salmonellosis	1
23.	Contagious bovine pleuropneumonia	1
24.	Contagious agalactia	1
25.	Anaplasmosis	1
26.	Chlamydiosis, Q fever, ehrilichiosis	1
27.	Blue tongue	1
28.	Sheep and goat pox	1
29.	Peste des petits ruminants	1
30.	Scrapie, louping ill	1

S. No.	Topics	No. of Lectures
31.	Maedi, visna, jagaskiae disease	1
32.	Rift valley fever	1
33.	Rinderpest	1
34.	Bovine viral diarrhea	1
35.	Malignant catarrhal fever	1
36.	Infectious bovine rhinotracheitis	1
37.	Enzootic bovine leucosis	1
38.	Ephemeral fever	1
39.	Foot and mouth disease	1
40.	Rabies	1
41.	Principles of control of parasitic diseases	1
42.	Amphistomosis	1
43.	Fascioliosis	1
44.	Gastrointestinal nematodiasis, schistosomosis	1
45.	Echinococcosis, tapeworm (cysticercosis)	1
46.	Verminous bronchitis, coeneurosis,	1
47.	Trypanosomosis, babesiosis	1
48.	Theileriosis, hepatozoonosis	1

Suggested Books

- *Dairy Herd Health*. 2012. MJ Green, Andrew J. Bradley. CABI Publishing.
- *Merck's Veterinary Manual* K. 2016. Susan E Aiello, Michael A Moses. (11th Edition). Merck Sharp and Dohme
- *Veterinary Medicine* 2016. Peter Constable, Kenneth W Hinchcliff, Stanley Done, Walter Gruenberg. 11th Edition. Saunders Ltd.
- Research and Review Papers in Current Journals.

VMD 503: Equine Medicine (2+0)

S. No.	Topics	No. of Lectures
1.	Manifestations and principles of treatment of gastrointestinal diseases	1
2.	Diseases of the buccal cavity and oesophagus	2
3.	Gastric dilation and rupture, gastro-duodenal ulceration	1
4.	Diseases of the intestine (colic, duodenitis-proximal jejunitis, acute and chronic diarrhea	3
5.	Diseases of liver	1
6.	Diseases of the pericardium, myocardium and endocardium	2
7.	Cardiac arrhythmias, thrombosis	1
8.	Purpura haemorrhagica, immune-mediated thrombocytopenia of the neonates, neonatal isoerythrolysis	1
9.	Sinusitis, ethmoidal hematoma, guttural pouch tympany/ empyema/ mycosis, pharyngitis, recurrent laryngeal neuropathy	2
10.	Pneumonia and pleuropneumonia,	2
11.	Inflammatory airway disease	1
12.	Recurrent airway obstruction	1
13.	Acute renal failure and chronic renal failure	1
14.	Urinary tract infections	1
15.	Exertional myopathy/ Tying up syndrome, myositis	1
16.	Hyperkalemic periodic paralysis, narcolepsy, myotonia	1
17.	Osteodystrophies	1

S. No.	Topics	No. of Lectures
18.	Encephalitis, meningo-encephalitis	2
19.	Facial nerve paralysis, radial nerve paralysis, sciatic nerve paralysis, femoral nerve paralysis, polyneuritis equi (cauda equine neuritis)	1
20.	Bacterial dermatitis (Dermatophilosis, furunculosis, cellulitis, ulcerative lymphangitis, fistulous withers, bacterial psuedomycosis (botryomycosis)	1
21.	Viral skin diseases	1
22.	Allergic dermatitis: Culicoides hypersensitivity, eosinophilic granuloma, anhidrosis, equine sarcoidosis	2
23.	Fungal skin diseases	1
24.	Parasitic skin diseases- habronemiasis, onchocerciasis	1

Suggested Books

- *Equine Internal Medicine*. 2017. Stephen Reed, Warwick Bayly, Debra Sellon, 4th Edition, Elsevier, Saunders.
- *Large Animal Internal Medicine*. 2019. Bradford Smith, David Van Metre, Nicola Pusterla, 6th Edition, Mosby
- Research and Review Papers in Current Journals.

VMD 504: Canine and Feline Medicine-I (2+0)

S. No.	Topics	No. of Lectures
1.	Diagnostic approach to manifestations of gastrointestinal disorders	2
2.	Disorders of oral cavity, pharynx and oesophagus	1
3.	Common disorders of stomach	1
4.	Disorders of small intestine	1
5.	Disorders of large intestine, rectum and anus	1
6.	Diagnostic approach to manifestations of hepato-biliary diseases	2
7.	Hepato-biliary diseases of dogs and cats	1
8.	Exocrine pancreatic disorders of dogs and cats	1
9.	Diagnostic approach to manifestations of hemo-lymphatic disorders	2
10.	Disorders of hematopoietic system	1
11.	Disorders of lymphatic system	1
12.	Diagnostic approach to manifestations of cardiac diseases	1
13.	Congenital heart diseases	1
14.	Acquired valvular diseases, myocardial and pericardial diseases	1
15.	Behaviour disorders of canine and feline	1
16.	Polysystemic protozoal infection of dogs and cats (Hepatozoonosis, babesiosis, trypanosomiasis, neosporosis, toxoplasmosis)	2
17.	Polysystemic rickettsial diseases of dogs and cats (Ehrlichiosis, lyme disease and rocky mountain spotted fever)	2
18.	Important bacterial diseases of canine and feline (Leptospirosis, tetanus, brucellosis and kennel cough)	2
19.	Endoparasitic infestation of dogs and cats	1
20.	Viral diseases of dogs (Canine parvo viral gastroenteritis, canine distemper, corona virus infection, Infectious hepatitis, Infectious trachebronchitis, canine herpes virus and rabies)	3
21.	Viral diseases of cats (Feline panleukopenia, feline infectious peritonitis, feline leukemia virus, feline immunodeficiency virus)	2
22.	Fungal diseases of dogs and cats	1
23.	Vaccination schedule of dogs and cats	1

Suggested Books

- *Small Animal Internal Medicine* 2013. Nelson and Couto, 5th edition, Elesvier Mosby, St. Louis, Missouri
- *Text book of Veterinary Internal Medicine* 2001. Part I and II, Ettinger and Feldman, 7th Edition, *Publisher*: Saunders
- *Small Animal Medical Diagnosis* 2009. MD Lorenz, TM Neer and PL Demars, 3rd Edition, Willey Blackwell, Iowa, USA.
- Research and Review Papers in Current Journals.

VMD 505: Canine and Feline Medicine-II (2+0)

S. No.	Topics	No. of Lectures
1.	Clinical manifestations of upper and lower respiratory tract disorders	1
2.	Canine infectious tracheobronchitis, chronic bronchitis in dogs. feline bronchitis.	1
3.	Pneumonia (viral, bacterial, fungal), pulmonary neoplasia, pulmonary edema	1
4.	Diagnostic approach to pleural effusions	1
5.	Diagnostic approach to diseases of nasal cavity	1
6.	Principles of therapeutic management of respiratory tract disorders	1
7.	Clinical manifestations of urinary tract disorders	1
8.	Acute and chronic renal failure	1
9.	Canine and feline urinary tract infections	1
10.	Disorders of micturition	1
11.	Neoplasms of urinary tract	1
12.	Neurological manifestations of systemic diseases	1
13.	Diagnostic approach to seizures, ataxia, paresis and paralysis	1
14.	Inflammatory brain disorders (bacterial, viral, protozoal, mycotic, parasitic)	2
15.	Diseases of spinal cord (osteomyelitis, intervertibral disc disease)	1
16.	Disorder of peripheral nerves (developmental and congenital disorders, metabolic and toxic disorders, inflammatory and immune mediated neuropathies)	2
17.	Joint diseases of dogs and cats (Non inflammatory and inflammatory)	1
18.	Disorders of muscles (inflammatory myopathies, bacterial, parasitic, immunemediated, degenerative and inherited myopathies	1
19.	Nutritional secondary hyperparathyroidism, rickets	1
20.	Diseases of ears (otitis externa, interna, media), neoplasms, principles of treatment of otitic infections	1
21.	Skin (endocrinopathies, bacterial, parasitic, fungal skin disorders, nutritional disorders related to skin)	2
22.	Alopecia, atopy, flea allergy dermatitis	1
23.	Diagnostic cytology of skin lesions, treatment and control measures.	1
24.	Eyes (diseases of eye lids, keratitis, conjuctivitis, uveitis, glaucoma, acute blindness, neoplasms of eye.	1
25.	Viral diseases of dogs and cats	2
26.	Vaccination for canine and feline diseases	1
27.	Fungal diseases of dogs and cats	2

Suggested books

- *Small Animal Internal Medicine* 2013. by Nelson RW and Couto, CG 5th edition, Elesvier Mosby, St. Louis Missouri

- *Text book of Veterinary Internal Medicine* 2010. by Ettinger and Feldman, 7th Edition, *Publisher*: Saunders
- Research and Review Papers in Current Journals.

VMD 506: Metabolic and Endocrine Diseases, Nutritional Deficiencies and Diseases of Mammary Gland (2+0)

S. No.	Topics	No. of lectures
1.	General aspects of production diseases and metabolic profile test	1
2.	Parturient paresis in dairy animals - etiology, pathogenesis, diagnosis, prevention and therapeutic management	1
3.	Downers cow syndrome and lactation tetany of mares	1
4.	Ketosis, sub clinical ketosis and fatty liver syndrome	1
5.	Nutritional haemoglobinuria in dairy animals	1
6.	Hypomagnesemic tetany in cattle	1
7.	Pregnancy toxaemia in sheep	1
8.	Eclampsia in bitches-etiology, pathogenesis, diagnosis, prevention and therapeutic management	1
9.	Acute hypokalemia and transit recumbency of ruminants	1
10.	Equine hyperlipemia, steatitis and neonatal hypoglycaemia	1
11.	Deficiencies of energy and protein	1
12.	Iodine deficiency disorders of ruminants	1
13.	Copper deficiency diseases of ruminants	1
14.	Diseases associated with deficiency of zinc and manganese	1
15.	Diseases associated with deficiency of iron and cobalt	1
16.	Vitamin E and selenium deficiency	1
17.	Diseases associated with deficiency of vitamin B-complex	1
18.	Diseases associated with deficiencies of vitamin A and K	1
19.	Rickets, osteoporosis and osteodystrophic fibrosa	1
20.	Diabetes mellitus in dogs	1
21.	Diabetes insipidus in dogs	1
22.	Hypo- and hyperthyroidism in dogs	1
23.	Hypo- and hyperadrenocorticism in dogs	1
24.	Anatomy of the mammary glands, physiology of lactation and congenital abnormalities of udder and teats	1
25.	Physical and chemical tests for detection of mastitis	1
26.	Detection and identification of pathogenic bacteria in milk	1
27.	Epidemiology, treatment and control of mastitis caused by contagious, environment and opportunistic pathogens	2
28.	Specific and non-specific viral lesions of teats and udder	1
29.	Teat stenosis; udder oedema; galactorrhagia, galactogogue; agalactia	1
30.	Heifer and goat mastitis, mastitis-metritis-agalactia in sows	1
31.	Public health importance of mastitis	1

Suggested books

- *Veterinary Medicine* 2007. *A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs and Goats by Otto M Radostits*, Clive C Gay, Kenneth W Hinchcliff and Peter D Constable. 10th Edition. Saunders.
- *Clinical Endocrinology of Companion Animals* (2013). Ed. J Rand 1st Edition edt.by Jacquie Rand (Editor), Ellen Behrend (Editor), Danielle Gunn-Moore (Editor), Michelle Campbell-Ward (Editor). Wiley-Blackwell.
- Research and Review Papers in Current Journals.

VMD 507: Paediatrics and Geriatrics (2+0)

S. No.	Topics	No. of Lectures
	Unit I	
1.	Perinatal adaptation, neonatal health, asphyxia and resuscitation	1
2.	Physical examination of the neonate, disease manifestation, supportive care of the abnormal newborn	1
3.	Failure of passive transfer of immunity and its management.	1
	Unit II	
4.	Pediatric pharmacology	1
5.	Fluid replacement therapy	1
6.	Immunization of neonates, nutritional support, blood and serum transfusion	1
	Unit III	
7.	Distended and painful abdomen, bloat	1
8.	Respiratory distress in the neonates	1
9.	Viral diseases of pups, foals and calves	2
10.	Bacterial diseases of pups, foals and calves	2
11.	Neonatal isoerythrolysis in foals, pups and kittens	1
12.	Congenital abnormalities of pups, foals and calves	1
13.	Peri-natal care and diseases of the newborn	1
14.	Non infectious diseases of pups	1
15.	Metabolic disorders, nutritional deficiencies, miscellaneous conditions (hypothermia, hyperthermia, starvation	2
16.	Care, management and treatment of sick puppies	1
	Unit IV	
17.	Guidelines for care of geriatric dogs	1
18.	Neuromuscular dysfunctions in geriatric dogs	1
19.	Common eye and ear affections in older canine and feline patients	1
20.	Hepatic and pancreatic disorders in older dogs and cats	1
21.	Paresis and/ or depressed mentation	1
22.	Urinary system diseases in geriatric dogs and cats	1
23.	Endocrine and metabolic disorders in geriatric patients	1
24.	Respiratory diseases in older dogs and cats	2
25.	Cardiac disorders in geriatric dogs and cats	1
26.	Cancer therapy in geriatric patients	1
27.	Skeletal disorders in geriatric patients	1
28.	Behaviour disorders in geriatric dogs	1

Suggested Readings

- *Equine Pediatric Medicine*. 2018. WV Bernard, BS Barr, 2nd edition, CRC Press.
- *Treatment and Care of the Geriatric Veterinary Patients* 2017. Mary Gardne and Dani McVety, Wiley-Blackwell.
- *Small Animal Pediatrics* 2011. Michael E. Peterson and Michelle Anne Kutzler, Elsevier.
- Research and Review Papers in Current Journals.

VMD 508: Avian and Swine Medicine (2+0)

S. No.	Topics	No. of Lectures
1.	General handling, sample collection and medication in various Avian Spps.	1

S. No.	Topics	No. of Lectures
2.	Etio-pathogenesis, symptomatology, diagnosis and treatment of diseases due to riboflavin deficiency in poultry	1
3.	Encephalomalacia (Crazy chick disease)	1
4.	Rickets and calcium deficiency in poultry	1
5.	Fatty liver and kidney syndrome	1
6.	Manganese and zinc deficiency in poultry	1
7.	Colibacillosis (including peritonitis in layers and salpingitis)	1
8.	Fowl cholera	1
9.	Yolk sac infection and omphalitis	1
10.	Salmonellosis and mycoplasmosis in poultry	1
11.	Infectious bursal disease (Gumboro disease) and Inclusion body hepatitis	1
12.	Infectious laryngotracheitis and infectious bronchitis	1
13.	New castle disease and marek's disease (including transient paralysis)	1
14.	Egg drop syndrome 76 (127 adenovirus/ BC14 infection)	1
15.	Lymphoid leukosis and other leukoses	1
16.	Parasitic diseases (Ascaridiasis and coccidiosis)	1
17.	Miscellaneous poultry diseases (cage layer fatigue, cannibalism, moult and prolapse of oviduct)	1
18.	General handling, physical examination and sample collection in pigs	1
19.	Mineral deficiency diseases in pigs (Calcium, phosphorus, iron, copper and zinc)	1
20.	Vitamin deficiency diseases in pigs (vitamin A, D, E, K, riboflavin and niacin)	1
21.	Swine influenza	1
22.	Swine fever (African and classical)	1
23.	Swine Pox	1
24.	Vesicular exanthema and vesicular stomatitis	1
25.	Swine dysentery (scours) and transmissible gastro-enteritis (TGE)	1
26.	Streptococcal meningitis	1
27.	Porcine reproductive and respiratory syndrome (PRRS)	1
28.	Pneumonia in pigs	1
29.	Glassers disease and greasy pig disease	1
30.	Swine erysipelas and mange	1
31.	FMD and brucellosis	1
32.	New and emerging diseases (Nipah virus)	1

Suggested Poultry Books

- *Diseases of Poultry*. 2013. DE Swayne, JR Glisson, LR McDougald, LK Nolan, DL Suarwz, and VL Nair. *13th Edition,* Wiley-Blackwell.
- *Diseases of poultry and their control*. 2001. R. Chandra, VDP Rao, JC Gomez-Villamandos, SK Shukla and PS Banerjee. 1st edition, International book distributing Co., Lucknow, India. 2001.
- Research and Review Papers in Current Journals.

Suggested Swine Books

- *Diseases of Swine*. 2012. JJ Zimmerman, LA Karriker, A Ramirez, KJ Schwartz and GW. Stevenson. 12th edition, Wiley-Blackwell.
- *Diseases of Swine* 2006. BE Straw, JJ Zimmerman, SD'Allaire and DJ Taylor. 9th edition, Blackwell Publishing.
- Research and Review Papers in Current Journals.

VMD 509: Zoo, Wild and Laboratory Animal Medicine (1+0)

S. No.	Topics	No. of Lectures
1.	Taxonomy of various genera of wild/ zoo animals of India along with their descriptions.	1
2.	Basic principles of habitat and housing of various classes of wild and zoo animals.	1
3.	Nutrient requirements, feeding habits and feeds of zoo, wild and laboratory animals.	2
4.	Diet formulation and feeding of various age groups, sick and geriatric animals.	1
5.	Post mortem examination, handling, processing and interpretation of pathological materials from zoo and wild animals.	1
6.	Breeding for conservation of wild animals.	1
7.	Population dynamics of wild animals, effective population size of wild animals in captivity/ zoo/ natural habitats.	1
8.	Restrain, capture, handling, physical examination and transport of wild and zoo animals.	1
9.	Principles of anesthesia, anesthetics, chemicals of restraining, common surgical Interventions; Capture myopathy.	2
10.	Acts and Rules related to zoo and wild animals.	1
11.	Principles of zoo hygiene, public health problems arising from zoos.	1
12.	Prevention, control and treatment of infectious, parasitic, nutritional and metabolic diseases in zoo and wild animals.	2
13.	Prevention, control and treatment of infectious, parasitic, nutritional and metabolic diseases of laboratory animals.	1

Suggested Books

- *Wild Mammals in Captivity: Principles and Techniques for Zoo Management* (2010). 2nd ed. - Kleiman, DG, University of Chicago Press
- *Zoo and Wild Animal Medicine Current Therapy* (2007). 6th ed. -C Fowler, ME
- *Zoo Animal and Wildlife Immobilization and Anesthesia* (2014). 2nd Ed.-C West, D Heard. N Caulkett, Wiley Blackwell
- Research and Review Papers in Current Journals.

VMD 510: Toxicology and Forensic Medicine (1+0)

S. No.	Topics	No. of Lectures
1.	Lead poisoning	1
2.	Arsenic and selenium poisoning	1
3.	Fluoride and copper toxicity	1
4.	Diseases associated with physical agents	1
5.	Chlorinated hydrocarbons, organophosphorous compounds and carbamates poisoning	1
6.	Nitrate nitrite poisoning, cyanide and urea poisoning	1
7.	Poisoning by mycotoxins and important phytotoxicoses	1
8.	Snakebite poisoning; Bee stings	1
9.	Examination of blood stains	1
10.	The vetero-legal wounds, causes of death from wounds	1
11.	Post-mortem examination of veterolegal case, submission of specimens in suspected cases of poisoning,	1

S. No.	Topics	No. of Lectures
12.	Collection and submission of specimens for histo-pathological examination, and various modern techniques for diagnosis of veterolegal cases	1
13.	Common frauds in the sale of livestock and livestock products	1
14.	Common offenses against animals in India	1
15.	Laws related to animal welfare in India	1
16.	Functioning of Animal welfare board	1

Suggested Books

- *Veterinary Toxicology*. 2014. SK Garg, CBS Publishers.
- *Veterinary Medicine- A textbook of the diseases of cattle, horses, sheep, pigs and goats* by Constable *et al*. 11th Ed., Saunders Ltd.
- *Animal Welfare Ethics and Jurisprudence* 2014. Kirti Dua, 1st Ed., Kalyani Publishers.
- *Veterinary Jurisprudence*. 2015. SN Sharma AK Gahlot and RK Tanwar. 7th Ed., NBS Publisher and Distributor.
- Research and Review Papers in Current Journals.

VMD 511: Clinical Diagnostic Techniques (0+2)

S. No.	Topics	No. of Practicals
1.	Endoscopy in small animals	1
2.	Endoscopic examination of URT in ruminants and equines	1
3.	Tracheo-broncheal lavage in ruminants, horses and dogs	2
4.	Thoracocentesis in dogs, cattle/ buffalo and horses	2
5.	Peritonial fluid collection and examination in dogs, cattle, buffalo and horse	1
6.	Cystocentesis in dogs and urine examination	1
7.	Electrocardiography in dogs and its interpretation	1
8.	Electrocardiography in large animals and its interpretation	1
9.	Techniques in ocular examination	1
10.	Cerebrospinal fluid collection and examination	1
11.	Dermatological examination	1
12.	Collection of biopsy samples (Skin and liver)	2
13.	Diagnosis tests in mastitis	1
14.	Nasogastric/ orogastric intubation in large animals	1
15.	Echocardiography in large and small animals	2
16.	Liver function tests and their interpretation	1
17.	Pericardiocentesis in large and small animals	1
18.	Urinary Catheterization in male and female dogs	1
19.	Urinary Catheterization in a cattle/ buffalo and a mare	1
20.	Renal function tests and their interpretation	1
21.	Arterial blood collection and interpretation of acid base and blood gas analysis	1
22.	Diagnostic tests in ear affections	1
23.	Physical and special examination of musculoskeletal system	1
24.	Neurological examination in small and large animals	2
25.	Bone marrow collection in small and large animals	2
26.	Ultrasonography of chest and abdomen in large animal disease diagnosis	1
27.	CT, MRI, Pulse Oximetry, Radioimmuno assay, Nuclear Medicine	2

Suggested Books

- *Large Animal Internal Medicine*. 2015. Bradford P. Smith, 5th Edition, Mosby Elsevier.
- *Small Animal Clinical Techniques*. 2010. Susan M. Taylor, Saunders Elsevier.
- *Handbook of Veterinary Neurology*. 2010. Michael D. Lorenz, Joan R. Coates and Marc Kent, 5th Edition, Saunders Elsevier.
- *Handbook of Equine Respiratory Endoscopy*. 2007. Safia Barakzai, First Edition, Saunders Elsevier.
- *Manual of Canine and Feline Cardiology*. 2008. Larry P. Tilley, Francis W.K. Smith Jr., M.A. Oyama and M.M. Sleeper, 4th Edition, Saunders Elsevier.
- *Diagnostic Techniques in Equine Medicine: A Textbook for Students and Practitioners Describing Diagnostic Techniques Applicable to the Adult Horse* (2009), Frank GR Taylor, Tim J Brazil and Mark H Hillyer, 2nd Edition, Saunders Elsevier.
- Research and Review Papers in Current Journals.

VMD 512: Emergency Medicine (0+2)

S. No.	Topics	No. of Practicals
1.	Triage and stabilization of critical ill patient	1
2.	Cardiopulmonary resuscitation (CPR) in dogs	1
3.	Oxygen therapy in dogs	1
3.	Gastrointestinal decompression in large and small animals	2
4.	Management of Acute respiratory distress syndrome in small animals	1
5.	Trans-thoracic drainage of pleural effusions in large and small animals	2
6.	Trans-thoracic drainage of pericardial effusions in large and small animals	2
8.	Intra-osseous fluid administration in pups	1
9.	Management of gastrointestinal emergencies; gastric lavage, pain management	1
10.	Endotracheal intubation in dogs	1
11.	Clinical examination and therapeutic management of status epilepticus in small animals	1
12.	Management of the shock patient	1
13.	Blood transfusion in small and large animals	2
14.	Entral nutrition in horse and dog	2
15.	Management of metabolic emergencies (Addison's disease, Diabetic ketoacidosis, Eclampsia, etc.)	2
16.	Management of acute renal failure	1
17.	Diagnosis and management of cardiac arrhythmias	1
18.	Acute obstrcutive colic and its management	1
19.	Poisons and toxins	2
20.	Urinary tract emergencies	2
21.	Ocular emergencies	2
22.	Neurological emergencies	2

Suggested Books

- *Kirk and Bistner's Handbook of Veterinary Procedures and Emergency Treatment*. 2012. Richard B. Ford and Elisa Mazaferro, 9th Edition, Saunders Elsevier.
- *Blackwell's Five Minute Veterinary Consult Clinical Companion, Small Animal Emergency and Critical Care*. 2010. Mazzaferro, M. E. 1st Edition, (Wiley Blackwell)
- *Equine Emergencies Treatment and Procedures*. 2008. Orsini J.A. and Divers T.J., 3rd Edition, Saunders Elsevier.
- Research and Review Papers in Current Journals.

VMD 513: Diagnosis of Veterinary Infectious Diseases (0+1)

S. No.	Topics	No. of Practicals
Practical		
1.	Techniques of random/ probability sampling and using survey tool box software for random selection of villages/ animals from a state population	1
2.	Sources of data and collection of animal health information using passive data and active surveillance	1
3.	Significance of sensitivity and specificity of a diagnostic test and false positive/ negative reactions of a particular test	1
4.	Diagnosis of mastitis by BTB card, SLS paddle test, electrical conductivity meter and somatic cell count.	1
5.	Inoculation of sample on culture media, and isolation/ identification of the organism	1
6.	Culture sensitivity tests on milk and other body fluids	1
7.	Collection and examination of samples for fungal infections	1
8.	Preparation of blood smear for protozoan and ricketssial disease examination	1
9.	Examination of parasitic eggs and along with their identification points including McMaster egg counting technique	1
10.	Collection and/ or examination of skin scrapings for mites, ticks, lice or fleas	1
11.	Screening tests for animal infectious diseases, including TB, JD, glanders and brucellosis	2
12.	Enzyme linked immunosorbant assay (ELISA): direct, indirect and competitive	1
13.	Use of Polymerase chain reaction (PCR) in animal disease diagnosis and its types	2
14.	Molecular epidemiology tools to study strain variation including RFLP, PCR-RFLP, etc.	1

Suggested Books

- *Veterinary Epidemiology* (2018). Michael Thrusfield, Robert Christley. Wiley-Blackwell
- *Veterinary Epidemiologic Research.* (2003). Ian Dohoo, Wayne Martin and Henryk Stryhn, AVC Inc., Charlottetown.
- *Diseases of Animals: Diagnosis and Management* (2013). Singh, Bhoj and Somvanshi, R. Indian Veterinary Research Institute
- *Veterinarian's Guide to the Laboratory Diagnosis of Infectious Diseases* (1986). Gordon R. Carter. Veterinary Medicine Publishing Company
- Research and Review Papers in Current Journals.

VMD 514: Oncology and Ethno-veterinary Medicine (1+0)

S. No.	Topics	No. of Lectures
1.	Introduction to tumors	1
2.	Conventional and advanced diagnostic techniques for diagnosis of tumors	1
3.	Basic and advancements in chemotherapy and radiation therapy for tumors	1
4.	Immune-therapy and other miscellaneous therapy for cancer patients	1
5.	Principles of nutrition and management of chronic pain in cancer patients	1

S. No.	Topics	No. of Lectures
6.	Tumors associated with gastrointestinal tracts	1
7.	Tumors associated with liver and spleen	1
8.	Tumors associated with endocrine system and urinary system	1
9.	Tumors associated with skin, subcutaneous tissues, eye and ear	1
10.	Tumors associated with hemopoietic and respiratory systems	1
11.	Principles of herbal medicines and their use in treating animal diseases	1
12.	Principles of homeopathic medicines and their use in treating animal diseases	1
13.	Application of acupuncture in the management of animal diseases	1
14.	Physiotherapy and laser therapy in animal diseases	1
15.	Common nutraceutical ingredients (prebiotics, probiotics, synbiotics, enzymes and antibacterial alternatives)	1
16.	Use of nutraceuticals in prevention and treatment of various animal diseases	1

Suggested Books

- *BSAVA Manual of Canine and Feline Oncology* by Dobson, Jane M. and Lascelles, B Duncan X. 3rd Ed., BSAVA.
- *Veterinary Herbal Medicine* by SG Wynn and BJ Fougere. 1st Ed., Mosby Elsevier.
- *Textbook of Veterinary Homeopathy*, by J Saxton and P Gregory. Beaconsfield Publishers, Beaconsfield
- *Complementary and Alternative Veterinary Medicine* by Narda G Robinson In: Merck Veterinary Manual. 11th Ed., Wiley.
- *Nutraceuticals in Veterinary Medicine* by, Ramesh C Gupta, Ajay Srivastava and Rajiv Lall. 1st Ed., 2019 Springer.
- Research and Review Papers in Current Journals.

VMD 515: Animal Disease Investigation and Biosecurity (1+1)

S. No.	Topics	No. of lectures/ Practicals
Theory		
1.	Investigation and diagnosis on dead animals and poultry	1
2.	Investigation and diagnosis on live animals and poultry	1
3.	Point source epidemics and propagating epidemics	1
4.	Collection, preservation and transport of material in the face of disease outbreak	1
5.	Processing of material in the laboratory for diagnosis	1
6.	Recording and analysis of epidemiological data	1
7.	Establishing working hypothesis	1
8.	Formulating and advising and/ or implementing treatment, control and prevention strategies	1
9.	Definition and related concepts of biosecurity, principles and basic components of biosecurity, physical operational elements of biosecurity	1
10.	Routes of entry and transmission dynamics of pathogens	1
11.	Shedding pattern of pathogens by infected animals and their survival in the environment	1
12.	Protection of susceptible animals, interruption of pathways of transmission	1
13.	Role of disinfection to break cycle of infection, sterilization, fumigation and disinfection methods	1

S. No.	Topics	No. of Lectures/ Practicals
14.	Disinfectants and its classification; microbial resistance to disinfectants, risk assessment and its management	1
15.	Principles of biosecurity for laboratory animal house, biosecurity in research laboratories, biosecurity measures for collection of specimen from wild animals	1
16.	Vaccines- success stories of disease eradication through vaccination	1
Practical		
1.	Isolation and identification of field isolates and vaccine strains by conventional, immunoassays and molecular techniques	3
2.	Outbreak investigation of infectious diseases in livestock and poultry in the field/ organized livestock farms	2
3.	Outbreak investigation of toxicological conditions in livestock and poultry in the field/ organized livestock farms	1
4.	Practical use of disinfectants in destruction of microbes in the laboratory and under field conditions	1
5.	Determination of efficacy/ phenol coefficient of commonly used disinfectants	1
6.	Approaches in animal disease control and eradication	1
7.	Preliminary steps to control animal disease outbreaks	1
8.	Types of vaccines- conventional and recombinants	1
9.	Vaccination schedule in cattle, sheep and, goats	2
10.	Vaccination schedule in horses and pigs	1
11.	Vaccination schedule of pets including dogs and cats	1
12.	Vaccination schedule of poultry including layers and broilers	1

Suggested Books

- *History of the Surveillance and Control of Transmissible Animal Diseases*. (2003). Jean Blancou. Office International des Epizooties
- *Veterinary Epidemiology* (2018). Michael Thrusfield, Robert Christley. Wiley-Blackwell
- *Biosecurity in Animal Production and Veterinary Medicine* (2018). Jeroen Dewulf, Filip Van Immerseel. *From Principles to Practice*. AMSTERDAM University Press
- Research and Review Papers in Current Journals.

Minor Courses for M.V.Sc. Degree programme

Courses of any one department/ discipline from the list given below:

- Veterinary Physiology
- Veterinary Microbiology
- Veterinary Parasitology
- Veterinary Pharmacology and Toxicology
- Veterinary Surgery and Radiology
- Veterinary Public Health and Epidemiology

Supporting Courses

It could be any subject considered relevant for student's research work. This will be decided by Advisor/ guide concerned.

Common Courses

The following courses (one credit each) will be offered to all students undergoing Master's degree programme.

- Library and Information Services
- Technical Writing and Communications Skills
- Intellectual Property and its management in Agriculture
- Basic Concepts in Laboratory Techniques
- Agricultural Research, Research Ethics and Rural Development Programmes

Course Contents
Ph.D. in Veterinary Medicine

Course Code	Course Title	Credit Hours
VMD 601	Farm Animal Gastroenterology	2+0
VMD 602	Farm Animal Cardiopulmonary and Urinary System Diseases	2+0
VMD 603	Farm Animal Neurological and Musculo-skeletal System Diseases	1+0
VMD 604	Farm Animal Neonatology	1+0
VMD 605	Herd Health Management	2+1
VMD 606	Canine and Feline Gastroenterology	2+0
VMD 607	Advances in Neurological and Musculoskeletal System Diseases of Canine and Feline	1+0
VMD 608	Canine and Feline Cardiopulmonary and Urinary System Diseases	1+0
VMD 609	Dermatology and Endocrinology	1+0
VMD 610	Canine and Feline Eye and Ear Diseases	1+0
VMD 611	Veterinary Diagnostics	0+2
VMD 612	Metabolic and Nutritional Deficiency Diseases	2+0
VMD 613	Emergency and Critical Care Medicine	1+1
VMD 614	Emerging and Re-emerging Animal Diseases	2+0
VMD 615	Prevention and Control of Infectious Diseases of Ruminants	2+0
VMD 616*	Clinical Practice-I	0+2
VMD 617*	Clinical Practice-II	0+2
VMD 618*	Clinical Practice-III	0+2
VMD 691	Doctoral Seminar-I	1+0
VMD 692	Doctoral Seminar-II	1+0

Course Contents
Ph.D. in Veterinary Medicine

I. Course Title : Farm Animal Gastroenterology

II. Course Code : VMD 601

III. Credit Hours : 2+0

IV. Aim of the course

Study of contemporary advancements in farm animal gastroenterology.

V. Theory

Unit I

Advances in diagnosis, Therapy and control of diseases of gastrointestinal system and associated organs of farm animals.

Unit II

Advances in diagnosis, Therapy, Control and prevention of infectious diseases of gastrointestinal system and associated organs of farm animals.

I. Course Title : Farm Animal Cardiopulmonary and Urinary System Diseases

II. Course Code : VMD 602

III. Credit Hours : 2+0

IV. Aim of the course

Advances in diseases of cardio-pulmonary and urinary systems.

V. Theory

Unit I

Advances in diagnosis and therapeutic management of internal diseases of circulatory system and urinary systems.

Unit II

Advances in diagnosis and therapeutic management of internal diseases of respiratory system.

Unit III

Advances in diagnosis, control, prevention and therapeutic management of infectious diseases of cardiopulmonary and urinary systems.

I. Course Title : Farm Animal Neurological and Musculo-skeletal System Diseases

II. Course Code : VMD 603

III. Credit Hours : 1+0

IV. Aim of the course

Study of recent advances in diseases of neurological and musculoskeletal systems.

V. Theory

Unit I

Advances in diagnosis, Therapy and control of internal diseases of nervous and musculoskeletal system.

Unit II

Advances in diagnosis, Therapy, Control and prevention of infectious diseases of nervous and musculo-skeletal systems.

I. Course Title : Farm Animal Neonatology

II. Course Code : VMD 604

III. Credit Hours : 1+0

IV. Aim of the course

Study of recent advances in care and disease management of equine and ruminant neonates.

V. Theory

Unit I

Advances in diagnosis, Therapy, Prevention and control of internal and infectious diseases of equine neonate.

Unit II

Advances in diagnosis, Therapy, Prevention and control of internal and infectious diseases of ruminant neonate.

I. Course Title : Herd Health Management

II. Course Code : VMD 605

III. Credit Hours : 2+1

IV. Aim of the course

Recent concepts in herd health medicine.

V. Theory

Unit I

General principles, Interactions between health and production, Herd medicine and population health.

Unit II

Herd health management programme for enzootic herds/ flocks.

Unit III

Recent concepts on herd management of chronic Bacterial, parasitic and fungal and rickettsial diseases.

Unit IV

Biosecurity and infection control, Herd and flock immunity, Quality management of herd health, Control of infectious diseases in the herd, Herd health economics.

VI. Practical

Visit to farms, Assessment of their problems, Estimating the presence and prevalence of a disease and new proposals for prevention and control strategies of a specific disease and its impact.

I. Course Title : Canine and Feline Gastroenterology

II. Course Code : VMD 606

III. Credit Hours : 2+0

IV. Aim of the course

Study of advancements in canine and feline gastroenterology.

V. Theory

Unit I

Advances in diagnosis, Therapy and control of internal diseases of gastrointestinal system and associated organs of canine and feline.

Unit II

Advances in diagnosis, Therapy, Control and prevention of infectious diseases of gastrointestinal system and associated organs in canine and feline.

I. Course Title : Advances in Neurological and Musculoskeletal System Diseases of Canine and Feline

II. Course Code : VMD 607

III. Credit Hours : 1+0

IV. Aim of the course

Study of recent advances in the field of neurological and musculoskeletal diseases.

V. Theory

Unit I

Advances in diagnosis, Therapy and control of internal diseases of nervous and musculoskeletal systems.

Unit II

Advances in diagnosis, Therapy and control of infectious diseases of nervous and musculoskeletal systems.

I. Course Title : Canine and Feline Cardiopulmonary and Urinary System Diseases

II. Course Code : VMD 608

III. Credit Hours : 1+0

IV. Aim of the course

Advances in cardiopulmonary and urinary systems.

V. Theory

Unit I

Advances in diagnosis and therapeutic management of internal diseases of circulatory and urinary systems.

Unit II

Advances in diagnosis, therapeutic management of internal diseases of respiratory system.

Unit III

Advances in diagnosis, therapeutic management, prevention and control of infectious diseases of cardiopulmonary and urinary systems.

I. Course Title : Dermatology and Endocrinology

II. Course Code : VMD 609

III. Credit Hours : 1+0

IV. Aim of the course

Recent concepts in diagnosis, management and control of diseases of skin and endocrine organs.

V. Theory

Unit I

Advances in diagnosis, therapy, prevention and control of infectious and non-infectious diseases of skin and integumentary systems.

Unit II

Advances in diagnosis, therapy and control of diseases of endocrine system.

I. Course Title : Canine and Feline Eye and Ear Diseases

II. Course Code : VMD 610

III. Credit Hours : 1+0

IV. Aim of the course

Study of recent advances in eye and ear diseases of canine and feline.

V. Theory

Unit I

Advances in examination, diagnosis and therapy of diseases of eye.

Unit II

Advances in diagnosis and therapy of diseases of ear.

I. Course Title : Veterinary Diagnostics

II. Course Code : VMD 611

III. Credit Hours : 0+2

IV. Aim of the course

Study of recent advances in diagnostics.

V. Practical

Unit I

Analysis and interpretation of hemogram, serum and blood biochemicals.

Unit II

Imaging techniques for the diagnosis of animal diseases (electrocardiography, echocardiography, etc.)

Unit III

Ophthalmoscopy, Ultrasonography, Pulse-oximetry. Assignments on advanced diagnostic techniques for various diseases of domestic animals. Use of above mentioned advanced diagnostic techniques where ever possible. Collection and examination of CSF, gastric/ rumen/ abomasal, peritoneal fluid, absorption and digestion tests, low and high dose dexamethasone test, ACTH stimulation test, hormone profile and enzyme profile.

I. Course Title : Metabolic and Nutritional Deficiency Diseases

II. Course Code : VMD 612

III. Credit Hours : 2+0

IV. Aim of the course

Recent trends in diagnosis, management and control of metabolic and nutritional diseases.

V. Theory

Unit I

Metabolic profile tests, Parturient paresis, Downer's cow syndrome, Acute hypokalemia in cattle, Transit recumbency and lactation tetany of mares, Hypomagnesemic tetany of calves, Ketosis, Subclinical ketosis, Pregnancy toxemia, Fatty liver syndrome, Equine hyperlipidemia, Steatitis, Neonatal hypoglycemia, Low milk fat syndrome, Postparturient hemoglobinuria and eclampsia in bitches.

Unit II

Deficiency of energy and protein, Deficiency of fat. Deficiency of fat and water soluble vitamins, Deficiency of macro and micro minerals.

Unit III

Diabetes mellitus, diabetes insipidus, hypothyroidism, obesity, hypo- and hyperadrenocorticism, hormone deficiency syndromes.

I. Course Title : Emergency and Critical Care Medicine

II. Course Code : VMD 613

III. Credit Hours : 1+1

IV. Aim of the course

Recent advancement in emergency medicine and critical care.

V. Theory

Unit

Diagnosis and therapeutic management of various emergencies of cardiovascular, respiratory, gastrointestinal, urinary and nervous systems.

Unit

Diagnosis and therapeutic management of various emergencies of toxicities, sting bites and burns in farm and companion animals.

Unit

Monitoring critical ill patient, application of emergency care procedures for resuscitation of critically ill patients.

VI. Practical

- Placement of central venous catheters, Intra-osseous fluid administration, Endotracheal intubation, Gastric lavage, Decompression of guttural pouch, Stomach, Cecum, Ventilation, Nebulisation, Fluid therapy, CPR, oxygen therapy, Enteral nutrition, Nasogastric intubation.
- Continuous rate infusion, Defibrillation– Demonstration, Peritoneal dialysis, Peritoneal diagnostic lavage, Management of hypo/ hyper thermia, Trocarization.

I. Course Title : Emerging and Re-emerging Animal Diseases
II. Course Code : VMD 614
III. Credit Hours : 2+0
IV. Aim of the course

Study on emerging and re-emerging diseases of animals.

Unit I

General concepts for emergence of new diseases and re-emergence of old diseases. Factors and determinants of emerging diseases. The role of wildlife in emerging and re-emerging diseases.

Unit II

Microbial adaptation and change; Epidemiological processes involved in the emergence of vector-borne diseases. Epidemiology of globally and nationally important emerging/ re-emerging diseases and designing of strategies for their prevention and control.

I. Course Title : Prevention and Control of Infectious Diseases of Ruminants
II. Course Code : VMD 615
III. Credit Hours : 2+0
IV. Aim of the course

Recent concepts in prevention and control of infectious diseases of ruminants.

V. Theory

Unit I

Bacterial and viral diseases of economic importance in bovines, sheep and goats.

Unit II

Fungal and parasitic diseases of economic importance in bovines, sheep and goats.

Unit III

Blood protozoan and rickettsial diseases of economic importance in bovines, sheep and goats.

I. Course Title : Clinical Practice-I
II. Course Code : VMD 616
III. Credit Hours : 0+2
IV. Aim of the course

Application of the theoretical concepts in practice.

V. Practical

Diagnostic and therapeutic protocol application, Specimen collection, Examination and management of sick farm and companion animals, Use of diagnostic techniques for diagnosis of medicinal cases, Acquaintance with different equipment, Client management, public relations, Code of conduct, hospital management, Database management and maintenance of case records, Disaster management.

Note: This course shall be conducted in Veterinary Clinical Complex (VCC) where students shall participate in diagnosis and treatment of diseased animals.

I. Course Title : Clinical Practice-II

II. Course Code : VMD 617

III. Credit Hours : 0+2

IV. Aim of the course

Application of the theoretical concepts in practice.

V. Practical

Diagnostic and therapeutic protocol application, Specimen collection, Examination and management of sick farm and companion animals, Use of diagnostic techniques for diagnosis of medicinal cases, Acquaintance with different equipment, Client management, Public relations, Code of conduct, Hospital management, Database management and maintenance of case records, Disaster management.

Note: This course shall be conducted in Veterinary Clinical Complex (VCC) where students shall participate in diagnosis and treatment of diseased animals.

I. Course Title : Clinical Practice-III

II. Course Code : VMD 618

III. Credit Hours : 0+2

IV. Aim of the course

Application of the theoretical concepts in practice.

V. Practical

Diagnostic and therapeutic protocol application, Specimen collection, Examination and management of sick farm and companion animals, Use of diagnostic techniques for diagnosis of medicinal cases, Acquaintance with different equipment, Client management, Public relations, Code of conduct, Hospital management, Database management and maintenance of case records, Disaster management.

Course Outline: Lecture wise

VMD 601: Farm Animal Gastroenterology (2+0)

S. No.	Topics	No. of Lectures
1.	Physical examination in gastrointestinal disease diagnostic strategies and initial plan in assessment of gastrointestinal function	1
2.	Imaging techniques for the gastrointestinal system radiography of the gastrointestinal system veterinary nuclear medicine	1
3.	Clinical pharmacology of the gastrointestinal tract	1
4.	Principles of fluid therapy in cattle, horse, pig, sheep and goat	1
5.	Diseases of the buccal cavity and related organs including pharynx, oesophagus	1
6.	Reticulo-ruminal disorders – recent concepts in fermentative disorders-simple indigestion, impaction, ruminal lactic acidosis, alkalosis	2
7.	Primary and secondary bloat- diagnosis	1
8.	Traumatic reticulo-peritonitis, vagal indigestion syndrome, generalised peritonitis, omasal impaction and abdominal distension	2
9.	Diseases of abomasum (impaction, displacements, ulcers)	1
10.	Intestinal disorders (intussusception, volvulus), strangulation, caecal dilatation and volvulus in ruminants.	1
11.	Diseases of bovine liver	1
12.	Diarrhea in cattle and small ruminants	1
13.	Bacterial and viral diseases: Campylobacteriosis, intestinal chlamydial infectionssalmonellosis, tyzzer's diseaseinfectious disease involving gut such as RP, BVD. FMD, actinomycosis, actinobacillosis	3
14.	Protozoal diseases: Coccidiosis, cryptosporidiosis	1
15.	Gastrointestinal parasites of pigsAscaris sp, oesophagostomum, stomach worms, strongyloides sp, trichuris sp	1
16.	Gastrointestinal parasites of horsesGastrophilus, habronema, oxyuris, parascaris, large strongyles, small strongyles, strongyloides, tapeworms, trichostrongylus	2
17.	Gastrointestinal Parasites of cattleCooperia, bunostomum, strongyloidees, nematodirus, toxocara, oesophgostomum, chabertia, trichuris, tapeworms	2
18.	Gastrointestinal parasites of sheep and goatsHaemonchus, ostertagia, and trichostrongylus, intestinal trichostrongylosis, nematodirus, oesophagostomum, chabertia, storngyloides, trichuris, tapeworms	2
19.	Gastrointestinal diseases – Horse and Pigs	1
20.	Dysphagia in horses	1
21.	Diseases of stomach: GIT ulceration, gastric dilation, impaction, gastric parasitism in horses and pigs	1
22.	Diseases causing equine colic such as anterior enteritis, small intestine strangulation, intestine impaction. Protocol and management of equine colic	1
23.	Obstructive intestinal diseases in horse	1
26.	Chronic weight loss without diarrhea, pain or icterus in horse	1
27.	Swine dysentery, hog cholera	1

Suggested Books

- *Equine Internal Medicine*. 2017. Stephen Reed, Warwick Bayly and Debra Sellon, 4th Edition, Elsiever, Saunders.
- *Large Animal Internal Medicine*. 2019. Bradford Smith, David Van Metre and Nicola Pusterla, 6th Edition, Mosby
- *Rebhun's Diseases of Dairy Cattle*. 2018. Simon F Peek and Thomas J Divers, 3rd Edition, Elseviers
- *Veterinary Gastroenterology*. 1992. Neil V. Anderson, 2nd Revised edition, Lea and Febiger, USA.
- Research and Review Papers in Current Journals.

VMD 602: Farm Animal Cardiopulmonary and Urinary System Diseases (2+0)

S. No	Topics	No. of Lectures
1.	Evaluation of patient with respiratory signs	1
2.	Diagnostic aids in evaluation of respiratory line	1
3.	Retropharyngeal lymph node abscessation in horses	1
4.	Pharyngeal affections in horses and Pharyngeal trauma in ruminants	1
5.	Diseases of guttural pouch in horses	1
6.	Laryngeal granuloma, abscess, edema	1
7.	Tracheal collapse and stenosis in farm animals	1
8.	Ethmoid hematoma in horses, diseases of paranasal sinuses in farm animals	1
9.	Disorders of equine soft palate	1
10.	Bacterial pneumonia and pleuropneumonia in adult horses	1
11.	Pneumonia in foals	1
12.	Pulmonary edema and smoke inhalation	1
13.	Recurrent airway obstruction in horses	1
14.	Inflammatory airway disease in horses	1
15.	Epistaxis and Exercise induced pulmonary hemorrhage in horses	1
16.	Bronchopneumonia and interstitial pneumonia in ruminants	1
17.	Hypersensitivity and metastatic pneumonia	1
18.	Progressive viral pneumonia of sheep and goats	1
19.	Pleuritis and pleural effusions, pneumothorax and lung tumors	1
20.	Viral pneumonia of sheep	1
21.	Congenital cardiac diseases	1
22.	Pericardial diseases	1
23.	Myocardial diseases	1
24.	Endocardial diseases	1
25.	Cardiac arrythmias	1
26.	Anaemia	1
27.	Bleeding disorders	1
28.	Renal failure in horses	1
29.	Urinary incontinence and urethral obstruction in equine and bovine	1
30.	Polyuria and polydypsia in horses, urinary system disorders in the foal	1
31.	Ulcerative posthitis and vulvitis in small ruminants	1
32.	Bacterial pyelonephritis and urinary tract infection, leptospirosis	1

Suggested Books

- *Large Animal Internal Medicine*. 2019. Bradford Smith, David Van Metre and Nicola Pusterla, 6th Edition, Mosby
- *Veterinary Medicine: A textbook of the diseases of cattle, horses, sheep, pigs and goats* by Otto M Radostits, Clive C Gay, Kenneth W Hinchcliff and Peter D Constable.10th Edition. Saunders

- *Rebhun's Diseases of Dairy Cattle*. 2018. Simon F Peek, Thomas and J Divers, 3rd Edition, Elseviers
- Research and Review Papers in Current Journals.

VMD 603: Farm Animal Neurological and Musculo-skeletal System Diseases (1+0)

S. No.	Topic	No. of Lectures
1.	Neurological examination in bovine and equine patients; Localization of lesions in nervous system	1
2.	Disease of brain stem in equines and bovines	1
3.	Diseases producing cortical signs in equines and bovines	1
4.	Diseases of spinal cord and Peripheral neuropathies	1
5.	Viral/ Prions encephalopathies: Equine herpes virus, Eastern/ Western equine encephalopathies, Bovine Spongifrom Encepahlopathy, etc.	2
6.	Parasitic thromboembolism and Equine Protozoal encephalomyelitis	1
7.	Encephalomalacia, Narcolepsy and Hyperkalemic periodic paralysis	1
8.	Diagnostic approach to musculoskeletal abnormalities	1
9.	Diseases of Muscle tone; Muscle Cramping	1
10.	Nonexertional Rhabdomyolysis in Horses: Inflammatory myopathies, nutritional, toxic and traumatic rhabdomyolysis	1
11.	Exertional Myopathies in Horses: Congenital, acquired and metabolic disorders	1
12	Osteochondrosis, Septic (Infectious) arthritis osteomyelitis, osteoarthritis, laminitis in horse	1
13	Bovine foot lameness: Characteristics of lameness, metabolic and infectious causes and conformation defects	2
14	Nutrition and Lameness, Claw trimming and foot baths	1

Suggested Books

- *Bovine Laminitis and Lameness*. 2007. Paul R Greenough, First Edition, Saunders Elsevier.
- *Large Animal Internal Medicine*. 2019. Bradford Smith, David Van Metre, Nicola Pusterla, 6th Edition, Mosby
- *Handbook of Veterinary Neurology*. 2010. Michael D Lorenz, Joan R Coates and Marc Kent, 5th Edition, Saunders Elsevier.
- *Equine Internal Medicine*. 2004. Stephen M Reed, Warwick M Bayly and Debra C Sellon, 2nd Edition, Saunders Elsevier.
- Research and Review Papers in Current Journals.

VMD 604: Farm Animal Neonatology (1+0)

S. No.	Topics	No. of Lectures
1.	Advances in management during perinatal adaption period	1
2.	Manifestations of neonatal diseases in calves	2
3.	Manifestations of neonatal diseases in foals	2
4.	Manifestations of neonatal diseases in lambs and kids	2
5.	Neonatal infection and sepsis	1
6.	Advances in diagnostic procedures in neonates	2
7.	Advances in intensive care of management of critically ill neonates	2
8.	Advances in chemotherapeutic management of neonatal diseases	2
9.	Vaccination and maternal antibody interference	1
10.	Advances in management of orphan neonates	1

Suggested Books

- *Equine Pediatric Medicine*. 2018.W V Bernard, BS Barr, 2nd edition, CRC Press
- *Practical Lambing and Lamb Care*. 2018. N Sargison, JP Crilly and A Hopker, 4th edition, Wiley Blackwell
- *Equine Neonatal Medicine*. 2006. MR Paradis, 1st edition, Saunders
- *Bovine Neonatology*. 2009. *Veterinary Clinics of North America: Food Animal Practice*. 1st Edition, Saunders
- Research and Review Papers in Current Journals.

VMD 605: Herd Health Management (2+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
1.	General principles of herd health management	2
2.	Factors to be considered for successful implementation of herd health program	1
3.	Interaction between health and production	2
4.	Monitoring young stock health	1
5.	Targets for young stock rearing and dairy cow culling	1
6.	Disease control in rearing period	1
7.	Herd Medicine and population health	2
8.	Herd nutrition for optimum health	2
9.	Recent concepts on herd management of bacterial diseases	2
10.	Recent concepts on herd management of viral diseases	2
11.	Recent concepts on herd management of parasitic diseases	1
12.	Recent concepts on herd management of fungal diseases	1
13.	Recent concepts on herd management of rickettsial diseases	1
14.	Herd management of metabolic diseases	1
15.	Herd management of deficiency diseases	1
16.	Biosecurity and infection control	1
17.	Herd and flock immunity	1
18.	Quality management of herd health	1
19.	Control of infectious diseases in the herd	1
20.	Herd health economics	1
21.	Importance and steps of record keeping	2
22.	Control of lameness	1
23.	Diagnosis and control of mastitis and enhancement of milk quality	2
Practicals		
1.	Recent advances in calf management and diseases	1
2.	Appropriate animal housing	1
3.	Epidemiological investigations for problem identification at farm	1
4.	Farm biosecurity	1
5.	Recent advances in disinfection of farm sheds and other equipments	1
6.	Stress control of farm animals with respect to environmental and production stress	1
7.	Record keeping	1
8.	Recent advances in disease testing (TB, JD, Brucellosis, Mastitis)	1
9.	Routine farm procedures	2
10.	Herd vaccination	1
11.	Ecto and endo parasitism: principles and latest control trends	1
12.	Recent advances in mastitis control	1

S. No.	Topics	No. of Lectures/ Practicals
13.	Recent advances in lameness control	1
14.	Establishment of farm laboratoty	1
15.	Use of medicines and food safety	1

Suggested Books

- *Dairy Herd Health*. 2012. MJ Green and Andrew J Bradley. CABI *Publishing*
- *Herd Health: Food, Animal, Production, Medicine*. 1994. OM Radostits, KE Leslie, J Fetrow and WB. Saunders,
- *Veterinary Epidemiology*. 2018. Michael Thrusfield, Robert Christley. Wiley-Blackwell
- *The Keys to Herd Health*. 2006. Jerry Brunetti. Acres U.S.A.
- *Herd Health and Production Management in Dairy Practice*. 2003. Arie Brand. International Book Distributing Company
- Research and Review Papers in Current Journals.

VMD 606: Canine and Feline Gastroenterology (2+0)

S. No.	Topics	No. of Lectures
1.	Introduction to gastrointestinal function and microbiota	02
2.	Diagnostic approach to anorexia, abdominal pain and vomiting	02
3.	Approach to clinical signs of diarrhea, constipation and tenesmus	02
4.	Diagnostic and therapeutic approach to hematochezia and melena	02
5.	Diagnostic approach to hepato-biliary diseases and pancreatic diseases, coagulopathy, icterus, ascites and hepatoencephalopathy	02
6.	Approach to clinical signs of weight loss and cachexia	01
7.	Nutritional approach to gastrointestinal disease management	02
8.	Pharmacological approach to gastrointestinal disease: antiemetic, antidiarrhoeal and cytoprotective agents	01
9.	Pharmacological approach to gastrointestinal disease: antimicrobial and anthelmintic agents	01
10.	Pharmacological approach to gastrointestinal disease: prokinetics, probiotics and laxatives	01
11.	Chemotherapy and immunosuppressive drugs in gastrointesinal disease	01
12.	Dentistry and diseases of oropharynx	01
13.	Diagnostic evaluation and diseases of esophagus	01
14.	Gastric diseases: Gastritis, ulceration, neoplasia and dysmotility	02
15.	Advances in treatment and management of Small intestinal diseases	01
16.	Diagnostic approach and management of inflammatory bowel disease (IBD), Ulcerative colitis, bacterial, parasitic and fungal infections of large intestine	02
17.	Diagnostic evaluation and treatment of diseases of anorectum	01
18.	Diagnostic evaluation and common affections of pancreas	01
19.	Liver: Parenchymal, neoplastic, metabolic and biliary disorders	03
20.	Breed related gastrointestinal disorders	01
21.	Behaviour and gastrointestinal disease	01

Suggested books

- *Canine and Feline Gastroenterology*. 2013. RJ Washabau and MJ Day, Elesvier Mosby, St. Louis Missouri
- *Text Book of Veterinary Internal Medicine*. 2001. Part I and II, Ettinger and Feldman, 7th Edition, Saunders

- *Small Animal Medical Diagnosis*. 2009. MD Lorenz, TM. Neer and PL Demars, 3rd Edition, Willey Blackwell, Iowa, USA.
- Research and Review Papers in Current Journals.

VMD-607 Advances in Neurological and Musculoskeletal System Diseases of Canine and Feline (1+0)

S. No	Topics	No. of Lectures
1.	Classification and general diagnostic features of acquired myopathies in dogs and cats	1
2.	Developmental and genetic bone disorders	1
3.	Idiopathic bone disorders	1
4.	Metabolic, nutritional and endocrine bone disorders	1
5.	Neoplasms of bones	1
6.	Focal brain diseases of rapid onset- idiopathic epilepsy, idiopathic vestibular disease, trigeminal neuropathy, idiopathic facial nerve paralysis	1
7.	Brain diseases of intermediate onset- brain abscesses	1
8.	Focal brain diseases of slow onset- Thiamine deficiency, hypoglycemia, poisons	1
9.	Inflammatory brain disorders- viral, bacterial, protozoal and mycotic encephalitis	1
10.	Inflammatory meningitis-granulomatous meningo-encephalitis, Pug encephalitis, rickettsial diseases	1
11.	Metabolic diseases with neurological signs	1
12.	Diseases affecting cervical spinal cord and brachial plexus	1
13.	Diseases affecting thoraco-lumbar and lumbo-sacral segments of spinal cord	2
14.	Inflammatory and immune mediated neuropathies	1
15.	Metabolic and toxic causes affecting peripheral nerves dysfunctions	1

Suggested Books

- *Handbook of Veterinary Neurology*. 2011. MD Lorenz, JR Coates and Marc Kent 5th Edition. Elsevier Saunders
- *Textbook of Veterinary Internal Medicine: Diseases of the Dog and Cat*. 2010. Stephen J. Ettinger and Edward C. Feldman, Elsevier Saunders 7th Edition.
- *Veterinary Clinics of North America: Small Animal Practice*, Elsevier, Monthly
- Research and Review Papers in Current Journals.

VMD 608: Canine and Feline Cardiopulmonary and Urinary System Diseases (1+0)

S. No	Topic	No. of Lectures
1.	Pathophysiology of heart failure, Clinical manifestations of cardiac diseases	1
2.	Diagnostic tests for cardiovascular system (radiography, electrocardiography and echocardiography)	1
3.	Therapeutic management of heart failure	1
4.	Cardiac arrhythmias and anti-arrhythmic therapy	1
5.	Acquired valvular heart diseases (Degenerative atrioventricular valve diseases and infectious endocarditis)	1
6.	Myocardial diseases od dogs and cats(Canine dilated cardiomyopathy, canine hypertrophic cardiomyopathy and feline cardiomyopathies)	1

S. No.	Topics	No. of Lectures
7.	Pericardial diseases and cardiac tumors, systemic arterial hypertension	1
8.	Clinical evaluation of patient with respiratory diseases	1
9.	Feline upper respiratory tract infections	1
10.	Bacterial rhinitis, allergic rhinitis, nasal mycosis, nasal tumors, polypsin dogs and cats	1
11.	Diseases of trachea (infectious tracheobronchitis, lungworms, tracheal hypoplasia and tracheal collapse), Canine and feline bronchitis	1
12.	Pulmonary parenchymal diseases (infectious- viral, bacterial, protozoal, fungal and parasitic)	1
13.	Pulmonary neoplasia, pulmonary edema, pleural effusions, pneumothorax	1
14.	Clinical approach and laboratory evaluation of renal diseases, Glomerulonephritis, Urolithiasis	1
15.	Acute and chronic renal failure	1
16.	Canine and feline lower urinary tract disorders, Disorders of micturition, Neoplasms of urinary tract	1

Suggested Books

- *Small Animal Internal Medicine*. 2013. Nelson RW and Couto, CG 5th edition, Elesvier Mosby, St. Louis Missouri
- *Text book of Veterinary Internal Medicine*. 2010. Ettinger and Feldman, 7th Edition, Saunders
- Research and Review Papers in Current Journals.

VMD 609: Dermatology and Endocrinology (1+0)

S. No.	Topics	No. of Lectures
1.	New trends in management of adrenal gland diseases in dogs and cats	1
2.	Hyperadrenocorticism (Pituitary pars intermedia dysfunction) in horses	1
3.	Primary hyperaldosteronism and pheochromocytoma in dogs and cats	1
4.	Advances in management of diabetes mellitus and diabetic ketoacidosis	1
5.	Equine metabolic syndrome/ Insulin resistance syndrome in horses	1
6.	Hypo and hyperthyroidism in dogs and cats	1
7.	Hypo and hypercalcemia in dogs and cats	1
8.	Hyposomatotropism and acromegaly in dogs	1
9.	Advances in management of diabetes Insipidus and polyuria/ polydipsia in Dogs and cats	1
10.	Advances in management of autoimmune disorders (different forms of pemphigus)	1
11.	Diagnosis, therapy and prevention of hypersensitivity disorders –Atopy, urticaria, milk allergy, vasculitis, contact dermatitis, culicoides hypersensitivity	1
12.	Diagnosis, therapy and prevention of bacterial skin dermatitis-dermatophillus, folliculitis, staphylococcal cellulitis, equine corynebacterial dermatitis	1
13.	Diagnosis, therapy and prevention of fungal skin dermatitis-dermatophytosis, malasezzial dermatitis	1
14.	Diagnosis, therapy and prevention of parasitic skin dermatitis-mange, culicoides hypersensitivity, onchocerciasis, stephanofilaria, cutaneous hebronemiasis	1
15.	Diagnosis, therapy and prevention of viral diseases-warts, pox diseases	1
16.	Advanced diagnosis of skin tumors	1

Suggested Books

- *Clinical Endocrinology of companion animals*. 2013. Ed. J Rand 1st Edition edt. by Jacquie Rand (Editor), Ellen Behrend (Editor), Danielle Gunn-Moore (Editor) and Michelle Campbell-Ward (Editor). Wiley-Blackwell.
- *Muller and Kirk's Small Animal Dermatology*. 2013. 8th Edition. Edited by WH Miller, CE Griffin and KL Campbell. Elsevier, St Louis, MO, USA,
- *Equine dermatology*. 2011. 2nd Edition edited by Danny W Scott and William H. Miller, Jr 2nd edition. Elsevier, St Louis, MO, USA.
- Research and Review Papers in Current Journals.

VMD 610: Canine and Feline Eye and Ear Diseases (1+0)

S. No.	Topics	No. of Lectures
Advances in Examination, Diagnosis and Therapy of diseases of eye		
1.	Diseases of the eyelid and Conjunctiva	2
2.	Diseases of the cornea and sclera	1
3.	Disease of the lens, uvea: Glaucoma	2
4.	Disease of the retina, choroid, and optic nerve	2
5.	Disease of the Lacrimal apparatus	1
6.	Diseases of the the Orbit	1
7.	Neuro-ophthalmology	1
8.	Tumors of eye	1
Advances in Diagnosis and Therapy of diseases of ear		
1.	Otitis Externa	1
2.	Diseases of the external ear canal and pinna	1
3.	Otitis media and Otitis interna	2
4.	Tumors of ear	1

Suggested Books

- *Veterinary Opthalmology*. 2013. Kirk N Gellat, Brian C Gilger and Thomas J Kern, 5th edition.Wiley Blackwell,
- *Saunders Manual of Small Animal Practice*. 2016. SJ Birchard and RG Sherding, WB Saunders Company
- Research and Review Papers in Current Journals.

VMD 611: Veterinary Diagnostics (0+2)

S. No.	Topics	No. of Practicals
Practical		
1.	(i) Endoscopic procedures in small animals (ii) Diagnostic aids and ancillary diagnostic tests in diseases of gastrointestinal system	2
2.	Endoscopic examination of URT in ruminants	1
3.	Endoscopic examination of URT in equines	1
4.	Tracheo-bronchial lavage in ruminants, horses and dogs	2
5.	Thoracocentesis in dogs, cattle/ buffalo and horses	2
6.	Electrocardiography in dogs and its interpretation/ Electrocardiographic diagnosis of arrhythmia in dogs	2
7.	Electrocardiography in diagnosis of arrhythmias in horses and dairy animals	1

S. No.	Topics	No. of Practicals
8.	Cerebrospinal fluid collection, examination and diagnosis and clinical case study (5 animals)	1
9.	Dermatological examination and case workup	1
10.	Biopsy collection techniques and its application on clinical cases	1
11.	Pericardiocentesis and drainage of effusions in large and small animals	1
12.	Neurological examination in small and large animals	2
13.	Techniques in ocular examination-cytology, opthalmoscopy, measurement of intraocular pressure	2
14.	Bone marrow collection and its application in diagnosis in small and large animals	1
15.	Ultrasonography in various thoracic and abdominal affections in large animals	1
16.	Echocardiography in valvular and myocardial diseases in small animals	1
17.	Echocardiography in valvular and myocardial diseases in large animals	1
18.	Liver function tests and their interpretation with case studies	1
19.	Arterial blood collection and interpretation of acid base and blood gas analysis	1
20.	Concepts and diagnostic tests in veterinary infectious diseases Sampling techniques for collection of samples during research	2
21.	ELISA and its types, molecular techniques and types of PCR	1
22.	Molecular epidemiology tools including RFLP, etc.	2
23.	Molecular diagnostic techniques of fungal diseases, protozoan and rickettsial diseases	2

Suggested Books

- *Large Animal Internal Medicine*. 2019. Bradford Smith, David Van Metre and Nicola Pusterla, 6th Edition, Mosby
- *Small Animal Clinical Techniques*. 2010. Susan M Taylor, Saunders Elsevier
- Handbook of Veterinary Neurology. 2010. Michael D. Lorenz, Joan R. Coates and Marc Kent, 5th Edition, Saunders Elsevier.
- *Handbook of Equine Respiratory Endoscopy*. 2007. Safia Barakzai, 5th Edition, Saunders Elsevier.
- *Manual of Canine and Feline Cardiology*. 2008. Larry P Tilley, Francis WK Smith Jr., MA Oyama and MM Sleeper, 4th Edition, Saunders Elsevier.
- *Diagnostic Techniques in Equine Medicine: A Textbook for Students and Practitioners Describing Diagnostic Techniques Applicable to the Adult Horse*. 2009. Frank GR Taylor, Tim J Brazil and Mark H Hillyer, 2nd Edition, Saunders Elsevier.
- Research and Review Papers in Current Journals.

VMD 612: Metabolic and Nutritional Deficiency Diseases (2+0)

S. No.	Topics	No. of Lectures
1.	Strategies for transition cow health management	1
2.	Latest trends in prevention and management of parturient paresis with special reference to calcium cyclers and DCAD	1
3.	Current approach to diagnosis and management of downer's cow syndrome and acute hypokalemia in cow	1
4.	Lactation tetany and transit recumbency in mares	1
5.	Update on diagnosis and management of hypomagnesemic tetany in calves	1

S. No.	Topics	No. of Lectures
6.	Recent trends in diagnosis and management of ketosis in dairy animals with special reference towards blood metabolites and genomic tools	1
7.	Pregnancy toxemia in sheep and goats: current diagnosis and treatment strategies	1
8.	Biomarkers of fatty liver syndrome in dairy cattle: Latest diagnosis and treatment protocols	1
9.	Update on equine hyperlipidemia and steatitis	1
10.	Neonatal hypoglycemia: Recent trends in diagnosis and management	1
11.	Sub-acute ruminal acidosis (SARA) and low milk fat syndrome	1
12.	Nutritional/ parturient/ puerperal hemoglobinuria	1
13.	Recent trends in diagnosis and management of eclampsia in bitches	1
14.	Exertional myopathies in horse	1
15.	Nutritional secondary hyperparathyroidism (bighead; bran disease)	1
16.	Recent trends in mineral supplementation in livestock with special reference to chelated and non-chelated supplements	1
17.	Diseases due to trace elements deficiency in dairy cattle	1
18.	Oxidative stress during transition period: Role of various vitamins and minerals	1
19.	Recent trends in feeding strategies during transition period for prevention of vitamin and mineral deficiencies	1
20.	Update on importance of vitamin E and selenium in transition cows	1
21.	Disorders due to sodium and potassium deficiency	1
22.	Canine diabetes mellitus: Update on diagnosis and management	1
23.	Canine diabetes insipidus: Update on diagnosis and management	1
24.	Hypothyroidism in canine: Recent trends in diagnosis and management	1
25.	Obesity in pet animals: etio-pathogenisis, diagnosis and lifestyle management	1
26.	Diagnostic tools and treatment protocols for hypo and hyper adrenocorticism in dogs	1
27.	Recent trends in diagnosis, treatment and prevention of vitamin A deficiency diseases	1
28.	Diseases due to thiamine deficiency (PEM)	1
29.	Disorders due to vit K deficiency	1
30.	Approaches towards diagnosis, treatment and prevention of riboflavin (vit B2) deficiency in swine and poultry	1
31.	Update on diagnosis, treatment and prevention strategies for niacin deficiency in swine and poultry	1
32.	Diagnosis, management and prevention of Pantothenic acid deficiency in swine and poultry	1

Suggested Books

- *Veterinary Medicine*. 2006. OM Radostits, CC Gay, KW Hinchcliff and PC Constable, 10th Edition, Saunders.
- *Large Animal Internal Medicine*. 2019. Bradford Smith, David Van Metre and Nicola Pusterla, 6th Edition, Mosby
- *Textbook of Preventive Veterinary Medicine and Epidemiology*. 2010. RD Sharma, M Kumar and MC Sharma, ICAR- New Delhi.
- *Textbook of Veterinary Internal Medicine Expert Consult*. 2016. SJ Ettinger, EC Feldman and E Cote, 8th Edition, Saunders-Elsevier
- Research and Review Papers in Current Journals.

VMD 613: Emergency and Critical Care Medicine (1+1)

S. No.	Topics	No. of Lectures/ Practicals
Theory		
1.	Triage and stabilization of critical ill patient	1
2.	Newer therapeutic approach in management of a shock patient	2
3.	Advances in management of respiratory emergencies	2
4.	Gastrointestinal emergencies in small and large animals	2
5.	Management of metabolic emergencies (Addison's disease, Diabetic ketoacidosis, Eclampsia, etc.) in small animals	1
6.	Diagnosis and management of Cardiac arrhythmias	1
7.	Acute obstructive colic and its management	1
8.	Poisoning and toxocosis in animals and its management	2
9.	Urinary system emergencies	1
10.	Ocular emergencies	1
11.	Neurological emergencies	1
12.	Pain, assessment and its management	1
Practicals		
1.	Cardiopulmonary resuscitation (CPR) in dogs and monitoring of critical ill patient and oxygen therapy in dogs	1
2.	Gastrointestinal decompression in large and small animals	1
3.	Clinical approach to acute respiratory distress syndrome in small animals	1
4.	Trans-thoracic drainage of pleural effusions in large animals	1
5.	Trans-thoracic drainage of pericardial effusions in large and small animals	1
6.	Intra-osseous fluid administration in pups	1
7.	Procedures for gastrointestinal emergencies in small animals	1
8.	Procedures for gastrointestinal emergencies in large animals	1
9.	Blood component therapy in critical patients	1
10.	Endotracheal intubation in dogs	1
11.	Clinical examination and therapeutic management of status epilepticus in small animals	1
12.	Case Studies on GIT emergencies	1
13.	Case Studies on Respiratory emergencies	1
14.	Case Studies on Cardiac emergencies	1
15.	Case Studies on hematological emergencies	1
16.	Case Studies on metabolic emergencies	1

Suggested Books

- *Kirk and Bistner's Handbook of Veterinary Procedures and Emergency Treatment*. 2012. Richard B Ford and Elisa Mazaferro, 9th Edition, Saunders Elsevier.
- *Blackwell's Five Minute Veterinary Consult Clinical Companion, Small Animal Emergency and Critical Care*. 2010. Mazzaferro ME. 1st Edition, (Wiley Blackwell)
- *Equine Emergencies Treatment and Procedures*. 2008. Orsini JA and Divers TJ, 3rd Edition, Saunders Elsevier.
- Research and Review Papers in Current Journals.

VMD 614: Emerging and Re-emerging Animal Diseases (2+0)

S. No.	Topics	No. of lectures
1.	Definitions and concepts of emerging, re-emerging, exotic, exzootic and endemic diseases	2

S. No.	Topics	No. of lectures
2.	General concepts of new animal diseases	1
3.	Conditions for emergence of new animal diseases	2
4.	General concepts for re-emergence of old animal diseases	1
5.	Conditions for re-emergence of old animal diseases	2
6.	Factors and determinants of emerging diseases	3
7.	Effect of climate change on emergence of diseases	2
8.	The role of wildlife in the emergence and re-emergence of animal diseases	2
9.	Microbial adaptation and change	2
10.	Epidemiological processes involved in the emergence of vector-borne diseases	2
Epidemiology of globally and nationally important emerging/ re-emerging diseases and designing of strategies for prevention and control of nationally important emerging/ re-emerging diseases		
11.	Tuberculosis	1
12.	Foot and mouth disease	1
13.	Hemorrhagic septicemia	1
14.	Bovine viral diarrhea	1
15.	Anthrax	1
16.	PPR	1
17.	Blue tongue	1
18.	Swine flu	1
19.	Swine fever	1
20.	Paratuberculosis	1
21.	Glanders	1
22.	Equine disesases manifested by nervous signs	1
23.	Equine infectious anemia and African horse sickness	1

Suggested Books

- *Veterinary Epidemiology*. 2018. Michael Thrusfield, Robert Christley. Wiley-Blackwell
- *Emerging Diseases of Animals*. 2000. Corrie Brown and Carole Bolin. ASM Press
- *Emerging and Re-emerging Infectious Diseases of Livestock*. 2017. Jagadeesh Bayry. Springer
- *Transboundary and Emerging Diseases of Animals*. 2016. Anna Rovid Spickler, James A Roth, Gayle Brown and Jane Galyon. Center for Food Security and Public Health
- Research and Review Papers in Current Journals.

VMD 615: Prevention and Control of Infectious Diseases of Ruminants (2+0)

S. No.	Topics	No. of Lectures
1.	Advances in principles of prevention and control of infectious diseases	1
2.	Anthrax as a biological weapon: strategies for its control in animals	1
3.	Screening and control of Brucellosis in organized dairy herds	1
4.	Diagnosis and management of Mastitis	1
5.	Pathogenesis and sympotomatology of Clostridial diseases	2
6.	Pathogenesis and control of Colibacillosis	1
7.	Recent advances in diagnosis and control of Hemorrhagic septicemia	1
8.	Approaches in diagnosis of Tuberculosis	1
9.	Paratuberculosis: differential diagnosis and control	1
10.	Epidemiology, pathogenesis and diagnosis of Listeriosis	1
11.	Pathogenesis and control of Leptospirosis in animals	1

S. No.	Topics	No. of lectures
12.	Clinical presentation, differential diagnosis and treatment of Acitnomycosis and Actinobacillosis	1
13.	Advancement in diagnosis and treatment of dermatophytosis and other fungal infections	1
14.	Differential diagnosis and control of campylobacteriosis	1
15.	Latest advancements in Salmonellosis	1
16.	Advancement in diagnosis and control of Mycoplasma infections	1
17.	Latest trends in diagnosis and treatment of anaplasmosis	1
18.	Latest trends in diagnosis and control of Blue tongue	1
19.	Recent advancement in management of sheep and goat pox	1
20.	Recent literature on diagnosis and control of Peste des petits ruminants	1
21.	Lessons to be learnt from eradication of Rinderpest	1
22.	Recent advances in Bovine viral diarrhea and malignant catarrhal fever	1
23.	Recent literature on Infectious bovine rhinotracheitis	1
24.	Recent studies on clinical symptomatology and diagnosis of ephemeral fever	1
25.	Advancements in diagnosis and control of Foot and mouth disease	1
26.	Recent approaches in diagnosis and control of Rabies	1
27.	Principles of control of parasitic diseases	1
28.	Recent trends in Clinical symptomatology, diagnosis and control of Amphistomosis and fascioliosis	1
29.	Recent approaches in control of major endoparasitic infestations	1
30.	Recent advancements in diagnosis and control of trypanosomosis	1
31.	Recent advancements in diagnosis and control of babesiosis and theileriosis	1

Suggested Books

- *Merck's Veterinary Manual K*. 2016. Susan E Aiello and Michael A Moses, 11th Edition, Merck Sharp and Dohme
- *Veterinary Medicine*. 2016. Peter Constable, Kenneth W Hinchcliff, Stanley Done and Walter Gruenberg, 11th Edition. Saunders Ltd.
- *Dairy Herd Health*. 2012. MJ Green and Andrew J Bradley. CABI Publishing
- Research and Review Papers in Current Journals.

Minor Courses for Ph.D. Degree programme

Courses of any one department/ discipline from the list given below:

- Veterinary Physiology
- Veterinary Microbiology
- Veterinary Parasitology
- Veterinary Pharmacology and Toxicology
- Veterinary Surgery and Radiology
- Veterinary Public Health and Epidemiology

Supporting Courses

It could be any subject considered relevant for student's research work. This will be decided by Advisor/ guide concerned.

ANNEXURE I

List of BSMA Committee Members for Veterinary Clinical Subjects

1. Animal Reproduction Gynaecology and Obstetrics
2. Veterinary Surgery and Radiology
3. Veterinary Medicine

Name	Address	Specialization
Dr Jit Singh Former Dean	Udaipur Veterinary College Flat No.310, Manglam Residency, Rose Block, New Navratan Complex, Bhuwana, Udaipur -313001	Chairman
Dr D.B. Patil Director Research and Dean PGS	Kamdhenu University Gandhinagar-382010, Gujarat	Convener
Dr J. K. Prasad Principal Scientist	Indian Veterinary Research Institute Division of Animal Reproduction, Gynaecology and Obstetrics, Izatnagar, Bareilly, (UP)-243122	Animal Reproduction Gynaecology and Obstetrics
Dr K.N. Aravinda Ghosh Former Professor and Head	College of Vety. and Animal Sciences Animal Reproducation Gynaecology and Obstetrics Department, Mannuthy, Kerala -680651	
Dr Naveen Kumar Principal Scientist	Indian Veterinary Research Institute Division of Veterinary Surgery Izatnagar,Bareilly- 243122 (UP)	Veterinary Surgery and Radiology
Dr Vinod Kumar Gupta Former Principal Scientist	Indian Veterinary Research Institute Division of Veterinary Medicine Izatnagar, Bareilly-243122 (UP)	Veterinary Medicine
Dr S. N. S. Randhawa Professor and Head	Khalsa College of Veterinary and Animal Sciences Ram Tirath Road, Amritsar Punjab-143002	

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 3

Veterinary Para-Clinical Subjects

- Veterinary Microbiology
- Veterinary Pathology
- Veterinary Parasitology
- Veterinary Public Health and Epidemiology
- Veterinary Pharmacology and Toxicology

Contents

Acknowledgements

The Chairperson and Convener of BSMA for Veterinary Paraclinical disciplines, express their sincere thanks and gratitude to all the committee members, experts and other stake holders for their direct and indirect contribution in formulation and revision of course curriculum and syllabi. The permission, logistic support and local hospitality provided by the administration of ICAR – Indian Veterinary Research Institute, Izatnagar, CoVAS, CSK HPKV, Palampur, Himachal Pradesh and SKUAST, JAMMU, J&K is duly acknowledged. The BSMA committee also express their deepest sense of gratitude to the Education Division, Indian Council of Agricultural Research (ICAR), New Delhi for giving the opportunity to revise and update the syllabus.

Minimum Credit requirements:

Subject		Master's Programme	Doctoral Programme
i.	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
ii.	**Seminar**	01	02
iii.	**Thesis/ Research**	30	75
	Total	**70**	**100**

Major courses

From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken is given *mark

Minor courses

From the subjects closely related to a student's major subject.

Supporting courses

The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overall competence.

Common Courses

For Master's degree programme.

Course Code	Course Title	Credits
PGS 501	Library and Information Services	0+1
PGS 502	Technical writing and communication skills	0+1

Course Code	Course Title	Credit Hours
PGS 503	Intellectual Property and its management	1+0
PGS 504	Basic concepts in laboratory techniques	0+1
PGS 505	Agricultural research, research ethics and rural development programmes	1+0

*A student shall be required to register for all the 5 credit hours core courses

*Mandatory Course for Doctoral Degree Programme.

CPE-RPE	Research and Publication Ethics	2+0

Preamble

During the recent years, there has been appreciable advancement in Veterinary Sciences and livestock sector. In order to reduce animal sufferings, ensuring food security and human health, livestock rearing have been gradually changed from subsistence to commercial and organized system. Moreover, the futuristic requirement of the society for better animal health care, public health, food safety, environment, etc. have posed greater challenge for veterinary academicians, scientific community and service providers. Therefore, in tune with the change of development in science and technology, industrial and economic order, etc. needs to be considered for exposing the post graduate students while producing the skilled veterinarians with higher qualification and experiential training. The course curricula and syllabi of all the Veterinary Para-clinical disciplines have been reviewed and revised looking into the contemporary developments in the field of veterinary sciences and other related fields. Several new courses have been introduced as per need of the day along with revision of the contents of earlier courses. The implementations of the new and restructured course curricula is expected to build and improve knowledge, skill and competence of the students so as to enhance their employability and render efficient service to the society, farming community and the Livestock Industry.

Academicians and Researchers are being involved in devising means and methods of developing diagnostics against prevalent and emerging pathogens, prevention and control of animal diseases and zoonosis, monitoring and surveillance of disease of livestock and poultry, combating bio-terrorism, genetic engineering to optimize production and develop disease resistance breeds of animals. Bio-medical research, being heavily dependent upon animal experimentation, demands deeper scientific knowledge of veterinary science. The dominant forces shaping the Veterinary-business and Veterinary-education are global and virtual with a large number of specialists offering tele-veterinary services from off-shore locations like India. The ever changing and demanding public service sector has necessitated re-look into the veterinary higher education. At undergraduate level, veterinary students acquire comprehensive knowledge and skills in basic, para-clinical and clinical subjects required for performing multi-tasking role of a veterinarian. However, at post graduate level, in depth knowledge of theory, practical aspects and research methodology in each subject is of paramount importance. Detailed study of the course curricula and syllabi, being implemented by veterinary colleges in India, revealed that there was enormous heterogeneity in the course structure, nomenclature and contents. In view of the above, the task of formulating need based contemporary post graduate courses and syllabi for implementation of post graduate education uniformly at national level was essential.

Five BSMA committees, constituted by ICAR vide Office order No. F.No.7/ 6/2017-EQR Dated 4th April, 2018 for restructuring of Master's and Doctorate course curricula and syllabi, worked in unison to formulate common basic format. The BSMA committee for Veterinary Para-clinical Subjects (Microbiology, Pathology, Parasitology, Public Health and Epidemiology and Pharmacology and Toxicology) was constituted for developing uniform course curricula, syllabi and academic regulations in line with changing global scenario. The new and restructured Post-Graduate curricula and syllabi in respect of Veterinary

Para-Clinical subjects contain several innovative and practically applicable courses and extensively revamped course contents, viz., ultra-structural studies, molecular techniques in understanding the disease pathogenesis, diagnosis and monitoring surveillance. Veterinary Para-clinical subjects provide essential support by employing disease diagnostic technologies for prevention and control of animal diseases, maintenance of biodiversity, etc. New courses in Veterinary Microbiology, on Cytokines and Chemokines, Immunoregulations and Techniques in Molecular Microbiology, in Veterinary Pathology, courses on Molecular and Ultra structural bases of cell injury, molecular bases of inflammation and pathology of laboratory animal diseases, in Veterinary Parasitology, courses on Biology and Ecology of Parasites, Molecular Veterinary Parasitology and Immunology of Parasitic Diseases, in Veterinary Public Health and Epidemiology, courses on Ecology and Animal/ Human Health, Surveys, Surveillance and Data Management, risk analysis and predictive modeling, Food Safety Standards and Regulations have been included, in Veterinary Pharmacology and Toxicology, courses on Bio-transformation of Xenobiotics, Molecular Pharmacology, Fundamentals of Pharmacokinetics. The contents of most of the courses have been revised and updated to include the latest developments. The learning of research methodology, scientific thinking, planning and experimentation and special problems has been introduced in all the subjects.

The implementations of the new and restructured post graduate course curricula is expected to build knowledge and skill of the students so as to enhance their employability and marketability as multi-service providers with practical skills and comprehensive knowledge of the entire subject area after Masters. The Doctorates should in turn prove as specialists, in their respective disciplines. The valuable inputs received from the stake holders', viz., eminent academicians, scientists, extension workers, leading veterinary practitioners, state animal husbandry department, etc. have immensely helped in preparation of this document.

Major changes made in the revised syllabi including addition of New Courses and updation of contents:

Veterinary Microbiology (VMC)

Masters Degree Programme

- VMC 501 : General Bacteriology (2+1), course name changed (Bacteriology – I) credit hour decreased and course contents updated.
- VMC 502 : Systematic Veterinary Bacteriology (2+1), course name changed (Bacteriology – II) with change in course contents.
- VMC 503 : General Virology (2+1), course number changed
- VMC 504 : Systematic Veterinary Virology (2+1), course number changed, 01 credit hour decreased with changes in course contents.
- VMC 505 : Principles of Veterinary Immunology (2+1), course number and name changed with changes in course contents.
- VMC 506 : Veterinary Mycology (1+1), course number and contents changed.
- VMC 507 : Vaccinology (2+0), course contents revised and updated.
- VMC 508 : Techniques In Microbiology (0+2), New course.
- VMC 509 : Techniques In Molecular Microbiology (1+2), New course.
- VMC 510 : Molecular Immunology (1+1), New course.
- VMC 511 : Mucosal Immunology (1+0), New course.
- VMC 512 : Introduction to Microbial Bioinformatics (1+0), New course

Doctoral Degree Programme

- VMC 601 : Advances in Veterinary Bacteriology (2+1), course contents revised and updated.
- VMC 602 : Advances in Veterinary Mycology (2+1), course contents revised and updated.
- VMC 603 : Bacterial Genetics (2+0), 01 credit hour (P) decreased with change in course contents.
- VMC 604 : Microbial Toxins (2+1), course contents revised and updated.
- VMC 605 : Bacterial Pathogenesis (2+0), course name changed (Molecular determinants of Bacterial Pathogenesis), 01 credit hour (P) decreased.
- VMC 606 : Advances in Veterinary Virology (2+1), course name changed (Advances in Virology), change in course contents.
- VMC 607 : Molecular Viral Pathogenesis (2+1), course name changed (Molecular and Genetic aspects of Viral Pathogenesis), change in course contents.
- VMC 608 : Structure Function Relationship of DNA and RNA Viruses (2+0), 01 credit hour (T) decreased.
- VMC 610 : Slow Viral Infections and Prions (1+0), 01 credit hour (T) decreased.
- VMC 611 : Advances in Veterinary Immunology (2+1), course name changed (Molecular Immunology), changes in course contents.
- VMC 612 : Cytokines and Chemokines (2+ 0), New course
- VMC 613 : Immunoregulation (1+0), New course
- VMC 614 : Advances in Vaccinology (2+0), Course contents revised and updated.
- VMC 615 : Current Topics in Infection and Immunity (2+0), 01 credit hour (T) decreased.

Veterinary Pathology (VPL)

Masters Degree Programme

- VPL 503 : Animal Oncology (1+1), course contents revised and updated.
- VPL 505 : Necropsy Procedures and Interpretations (1+1), 02 courses VPL (VPL – 605, 606) have been merged and course contents revised.
- VPL 506 : Necropsy Conference (0+1), New Course
- VPL 508 : Pathology of Infectious Diseases of Domestic Animals (2+1), course contents updated.
- VPL 509 : Toxicopathology (2+1), course contents revised.
- VPL 510 : Avian Pathology (2+1), course contents updated.
- VPL 511 : Pathology of Wild/ Zoo and Aquatic Animal Diseases (2+1), course reframed, Wild/ Zoo/ Fish diseases included.
- VPL 512 : Pathology of Laboratory Animal Diseases (2+1). New course

Doctoral Degree Programme

- VPL 601 : Molecular and Ultrastructural Basis of Cell Injury (2+1), New course with the merging of contents of molecular pathology of cell injury.
- VPL 602 : Molecular Basis of Inflammation (1+1), New course
- VPL 603 : Molecular Basis of Neoplasia (1+1), New course
- VPL 605 : Advances in Diagnostic Pathology (1+2), course contents revised and updated.
- VPL 607 : Pathology of Important Emerging and Re-emerging Diseases of Pets and Livestock (2+1). Course contents revised and updated.
- VPL 608 : Research Methodology in Pathology (1+0), New course

Veterinary Parasitology (VPA)

Masters Degree Programme

- VPA 501 : Platyhelminthes – I (1+1), Name and contents of old VPA-601 (2+1) changed.
- VPA 502 : Platyhelminthes – II (1+1), Name and contents of old VPA-601 (2+1) changed.
- VPA 503 : Nematyhelminthes and Acanthocephala (2+1), Name of old VPA 602 changed.
- VPA 504 : Arthropod Parasites (2+1), Name and contents of old VPA 603 revised and updated.
- VPA 505 : Parasitic Protozoa (2+1), old VPA 604, course contents revised and updated.
- VPA 506 : Diagnostic Parasitology (0+2), Name and contents of old VPA 605 changed and updated.
- VPA 507 : Clinical Parasitology (1+1), Name and contents of old VPA 606 changed.
- VPA 508 : Management of Parasitic Diseases (1+1), old VPA 607 with revised and updated contents.
- VPA 509 : Immunoparasitology (2+1), old VPA 608 with revised and updated course contents.
- VPA 510 : Parasitic Zoonoses (2+0), old VPA 609.
- VPA 511 : Parasites of Wildlife (1+1), old VPA 610 with change in course title.

Doctoral Degree Programme

- VPA 601 : Advances In Helminthology – I (2+1), old VPA 705 with revised and updated contents.
- VPA 602 : Advances In Helminthology – II (2+1), old VPA 706 with revised and updated contents.
- VPA 603 : Advances in Entomology and Acarology (2+1), old VPA 707 with revised and updated contents.
- VPA 604 : Advances in Protozoology (2+1), course contents revised and updated.
- VPA 605 : Immunology of Parasitic Diseases (1+2), New course.
- VPA 606 : Molecular Diagnostics and Vaccine Development in Parasitology (2+1), old VPA 702 with revised and updated course contents.
- VPA 607 : Host Parasite Interactions (2+0), old VPA 703 with revised and updated course contents.
- VPA 608 : *In-vitro* cultivation of parasites (1+2), New Course.
- VPA 609 : Emerging and Re-emerging Parasitic Diseases (2+0), No change.
- VPA 610 : Biology and Ecology of Parasites (3+0), New course including old VPA 701, 710 and 711 with revised and updated course contents.
- VPA 611 : Molecular Veterinary Parasitology (2+0), New course.
- VPA 612 : Parasite Epidemiology (2+0), New course.

Veterinary Public Health and Epidemiology (VPE)

Masters Degree Programme

- VPE 501 : Concepts in Veterinary Public Health and One Health (2+0), title modified with updated contents.
- VPE 502 : Zoonoses – I (2+1), title modified with updated contents.

- VPE 503 : Zoonoses – II (2+1), title modified with updated contents.
- VPE 504 : Principles of Epidemiology (2+1), New course.
- VPE 505 : Hygiene and Safety of Foods of Animal and Aquatic Origin (2+1), two courses merged (milk and meat hygiene, Fish/ Fish product).
- VPE 506 : Food-borne Infections and Intoxications (2+1), course contents revised and updated.
- VPE 507 : Food Safety Standards, and Regulations (2+1), New course.
- VPE 508 : Environmental Hygiene and Safety (2+1), title modified with updated contents. 01 credit hour reduced.
- VPE 509 : Applied Epidemiology (2+1). New course.
- VPE 510 : Bio-security, Bioterrorism and Disaster Management (2+0), title modified with updated contents.
- VPE 511 : Laboratory Techniques in Veterinary Public Health (0+3), New course.

Doctoral Degree Programme

- VPE 601 : Advances in Veterinary Public Health and Epidemiology (2+1), course contents revised and updated.
- VPE 602 : Emerging, Re-emerging Zoonoses and One Health (2+1), course contents revised and updated.
- VPE 603 : Advances in Food Safety and Quality Control of Foods of Animal Aquatic origin (2+1), course contents revised and updated.
- VPE 604 : Bio-security and Occupational Health Safety (2+1), course contents revised and updated.
- VPE 605 : Recent Concepts in Epidemiology and Disease Forecasting (2+1), New course.
- VPE 606 : Risk Analysis and Predictive Modelling (2+1), New course.
- VPE 607 : Advances in Environmental Hygiene (2+1), course contents revised and updated.
- VPE 608 : Herd Health Management and Disease Economics (2+1), New course.
- VPE 609 : Epidemiology of Trans-boundary, Non-infectious and Chronic diseases (2+1), New course.
- VPE 610 : Ecology and Animal/ Human Health (2+0), New course.
- VPE 611 : Diagnostic Approaches in Epidemiology (2+1), New course.
- VPE 612 : Surveys, Surveillance and Data Management (2+1), New course.

Veterinary Pharmacology and Toxicology (VPT):

Masters Degree Programme

- VPT 501 : Concept of Pharmacology, Drug, Design and Development (2+0), course title changed with revised and updated course contents of General Pharmacology.
- VPT 504 : Digestive and Respiratory Pharmacology (2+1), one practical credit hour added.
- VPT 506 : Endocrine and Reproductive Pharmacology (2+1), one practical credit hour added.
- VPT 509 : Toxinology (2+1), course title changed and 01 practical credit hour added (Toxicology of plant and Toxins).
- VPT 510 : Pharmacological Technique (0+2), one theory credit hour converted to practical.

- VPT 511 : Techniques in Toxicology (0+2), one theory credit hour converted to practical.
- VPT 512 : Ethnopharmacology (1+1), one theory credit hour converted to practical.
- VPT 513 : Fundamental of Pharmacokinetics (1+1), New Course

Doctoral Degree Programme

- VPT 601 : Molecular Pharmacology (3+0), course contents of Advances in Neuropharmacology and Molecular Pharmacology merged.
- VPT 602 : Advances in Autacoid Pharmacology (1+0), course title changed.
- VPT 604 : Biotransformation of Xenobiotics (2+0), course title changed (Drug metabolism).
- VPT 605 : Clinical Pharmacology and Pharmacokinetics (2+1), clinical pharmacology and Pharmacokinetics have been merged.
- VPT 606 : Pharmacogenomics (2+0), course number changed with revised and updated course contents.
- VPT 607 : Immunopharmacology and Immunotoxicology (2+0), course number changed and 01 theory credit hour increased and course title changed to include immunotoxicology.
- VPT 608 : Molecular toxicology (3+0), course number changed and 01 theory credit hour increased.
- VPT 609 : Clinical Toxicology (2+1), course number and course title changed (Clinical Toxicology).
- VPT 610 : Ecotoxicology (3+0), course number changed and 01 theory credit hour increased.
- VPT 611 : Regulatory Toxicology (2+1), course number changed.

Suggested list of specified minor and supporting subjects

Veterinary Microbiology (VMC): Animal/ Veterinary Biotechnology, Veterinary Biochemistry, Veterinary Pathology, Veterinary Public Health and Epidemiology, Animal Genetics or any other discipline as per the requirement of the research problem of the student.

Veterinary Pathology (VPL): Veterinary Microbiology, Animal/ Veterinary Biotechnology, Veterinary Biochemistry, Veterinary Medicine, Veterinary Parasitology, Veterinary Public Health and Epidemiology, Veterinary Pharmacology and Toxicology or any other discipline as per the requirement of the research problem of the student.

Veterinary Parasitology (VPA): Veterinary Microbiology, Animal/ Veterinary Biotechnology, Veterinary Biochemistry, Veterinary Medicine, Veterinary Pathology, Veterinary Public Health and Epidemiology, Veterinary Pharmacology and Toxicology or any other discipline as per the requirement of the research problem of the student.

Veterinary Public Health and Epidemiology (VPE): Veterinary Microbiology, Animal/ Veterinary Biotechnology, Veterinary Medicine, Veterinary Parasitology, Veterinary Pathology, Veterinary Pharmacology and Toxicology, Statistics or any other discipline as per the requirement of the research problem of the student.

Veterinary Pharmacology and Toxicology (VPT): Veterinary Biochemistry; Animal/ Veterinary Biotechnology; Veterinary Physiology; Veterinary Microbiology; Veterinary Pathology; Veterinary Medicine; Veterinary Public Health and Epidemiology or any other discipline as per the requirement of the research problem of the student.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Para-Clinical Subjects
– Veterinary Microbiology

Course Title with Credit Load
M.V.Sc. in Veterinary Microbiology

Course Code	Course Title	Credit Hours
VMC 501	General Bacteriology*	2+1
VMC 502	Systematic Veterinary Bacteriology	2+1
VMC 503	General Virology*	2+1
VMC 504	Systematic Veterinary Virology	2+1
VMC 505	Principles of Veterinary Immunology*	2+1
VMC 506	Veterinary Mycology*	1+1
VMC 507	Vaccinology	2+0
VMC 508	Techniques in Microbiology	0+2
VMC 509	Techniques in Molecular Microbiology	1+2
VMC 510	Molecular Immunology	1+1
VMC 511	Mucosal Immunology	1+0
VMC 512	Introduction to Microbial Bio-informatics	1+0
VMC 591	Master's Seminar*	1+0
VMC 599	Master's Research	0+30

*Core Courses

Course Contents
M.V.Sc. in Veterinary Microbiology

I. Course Title : General Bacteriology
II. Course Code : VMC 501
III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge of general bacteriology.

V. Theory

Unit I

Historical events of microbiology, Taxonomy and nomenclature of bacteria. Basic principles of microscopy and micrometry, Classical, Confocal, Nomaraski and electron microscopy. Staining of bacteria, Structure and function of bacterial cell. Growth, Nutrition, Metabolism, Secretion and excretion systems of bacteria. General principles of bacterial disease diagnosis.

Unit II

Bacterial genetics, Bacterial variation, Horizontal genetic transfer mechanisms (transformation, transduction and conjugation), Plasmids, Transposons and drug resistance.

Unit III

Determinants of pathogenicity and its molecular basis, Markers and PAMPs, exotoxin and endotoxin.
Bacteriophages: temperate and virulent phages; lysogeny and lysogenic conversion.
Antimicrobial agents and disinfectants: Mechanism of action, Resistance and susceptibility testing. Bacterial immunity.

VI. Practical

Orientation to a bacteriology laboratory, Sterilization and disinfection techniques, Laboratory biosafety and biosecurity. Cultivation of aerobic, Microaerophilic and anaerobic bacteria, Isolation of bacteria in pure culture, Microscopy, Morphological characterization of bacteria, Different staining methods and biochemical tests for identification of bacteria, Determination of bacterial number and biomass and standard protocols for antibiotic sensitivity test and detection of MIC.

I. Course Title : Systematic Veterinary Bacteriology
II. Course Code : VMC 502
III. Credit Hours : 2+1

IV. Aim of the course

To learn different aspects with regards to the virulence factors, Antigenic and structural components, Epidemiology, Pathogenesis, Diagnosis and control of important aerobic, Microaerophilic and anaerobic pathogenic bacteria causing diseases in animals and disease status in India.

V. Theory

Unit I

Systematic study of following groups of bacteria:
Spirochetes: *Leptospira, Brachyspira* and *Borrelia.*
Gram-negative

- Aerobic/ Microaerophillic, motile helical/ vibrioid: *Campylobacter;*
- Aerobic/ Microaerophillic rods/ cocci: *Bordetella, Brucella, Morexella, Pseudomonas* and *Burkholderia;*
- Facultative anaerobic Gram-negative rods: members of *Enterobacteriaceae, Pasteurella, Mannheimia* and *Haemophilus;*
- Anaerobic, straight, curved and helical rods: *Dichelobacter* and*Fusobacterium*

Unit II

Rickettsia and Chlamydia: *Rickettsia, Chlamydia* (*Chlamydophila*) and *Coxiella.*
Gram-positive

- Gram-positive cocci: *Staphylococcus* and *Streptococcus* including *Enterococcus*.
- Endospore-forming rods: *Bacillus*and *Clostridium*.
- Regular non-spore forming rods: *Erysipelothrixa* and *Listeria*
- Irregular non-spore forming rods: *Actinomyces*, *Corynebacterium* and *Truepurella.*

Unit III

- Mycobacteria: Mycobacterium; *Actinomycetes*: *Nocardia* and *Rhodococcus, Dermatophilus.*
- Mollicutes: *Mycoplasma.*

Unit IV

- Emerging and transboundary bacterial pathogens.

VI. Practical

Collection, transport and dispatch of clinical samples from various disease conditions. Isolation of bacteria in pure cultures from different clinical samples. Identification of the bacteria using staining, biochemical tests and other molecular techniques. Preservation and storage of bacterial cultures.

I. Course Title : General Virology
II. Course Code : VMC 503
III. Credit Hours : 2+1

IV. Aim of the course

To study general aspects of viral structure, classification, replication, interactions and immunity against viruses.

V. Theory

Unit I

History of virology, Origin and nature of viruses, Morphological structure and chemical composition of viruses, Nomenclature and classification of viruses, Cultivation and purification of viruses, Laboratory diagnosis of viral infections, Viroid and Prions.

Unit II

Replication of DNA and RNA viruses, genetic and non-genetic interactions between viruses.

Unit III

Virus-cell interactions, viral pathogenesis, viral persistence, oncogenic, oncolytic viruses and epidemiology of viral infections.

Unit IV

Immune response to viruses, viral vaccines, viral chemotherapy.

VI. Practical

Orientation to a virology laboratory, Preparation of glassware, Plasticware, Media and reagents for cell culture and other items required for virus cultivation. Protocols for primary and secondary cell cultures, Maintenance of cell lines, Cryopreservation of cells and their revival. Staining of virus infected cultured cells and demonstration of inclusion bodies. Viable cell counting. Cultivation of viruses in embryonated chicken eggs and cell cultures.

I. Course Title : Systematic Veterinary Virology

II. Course Code : VMC 504

III. Credit Hours : 2+1

IV. Aim of the course

To study viral properties, epidemiology, pathogenesis and disease status in India, diagnosis, immunity and control of diseases caused by viruses belonging to different families of animal viruses.

V. Theory

Unit I: Double and Single stranded DNA virus families

Poxviridae, *Asfarviridae*, *Herpesviridae*, *Adenoviridae*, *Papilomaviridae*, *Polyomaviridae*, *Parvoviride*, *Circoviridae* and *Hepdnaviridae.*

Unit II: Single stranded Negative sense and Double stranded RNA viruses

Orthomyxoviridae, *Paramyxoviridae, Rhabdoviridae, Bornaviridae, Reoviridae* and *Birnaviridae.*

Unit III: Single stranded Positive sense RNA viruses

Picornaviridae, *Caliciviridae*, *Togaviridae*, *Flaviviridae*, *Coronaviridae*, *Arteriviridae*, *Astroviridae* and *Retroviridae.*

Unit IV: Prions

BSE, Scrapie and introduction to viriods.

Unit V

Emerging, re-emerging and transboundary viral pathogens

VI. Practical

Collection, Preservation, Transportation of clinical samples and their processing for virus isolation and identification. Isolation and cultivation of viruses from clinical samples, using different methods and its plaque purification. Titration of viruses for 50% end points using different methods, Serum neutralization test.

Electropherotyping. Concentration and purification of viruses by chemical agents, differential centrifugation, density gradient centrifugation and ultra-filtration. Methods for preservation of animal viruses.

I. Course Title : Principles of Veterinary Immunology
II. Course Code : VMC 505
III. Credit Hours : 2+1

IV. Aim of the course

To understand the fundamental principles of veterinary immunology and its applications.

V. Theory

Unit I

Introduction to livestock and poultry immune system: ontogeny and phylogeny of vertebrate immune system, cells and organs of immune system. Types of immunity: Innate and adaptive immune system.

Unit II: Antigen and its characteristics

Characteristic of ideal antigen; Classification of antigens, Factors affecting immunogenicity, Concept of hapten and carrier. Antigenic determinant/ epitope and cross reactivity. B-cell epitope and T cell epitope. Immunoglobulins: Basic structure and function of immunoglobulins, Immunoglobulin diversity and immunoglobulin classes.

Antigen recognition by B cell and T cell: B cell receptor, T cell receptor, receptor diversity, B cell and T cell activation.

Unit III: Major Histocompatibility Complex

General feature, structure, function, gene organization, MHC and immune response. Immune-response development: Phases of humoral and cell mediated immune response. Immunoregulation with B and T cells: Antigen recognition, antigen presentation and processing, antigen recognition by TCR, MHC restriction, Cytokines and chemokines. Cell mediated immune response: General properties of effector T cells, cytotoxic T cells, NK-cells and ADCC. Role of integrin and selectin.

Unit IV: Complement System

Basic concept of complement, mechanism of complement activation, complement pathways and Complement deficiencies. Autoimmunity and autoimmune diseases, immunological tolerance and hypersensitivity: classification, mechanism of induction with examples.

Immunodeficiency: Types with examples. Immune response in foetus and new born.

Unit V: Antigen antibody interaction

Antibody affinity, avidity, cross reactivity, precipitation and agglutination test, radio-immunoprecipitation assay (RIPA), ELISA, Western blotting, Immunodiagnostics and Immunotherapy. Monoclonal antibodies and methods for production and characterization of monoclonal antibodies.

VI. Practical

Preparation of antigens, raising of antisera against soluble and insoluble antigens.

Detection of antibody by gel diffusion, radial immunodiffusion, immune-electrophoresis techniques. Haemagglutination and haemagglutination inhibition test, ELISA and its modifications. Immunoblotting. Agglutination tests. Separation and purification of Immunoglobulin from serum. Separation of mononuclear cells from blood by density gradient centrifugation, viable count of lymphocyte by dye exclusion method. Measurement of T cell response (DTH, lymphoproliferative assay).

I. Course Title : Veterinary Mycology

II. Course Code : VMC 506

III. Credit Hours : 1+1

IV. Aim of the course

To learn detailed morphological, cultural features, virulence factors, antigenic and structural components, epidemiology, pathogenesis, diagnosis and control of fungal infections.

V. Theory

Unit I

History of mycology, Glossary of mycological terms; Morphology of fungi: structure and ultra-structure, differentiation, nutrition, physiology, reproduction, spores, cultural characters and classification of fungi of veterinary importance. Fungal immunity. Antifungal agents and important techniques in diagnosis of fungal infections.

Unit II: Systematic study of animal mycoses:

Aspergillosis, Candidiasis, Cryptococcosis, Epizootic lymphangitis, Rhinosporodiosis, Zygomycosis, Blastomycosis, Sporotrichosis, Histoplasmosis, Coccidioidomycosis, Mycetomas, Dermatophytoses, Dermatomycosis, Mycotoxicosis, Malassezia infections, Mycotic abortion, Mycotic mastitis, and Emerging mycoses.

VI. Practical

Collection and processing of clinical material for isolation of fungi. Microscopy of fungi: Lactophenol cotton blue and India ink preparations. Preparation of basal and special fungal media of veterinary importance. Slide culture and cellophane tape technique for fungi. Diagnosis of dermatophytes. Biosafety precautions in handling yeast and dimorphic fungi. Study of gross and microscopic characters of pathogenic fungi, antifungal sensitivity testing, detection of mycotoxin. Serological and molecular diagnosis in fungi.

I. Course Title : Vaccinology

II. Course Code : VMC 507

III. Credit Hours : 2+0

IV. Aim of the course

To understand different aspects of vaccines, their production, standardization and quality control of various vaccine used in animals.

Unit I

Types of vaccines andvaccine components, factors influencing choice of vaccines. **New generation vaccines:** subunit vaccines, peptide vaccines, recombinant vaccines, reverse genetics vaccines, Marker and DIVA enabled vaccines and transmission blocking vaccines.

Unit II: Preparation of vaccines

Identification of candidate strain, identification of epitopes, seed and challenge strain maintenance. Classical methods of exaltation and attenuation of pathogens and their molecular basis. Technology of production of different types of vaccines.Multicomponent vaccines. Recent advances in vaccine delivery systems. Advances in vaccinesadjuvants with their classification and mode of action.

Unit III

Standardization of veterinary vaccines as per National and Global standards. Laws and regulatory requirements about veterinary biological and Indian pharmacopoeia.

Unit IV

Vaccine failure and post vaccinal reactions. Factors affecting response to vaccines: maintenance of vaccines and cold chain. Quality control. Principles of development of vaccination schedule, methods of conducting vaccine trials (lab to field use) and pharmaco-vigilance. Scaling up methods of vaccine production.

I. Course Title : Techniques in Microbiology

II. Course Code : VMC 508

III. Credit Hours : 0+2

(Course to be offered to the students not majoring in Veterinary Microbiology)

IV. Aim of the course

To give overview of the techniques used in microbiology.

V. Practical

Unit I

Orientation to a microbiology laboratory. Different sterilization and disinfection techniques. Laboratory biosafety and biosecurity. Microscopy, media preparation, isolation, cultivation and purification of bacteria and fungi and their morphological and biochemical characterization. Antibacterial sensitivity test by Disc diffusion, broth dilution and MIC determination technique.

Unit II

Cultivation of viruses in embryonated eggs and cell culture. Virus Neutralization test.

Unit III

Different immunological techniques: Agglutination, precipitation, ELISA, Haemagglutination and HaemagglutinationInhibition and other immunological assays.

I. Course Title : Techniques in Molecular Microbiology

II. Course Code : VMC 509

III. Credit Hours : 1+2

IV. Aim of the course

To provide training in molecular biology and other diagnostic techniques used in microbiology.

V. Theory

Unit I

Basic requirements for establishing molecular diagnostics Laboratory. Principles of molecular diagnostic tests. Methods of nucleic acid extraction from pathogenic microorganisms.

Unit II

PCR, and variants of PCR. Principles of primer designing. Gel electrophoresis methods andblotting techniques: Southern blotting, northern blotting, western blotting, dot-blot. Microarrays, nucleic acid sequencing methods. Sequence analysis-sequence editing, sequence alignment, sequence comparison and phylogentic analysis. Gene cloning and expression. Molecular diagnosis as epidemiological tool.Development and validation of diagnostic tests.

VI. Practical

Unit I

Orientation of molecular diagnosis laboratory: especially RNA and diagnostic PCR laboratory (handling RNA and DNA). Extraction of nucleic acid from different microbes: Gram positive bacteria, Gram negative bacteria, DNA viruses, RNA Viruses and fungi, DNA and RNA isolation from cell culture and blood and isolation of plasmids. Quality and quantity check of nucleic acids.

Unit II

Principles for Primer designing. Procedure for molecular diagnostic tests like PCR, RT-PCR and LAMP. Absolute and relative quantitation of DNA/ RNA using Q-PCR. SDS PAGE of proteins and RNA, study of nucleic acid and proteins by blotting techniques. Restriction Enzyme digestion Techniques and RFLP; PCR product concentration and purification for sequencing. Nucleic acid sequence analysis. Gene Cloning, expression and purification of expression products. An introduction to high throughput sequencing and MALDI-TOF.

I. Course Title : Molecular Immunology

II. Course Code : VMC 510

III. Credit Hours : 1+1

IV. Aim of the course

To learn about molecular aspects of immunology.

V. Theory

Unit I

Molecular Structure and function of PRRs. Ligands of PRRs, signal transduction through PRRs andinflammosome. Cytokines, Lymphocyte markers and CD nomenclature.

Unit II

Molecular structure of Immunoglobulin and class, Isotypes, Synthesis and expression of immunoglobulin, Rearrangement and its organization, Immunoglobulin gene diversity and mechanism of recombination of B cell gene. Theory of antibody generation. Signature molecules of T cell and T regulatory cell. T cell receptor and T cell gene diversity.

Unit III

MHC structure, Genomic organization of the MHC gene haplotype. Concept of congenic and syngeneic, concept of polymorphism of MHC gene, pathway of signal transduction, role of co-stimulators in B cell and T cell activation and recruitment of adaptor proteins. Molecular mechanisms (events) of cell cytotoxicity.

VI. Practical

Isolation and purification of mammalian and avian immunoglobulin by precipitation technique: Caprylic acid, PEG, Ammonium Sulphate, Sodium Sulphate. Separation of immunoglobulins by size, charge and ligand affinity: size exclusion chromatography (gel filteration on Sephadex G200), ion exchange chromatography, affinity chromatography (Protein-A-Sepharose). Immuno-electrophoresis Technique: polyacrylamide gel electrophoresis innative and reducing conditions, fixed andgradient gel, Western blot, Crossed immune-electrophoresis. Chemiluminscence assay and Cell cytotoxicity assays; Non-radioactive methods like LDH realease assay. Antigen detection by Immuno PCR. Haplotype matching between individuals, Flow cytometry for CD4 and CD8 ratio determination and other applications. ELISpot test for cytokine assay.

I. Course Title : Mucosal Immunology

II. Course Code : VMC 511

III. Credit Hours : 1+0

IV. Aim of the course

To learn about mucosal immunity.

V. Theory

Unit I: Innate Mechanisms

Mucosal barrier: Development and physiology of mucosal defense. Cells and lymphoid tissues of mucosal immune system: MALT, GALT, NALT and BALT. Innate immune response at mucosal surfaces: mucus, antimicrobial peptides, role of PPRs, intestinal Dendritic cell, intestinal macrophage, mucosal inductive and effector sites. Antigen uptake and presentation at mucosal sites, transepithelial transport of antigen.

Unit II: Acquired response

Mucosal Immunoglobulin, IgA synthesis and transport to intestinal lumen.Description and role of Paneth cell and crypto patches.M-cells and their functions.Mucosal immune effector mechanisms including secretory IgA response. Extrathymic T cell development in mucosal tissues and their phenotypes and functions.

Unit III: Applications

Importance and limitations of mucosal immunization. Mucosal adjuvants and delivery systems. Oral tolerance mechanistic approach. Immunopathology at mucosal surfaces: Celiac disease, Inflammatory bowel disease, Jhone's disease; Assessment of mucosal immune response and potency testing.

I. Course Title : Introduction to Microbial Bioinformatics

II. Course Code : VMC 512

III. Credit Hours : 1+0

(Relevant practical demonstrations be given along with theory topic)

IV. Aim of the courses

To learn about key bioinformatics techniques, tools and databases.

V. Theory

Unit I

Introduction to Bioinformatics; History, Scope and Application, Internet and world wide web. Bioinformatics resources and information retrieval system. Nucleic acid sequence databases, Genome databases, Protein sequence databases, Metabolic pathways databases, NCBI, ExPASy and Ensembl Genome browser.

Unit II

Sequence comparison and alignment methods; Introduction to sequence alignment, principal methods of pairwise sequence alignment and Dot plot analysis. Significance of BLAST and FASTA programs in DNA and protein sequence analysis, variants of BLAST and FASTA programs. Introduction to multiple sequence alignment and Phylogenetic analysis to retrieve evolutionary information, Global multiple sequence alignment tool- CLUSTAL-W.

Unit III

Overview of protein structure and databases, Structure based protein classification, Protein structure database (CASP), Protein structure alignment tools (VAST, DALI), Protein 3-D structure visualization and modeling using SWISS PROT.

Course Outline-cum-Lecture Schedule for Master degree Programme

VMC 501: General Bacteriology (2+1)

S.No.	Topic of Syllabus	Lecture/ Practical
Theory		
1.	Historical events of Microbiology	2
2.	Taxonomy and nomenclature of bacteria	1
3.	Basic principle of microscopy and micrometry	1
4.	Classical, Confocal, Nomaraski and Electron Microscopy	2
5.	Staining of bacteria	1
6.	Structure and function of bacterial cell	3
7.	Bacterial growth, nutrition and metabolism	3
8.	Secretion and excretion systems of bacteria	2
9.	General Principles of bacterial disease diagnosis	2
10.	Bacterial genetics and Bacterial variation	1
11.	Horizontal genetic transfer mechanisms- transformation, transduction and conjugation	1
12.	Plasmids, transposons and drug resistance	1
13.	Determinants of pathogenicity and its molecular basis	2
14.	Markers and PAMPs, exotoxin and endotoxin	1
15.	Bacteriophages- temperate and virulent phages, lysogeny and lysogenic conversion	2
16.	Antimicrobial agents	2
17.	Disinfectants -Mechanism of action	2
18.	Disinfectants -resistance and susceptibility testing	1
19.	Bacterial immunity	2
	Total	**32**
Practical		
1.	Orientation to a bacteriology laboratory	1
2.	Different sterilization and disinfection techniques	2
3.	Laboratory biosafety and biosecurity	1
4.	Cultivation of aerobic, microaerophilic and anaerobic Bacteria using bacteriological media	2
5.	Isolation of bacteria in pure culture	2
6.	Microscopy	1
7.	Morphological characterization of bacteria by different staining methods	2
8.	Important biochemical tests for identification of bacteria	2
9.	Determination of bacterial number and biomass by different methods	1
10.	Standard protocols for antibiotic sensitivity test	2
11.	Detection of MIC	1
	Total	**16**

VMC 502: Systematic Veterinary Bacteriology (2+1)

S.No.	Topic of Syllabus	Lecture/ Practical
Theory		
1.	Spirochetes: *Leptospira, Brachyspira* and *Borrelia*	2
2.	*Campylobacter*	1
3.	*Bordetella* and *Morexella*	1
4.	*Brucella*	2
5.	*Pseudomonas* and *Burkholderia*	1
6.	*Enterobacteriaceae*	3
7.	*Pasteurella* and *Mannheimia*	2
8.	*Haemophilus*	1
9.	*Dichelobacter* and *Fusobacterium*	1
10.	Rickettsia and Chlamydia-*Rickettsia*	1
11.	Rickettsia and Chlamydia- *Chlamydia* (*Chlamydophila*) and *Coxiella*	1
12.	*Staphylococcus*	1
13.	*Streptococcus* and *Enterococcus*	2
14.	*Bacillus*	1
15.	*Clostridium*	3
16.	*Erysipelothrix*and*Listeria*	2
17.	*Actinomyces*, *Corynebacterium* and *Truepurella.*	1
18.	*Mycobacterium*	2
19.	Actinomycetes: *Nocardia* and *Rhodococcus* and *Dermatophilus*	2
20.	Mollicutes (*Mycoplasma)*	1
21.	Emerging and transboundary bacterial pathogens	2
	Total	**32**
Practical		
1.	Collection, transport and dispatch of clinical samples from various disease conditions	2
2.	Isolation of bacteria in pure cultures from different clinical samples	12
3.	Identification of the bacteria using staining, biochemical tests and other molecular techniques	
4.	Preservation and storage of bacterial cultures	2
	Total	**16**

VMC 503: General Virology (2+1)

S.No.	Topic of Syllabus	Lecture/ Practical
Theory		
1.	History of virology	1
2.	Origin and nature of viruses	1
3.	Morphological structure and chemical composition of viruses	2
4.	Nomenclature and classification of viruses	2
5.	Cultivation and purifications of viruses	2
6.	Laboratory diagnosis of viral infections	2
7.	Viroid and Prions	1
8.	Replication of DNA viruses	2
9.	Replication of RNA viruses	3
10.	Genetic and non-genetic interactions between viruses	2
11.	Virus-cell interactions	1
12.	Viral pathogenesis	2

S.No.	Topic of Syllabus	Lectures/ Practicals
13.	Viral persistence	1
14.	Oncogenic and oncolytic viruses	2
15.	Epidemiology of viral infections	2
16.	Immune response to viruses	2
17.	Viral vaccines	2
18.	Viral chemotherapy	2
	Total	**32**
Practical		
1.	Orientation to a virology laboratory	1
2.	Preparation of glassware, plasticware, media and reagents for cell culture	2
3.	Other items required for virus cultivation	1
4.	Protocols for primary and secondary cell cultures	2
5.	Maintenance of cell lines	1
6.	Cryopreservation of cells and their revival	2
7.	Staining of virus infected cultured cells	1
8.	Demonstration of inclusion bodies	1
9.	Viable cell counting	1
10.	Cultivation of viruses in embryonated chicken eggs	2
11.	Virus cultivation in primary cell cultures and cell lines	2
	Total	**16**

VMC 504: Systematic Veterinary Virology (2+1)

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	*Poxviridae*	2
2.	*Asfarviridae*	1
3.	*Herpesviridae*	3
4.	*Adenoviridae*	2
5.	*Papilomaviridae* and *Polyomaviridae*	1
6.	*Parvoviride*	1
7.	*Circoviridae* and *Hepdnaviridae*	1
8.	*Orthomyxoviridae*	2
9.	*Paramyxoviridae*	2
10.	*Rhabdoviridae*	2
11.	*Bornaviridae*	1
12.	*Reoviridae*	2
13.	*Birnaviridae*	1
14.	*Picorna* and *Caliciviridae*	2
15.	*Togaviridae* and *Flaviviridae*	2
16.	*Coronaviridae*	1
17.	*Arteriviridae* and *Astrovirida*	1
18.	*Retroviridae*	2
19.	Prions: BSE, Scrapie and introduction to viriods	2
20.	Emerging, re-emerging and transboundary viral pathogens	1
	Total	**32**
Practical		
1.	Collection, preservation, transportation of clinical samples	1

S.No.	Topic of Syllabus	Lectures/ Practicals
2.	Processing clinical samples for virus isolation and identification	6
3.	Isolation and cultivation of viruses from clinical samples, using different methods and its plaque purification	
4.	Titration of viruses for 50% end points using different methods	2
5.	Detection of viral antibodies by serum neutralization test	2
6.	Electropherotyping	2
7.	Concentration and purification of animal viruses by chemical agents, differential centrifugation, density gradient centrifugation and ultra-filtration	2
8.	Methods for preservation of animal viruses	1
	Total	**16**

VMC 505: Principles of Veterinary Immunology (2+1)

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Introduction to livestock and poultry immune system	1
2.	Ontogeny and phylogeny of vertebrate immune system	1
3.	Cells and organs of immune system	1
4.	Types of immunity- Innate and adaptive immune system	1
5.	Antigen and its characteristics- Characteristic of ideal antigen, classification of antigens, Factors affecting immunogenicity, Concept of hapten and carrier, Antigenic determinant/ epitope and cross reactivity, B-cell epitope and T cell epitope	2
6.	Immunoglobulins- Basic structure and function of immunoglobulins	1
7.	Immunoglobulin diversity and Immunoglobulin classes	1
8.	Antigen recognition by B cell and T cell	1
9.	B cell receptor/ immunoglobulins and T cell receptor	1
10.	Receptor diversity- B cell and T cell activation	1
11.	Major Histocompatibility Complex(General feature, structure, function, gene organization, MHC and immune response and Cytokines and chemokines)	2
12.	Immune response development- Phases of humoral and cell mediated immune response	2
13.	Immunoregulation with B and T cells(Antigen recognition, Antigen presentation and processing, Antigen recognition by TCR and MHC restriction)	1
14.	Cell mediated immune response- General properties of effector T cells, cytotoxic T cells, NK-cells and ADCC, Role of integrin and selectin	2
15.	Complement System- Basic concept of complement, Mechanism of complement activation, complement pathways and Complement deficiencies	2
16.	Autoimmunity, autoimmune diseases and Immunological tolerance	1
17.	Hypersensitivity- Classification and mechanism of induction with examples	2
18.	Immunodeficiency- Types with examples	1
19.	Immune response in foetus and new born	1
20.	Antigen antibody interaction- Antibody affinity, avidity, cross reactivity, precipitation and agglutination test	2
21.	ELISA and Western blotting	1

S.No.	Topic of Syllabus	Lectures/ Practicals
22.	Immunodiagnostics and Immunotherapy	1
23.	Monoclonal antibodies and methods for production of monoclonal antibodies	1
	Total	**32**
Practical		
1.	Preparation of antigens	1
2.	Raising of antisera against soluble and insoluble antigens	1
3.	Detection of antibody by gel diffusion, radial immune-diffusion and immune-electrophoresis techniques	2
4.	Haemagglutination and haemagglutination inhibition test	2
5.	ELISA and its modifications	2
6.	Immunoblotting	1
7.	Different agglutination tests	2
8.	Separation and purification of Immunoglobulin from serum	1
9.	Separation of mononuclear cells from blood by density gradient centrifugation	1
10.	Viable count of lymphocyte by dye exclusion method	1
11.	Measurement of T cell response- DTH and lymphoproliferative assay	2
	Total	**16**

VMC 506: Veterinary Mycology (1+1)

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Historyof mycology and Morphology of fungi	1
2.	Structure and Ultra structure	1
3.	Differentiation, nutrition, physiology, reproduction, spores and cultural characters	2
4.	Classification of fungi of veterinary importance	1
5.	Glossary of mycological terms and antifungal agents	1
6.	Important techniques in diagnosis of fungal infections	1
7.	Aspergillosis	1
8.	Candidiasis, Cryptococcosis and Pachydermatitis	1
9.	Epizootic lymphangitis and Rhinosporodiosis	1
10.	Zygomycosis and Blastomycosis	1
11.	Sporotrichosis and Histoplasmosis	1
12.	Coccidioidomycosis and Mycetomas	1
13.	Mycotic abortion and mycotic mastitis	1
14.	Dermatophytoses and dermatomycosis	2
15.	Mycotoxicosis and Emerging mycoses	1
	Total	**16**
Practical		
1.	Collection and processing of clinical material for isolation of fungi	1
2.	Microscopy of fungi-Lactophenol cotton blue and india ink preparations	2
3.	Preparation of basal and special fungal media of veterinary importance	1
4.	Slide culture and cellophane tape technique for fungi	2
5.	Biosafety precautions in handling yeast and dimorphic fungi	1
6.	Study of gross and microscopic characters of pathogenic fungi	5
7.	Diagnosis of dermatophytes	1

S.No.	Topic of Syllabus	Lectures/ Practicals
8.	Antifungal sensitivity testing	1
9.	Detection of mycotoxin	1
10.	Serological and molecular diagnosis in fungi	1
	Total	**16**

VMC 507: Vaccinology (2+0)

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Types of vaccines	1
2.	Vaccine components, Immunogens and factors influencing choice of vaccines	1
3.	New generation vaccines- subunit vaccines, peptide vaccines and recombinant vaccines	2
4.	Reverse genetics vaccines, Marker and DIVA vaccines and transmission blocking vaccines	2
5.	Preparation of vaccines- Identification of candidate strain, identification of epitopes	2
6.	Seed and challenge strain maintenance	1
7.	Classical methods of exaltation and attenuation of pathogens and their molecular basis	2
8.	Technology of production of different types of vaccines	1
9.	Recent advances in vaccine delivery systems and multicomponent vaccines	2
10.	Advances in vaccines, adjuvants with their classification and mode of action	2
11.	Standardization of veterinary vaccines as per National and Global standards	2
12.	Laws and regulatory requirements concerning veterinary biologicals	2
13.	Indian pharmacopoeia	2
14.	Vaccine failure and Post vaccinal reactions	1
15.	Factors affecting response to vaccines and Quality control	2
16.	Principles of development of vaccination schedule	1
17.	Principles of development of vaccination schedule	1
18.	Methods of conducting vaccine trials (lab to field use)	1
19.	Pharmaco-vigilance	1
20.	Scaling up methods of vaccine production	1
	Total	**32**

VMC 508: Techniques in Microbiology (0+2)

S.No.	Topic of Syllabus	Practicals
Practical		
1.	Orientation to a microbiology laboratory	1
2.	Different sterilization and disinfection techniques	2
3.	Laboratory biosafety and biosecurity	1
4.	Microscopy	2

S.No.	Topic of Syllabus	Practicals
5.	Media preparation	2
6.	Isolation, cultivation and purification of bacteria and fungi	2
7.	Morphological and biochemical characterization	3
8.	Antibacterial sensitivity test by Disc diffusion, broth dilution and MIC determination technique	3
9.	Cultivation of viruses in embryonated eggs	2
10.	Cultivation of viruses in cell culture	3
11.	VNT	1
12.	Different immunological techniques- Agglutination	2
13.	Precipitation	2
14.	HA and HI	2
15.	ELISA	2
16.	Other immunological assays	2
	Total	**32**

VMC 509: Techniques in Molecular Microbiology (1+2)

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Basic requirements for establishing molecular diagnostics Laboratory	1
2.	Principles of molecular diagnostic tests	2
3.	Methods of nucleic acid extraction from pathogenic microorganisms	2
4.	PCR and variants of PCR	3
5.	Principles of primer designing	1
6.	Gel electrophoresis methods	1
7.	Blotting Techniques- Southern blotting, northern blotting, western blotting and dot-blot	1
8.	Nucleic acid sequencing methods	1
9.	Sequence analysis-sequence editing, sequence alignment, sequence comparison and phylogentic analysis	1
10.	Gene cloning and expression	1
11.	Molecular diagnosis as epidemiological tool	1
12.	Development and validation of diagnostic tests	1
	Total	**16**
Practical		
1.	Orientation of molecular diagnosis laboratory	1
2.	RNA and Diagnostic PCR lab (Handling RNA and DNA)	2
3.	Extraction of nucleic acid from different microbes(Gram Positive bacteria, Gram Negative bacteria, DNA viruses and RNA Viruses and fungi)	4
4.	DNA and RNA isolation from cell culture and blood	2
5.	Quality and quantity check of nucleic acid-Microlitre spectrophotometery and gel electrophoresis	2
6.	Principles for Primer designing	1
7.	Procedure for molecular diagnostic tests like PCR, RT-PCR and LAMP	3
8.	Absolute and relative quantitation of DNA/ RNA using Real time PCR.	2
9.	SDS PAGE of proteins and RNA	2
10.	Study of nucleic acid and proteins by blotting techniques	2
11.	Restriction Enzyme Techniques (REA and RFLP)	2
12.	PCR product concentration and purification for sequencing	2

S.No.	Topic of Syllabus	Lectures/ Practicals
13.	Nucleic acid sequence analysis	2
14.	Gene Cloning, expression and purification of expression products	3
15.	Idea of high throughput sequencing and MALDI-TOF	2
	Total	**32**

VMC 510: Molecular Immunology (1+1)

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Molecular Structure and function of PRRs	1
2.	Ligands of PRRs and signal transduction through TLR,	1
3.	Inflammosome	1
4.	Cytokines	1
5.	Lymphocyte markers and CD nomenclature	1
6.	Molecular structure of Immunoglobulin and class, isotypes, synthesis and expression of immunoglobulin,	1
7.	Rearrangement and its organization, immunoglobulin gene diversity and mechanism of recombination of B cell gene	2
8.	Theory of antibody generation	1
9.	Signature molecules of T cell and T reg cell, T cell receptor and T cell gene diversity	2
10.	MHC structure, Genomic organization of the MHC gene haplotype and pathway of signal transduction	1
11.	Concept of congenic and syngeneic and Concept of polymorphism of MHC gene	1
12.	Role co-stimulators in B cell and T cell activation and recruitment of adaptor proteins	1
13.	Molecular mechanisms (events) of cell cytotoxicity	2
	Total	**16**
Practical		
1.	Isolation and purification of mammalian and avian immunoglobulin by precipitation technique: - Caprylic acid, PEG, Ammonium Sulphate and Sodium Sulphate	2
2.	Separation of immunoglobulins by size, charge and ligand affinity size exclusion chromatography (Sephadex 200), Ion exchange chromatography (DEAE), affinity chromatography (Protein-A, Sepharose) Immuno-electrophoresis Technique	2
3.	Polyacrylamide gel electrophoresis innative and reducing conditions; fixed and gradient gel	2
4.	Western blot and Crossed immune-electrophoresis	2
5.	Solid Phase ELISA and Chemiluminscence assay	1
6.	Cell cytotoxicity assaya - Non radioactive methods like LDH realease assay	2
7.	Antigen detection by Immuno PCR	1
8.	Haplotype matching between individuals	2
9.	Flow cytometry for CD4 and CD8 ratio determination and other applications	1
10.	ELISPOT test for cytokine assay	1
	Total	**16**

VMC 511: Mucosal Immunology (1+0)

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Mucosal barrier- Development and physiology of mucosal defence. Mucosal inductive and effector sites	1
2.	Cells and lymphoid tissues of mucosal immune system	1
3.	MALT, GALT, NALT and BALT	1
4.	Innate immune response at mucosal surfaces: Mucus, Antimicrobial peptides and Role of PPRs	1
5.	Intestinal Dendritic cell and intestinal macrophage	1
6.	Antigen uptake and presentation at mucosal sites and transepithelial transport of antigen	1
7.	Mucosal Immunoglobulin, IgA synthesis and transport to intestinal lumen	1
8.	Extrathymic Description and role ofPaneth cell and crypto patches	1
9.	M-cells and their functions	1
10.	Mucosal immune effector mechanisms including secretory IgA response	1
11.	T cell development in mucosal tissues and their phenotypes and functions	1
12.	Importance and limitations of mucosal immunization.	1
13.	Mucosal adjuvants and delivery systems	1
14.	Oral tolerance mechanistic approach.	1
15.	Immunopathology at mucosal surfaces: Celiac disease, Inflammatory bowel disease, Jhone's disease	1
16.	Assessment of mucosal immune response and potency testing	1
	Total	**16**

VMC 512: Introduction to Microbial Bio-informatics (1+0)

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Introduction to Bioinformatics; History, Scope and Application	1
2.	Bioinformatics Resources and databases	1
3.	Introduction to NCBI, ExPASy and Ensembl Genome browser	1
4.	Sequence comparison and alignment methods	1
5.	Principal and methods of Pairwise sequence alignment	1
6.	Dotplot analysis	1
7.	BLAST and FASTA programs and their variants	1
8.	DNA and protein sequence analysis	1
9.	Introduction to Multiple sequence alignment	1
10.	Introduction to Phylogenetic analysis	1
11.	Global multiple sequence alignment (CLUSTAL-W)	1
12.	Introduction to protein structure and databases	1
13.	Structure based protein classification	1
14.	Protein structure database -CASP	1
15.	Protein structure alignment tools (VAST, DALI)	1
16.	Protein 3-D structure visualization and modeling	1
	Total	**16**

Course Title with Credit Load
Ph.D. in Veterinary Microbiology

Course Code	Course Title	Credit Hours
VMC 601	Advances in Veterinary Bacteriology*	2+1
VMC 602	Advances in Veterinary Mycology	2+1
VMC 603	Bacterial Genetics	2+0
VMC 604	Microbial Toxins	2+1
VMC 605	Bacterial Pathogenesis	2+0
VMC 606	Advances in Veterinary Virology*	2+1
VMC 607	Molecular Viral Pathogenesis	2+1
VMC 608	Structure Function Relationship of DNA and RNA Viruses	2+0
VMC 609	Oncogenic Viruses	2+0
VMC 610	Slow Viral Infections and Prions	1+0
VMC 611	Advances in Veterinary Immunology*	2+1
VMC 612	Cytokines and Chemokines	2+ 0
VMC 613	Immunoregulation	1+0
VMC 614	Advances in Vaccinology	2+0
VMC 615	Current topics in Infection and Immunity	2+0
VMC 616	Veterinary Microbial Biotechnology	2+1
VMC 690	Special Problem	0+1
VMC 691	Doctoral Seminar-I*	1+0
VMC 692	Doctoral Seminar-II*	1+0
VMC 699	Doctoral Research	0+75

* Core courses

Course Contents
Ph.D. in Veterinary Microbiology

I. Course Title : Advances in Veterinary Bacteriology
II. Course Code : VMC 601
III. Credit Hours : 2+1

IV. Aim of the course

To learn about the latest development in field of bacteriology.

V. Theory

Unit I

Recent advances in bacterial taxonomy and phylogeny, advanced studies on cytology, molecular structure and function of bacterial cell surface, peptidoglycans, walls of Gram-positive and Gram-negative bacteria, Cell surface appendages: Flagella and Fimbriae. Role of bacteria cell envelope in pathogenicity and immunogenicity, Biochemical activities, Antigenic structure. Bacterial secretory and excretory system.

Unit II

Bacterial whole genome sequence analysis and its application.

VI. Practical

Isolation of bacterial LPS, OMP, Peptidoglycans, Capsule, Flagellar antigen, genotyping, phage typing, serotyping of bacteria, studies on host pathogen interactions.

I. Course Title : Advances in Veterinary Mycology
II. Course Code : VMC 602
III. Credit Hours : 2+1

IV. Aim of the course

To learn about the latest development in the field of mycology.

V. Theory

Unit I

Advanced studies on taxonomy, Genetics, Physiology and Antigenic characterization of pathogenic fungi.

Unit II

Advanced studies on molecular approaches for identification of fungi; immunology and serology of mycoses, antifungal therapy, fungal vaccines, fungal viruses.

VI. Practical

Morphological, Biochemical and Physiological studies of various fungi. *In vivo* pathogenicity study. Molecular detection and characterization of fungi.

I. Course Title : Bacterial Genetic
II. Course Code : VMC 603
III. Credit Hours : 2+0

IV. Aim of the course

To learn the various aspects of bacterial genetics.

V. Theory

Unit I

Comparative studies of prokaryotic and eukaryotic genome and their replication; structure, classification and replication of plasmids.

Unit II

Bacterial variations: Phenotypic and genotypic variations, Mutations and mutagenesis, Types of bacterial mutants, Detection of mutants and genemapping. Mechanism of gene transfer: Transduction, Transformation and conjugation. Types and mechanism of recombination: Reciprocal, Non-reciprocal and illegitimate recombination's.

Unit III

Mobile genetic elements, molecular mechanism of antibiotic resistance, regulation of gene expression.

I. Course Title : Microbial Toxins
II. Course Code : VMC 604
III. Credit Hours : 2+1

IV. Aim of the course

To learn about the structure, Mechanism of action, Methods of detection of various bacterial and fungal toxins.

V. Theory

Unit I

Classification of bacterial and fungal toxin on the basis of their structure and functions. The role of microbial toxins in the pathogenesis of diseases; biochemical and biological characteristics of toxins. Toxin producing Grams-positive and Grams-negative bacteria. Properties and clinical conditions produced by different bacterial and fungal toxins. Analytical methods for detection of bacterial and fungal toxins: Biological assays, Immunological assays, Nucleic acid-based methods.

Unit II

Application of microbial toxins andimmunobiological studies of toxins.

VI. Practical

Detection and identification of Mycotoxigenic fungi and mycotoxins. Method of detection of bacterial endotoxin, Production of toxins in suitable media, Purification and characterization of toxins, Biological characterization in animal and in tissue culture. Toxin neutralization test.

I. Course Title : Bacterial Pathogenesis
II. Course Code : VMC 605
III. Credit Hours : 2+0
IV. Aim of the course

To learn the molecular mechanisms of bacterial pathogenesis.

V. Theory

Unit I

Molecular structure, Production and mode of action of bacterial virulence factors, Bacterial biofilms and advance studies on pathogenesis of bacterial diseases of various systems.

Unit II

Host-pathogen interaction, Animal models for bacterial pathogens.

I. Course Title : Advances in Veterinary Virology
II. Course Code : VMC 606
III. Credit Hours : 2+1
IV. Aim of the course

Advanced study of virus structure, Their nucleic acids and proteins; Latest trends in animal virus research.

V. Theory

Unit I

Biology of RNA and DNA virus replication. An introduction to bacteriophages and phage replication.

Unit II

Current concepts in animal virus research with respect to viral structure and architecture, viral virulence, viral pathogenesis, persistence and oncogenesis. Viruses as bio-terror agents and viruses for pest management (Bio-control).

Unit III

Antiviral drugs: Scope, Use and limitations, Existing antiviral drugs and their mechanism of action, Latest trends in antiviral drug development.

Unit IV

Preparation of plasmid backbone, Preparation of viral genes for cloning and cloning in viral genome backbone, Confirmation of cloned genes, Development of positive marker and negative markers, DIVA vaccine, Different types of viral vectors (vaccinia, adenoviral, retroviral vectors).

VI. Practical

Characterization of viral proteins and genome. Problem oriented practical assignments aimed at development of bioreagents and relevant diagnostic tests.

I. Course Title : Molecular Viral Pathogenesis
II. Course Code : VMC 607
III. Credit Hours : 2+1
IV. Aim of the course

To study molecular and genetic determinants of viral virulence and pathogenesis;

animal models for studying viral pathogenesis.

V. Theory

Unit I

Study of virus host interactions: Host specificity, Tissue tropism, Mechanism of virus spread in the body.

Unit II

Host immune responses to viral infections; Viral strategies to evade host immune responses. Viral interference and interferons.

Unit III

Pathogenesis of viral diseases of various systems, animal models for studying viral pathogenesis, molecular and genetic determinants of viral virulence, mechanisms of viral virulence.

Unit IV

Molecular and genetic determinants of viral persistence, viral oncogenesis, viral immunosuppression, and immunopathology.

VI. Practical

Pathotyping of animal viruses using Newcastle disease virus as model, Determination of immunosuppressive potential of animal viruses using infectious bursal disease virus/ Marek's disease virus/ chicken anaemia virus, Characterization of molecular determinants of viral virulence using variants, Recombinants and reassortants.

I. Course Title : Structure Function Relationship of DNA and RNA Viruses

II. Course Code : VMC 608

III. Credit Hours : 2+0

IV. Aim of the course

To understand the relationship between structure and function of DNA and RNA viruses of animals for the development of next generation viral vaccine and antivirals.

V. Theory

Unit I

Methods of studying virus structure and architecture, Methods of amplification of viral nucleicacids, Molecular characterization of viral protein and nucleic acids, Nucleotide sequencing and its analysis by software programmes.

Unit II

Detailed study of virus replication in various groups of animal viruses.

Unit III

Understanding the relationship between structure and function of animal DNA and RNA viruses, Development of modern vaccines and antivirals using the relationship between structure and function of animal DNA and RNA viruses.

I. Course Title : Oncogenic Viruses
II. Course Code : VMC 609
III. Credit Hours : 2+0

IV. Aim of the course

To study mechanisms of viral oncogenesis.

V. Theory

Unit I

General features of cell transformation and characterization of transformed cells. Oncogenic RNA and DNA viruses. Oncolytic viruses, viral and cellular oncogenes.

Unit II

Mechanisms of viral oncogenesis and diagnosis of viral oncogenesis.

I. Course Title : Slow Viral Infections and Prions
II. Course Code : VMC 610
III. Credit Hours : 1+0

IV. Aim of the course

To study slow viral infections, properties and replication of prions and diseases caused by them.

V. Theory

Unit I

Epidemiology, Pathogenesis, Diagnosis and control of slow viral infections.

Unit II

Properties, Replication and epidemiology of prions. Pathogenesis, immunity, Diagnosis and control of Scrapies, Bovine spongiform encephalopathy, Chronic wasting disease of dear, Transmissible mink encephalopathy. Recent trends in prion research.

I. Course Title : Advances in Veterinary Immunology
II. Course Code : VMC 611
III. Credit Hours : 2+1

IV. Aim of the course

To study recent advances in immunology.

V. Theory

Unit I

Cells and tissues of immune system: Significance of HSC l, Origin of myeloid cells; Lymphoid cells (T and B cells), NK cells, NKT cell, Apoptosis and its role in homeostatic mechanism. Ontogeny of the lymphoid tissue in mammals and birds. Cell adhesion molecules, Recirculation and trafficking, Cell homing receptor. Antigen presenting cells and their functions at cellular level.

Unit II

Cytokines, chemokines and cytokine receptors.

Unit III

Developmental biology of Immune cells**:** Early development of T and B cells and its differentiation, Maturation in primary lymphoid organ. B cell development and T cell development. Lineage commitment, Memory generation. Organization of expression of lymphocyte receptors gene, Multigenic organization of immunoglobulin gene andthymic selection of T cell repertoire. Concept of extrathymic origin of T cells. Effector and memory T and B cells.

Unit IV

Recombination events in T and B cell: Mechanism of recombination of immunoglobulin genes and T cell receptor genes.

Unit V

Activation of T and B cells: Clonal expansion. Role of T cell help in B cell response, affinity maturation of B cells and class switching and T cell activation.

Unit VI

MHC**:** MHC class-I and II structure and gene arrangement, polymorphism, antigen processing and presentation mechanism.

Unit VII

Antibody mediated and cell mediated effector functions. Cellular immune response: Effector mechanisms of CTL, NK cells and NK T cell activation. Regulation of immune response. Role of T reg-cells, immunological tolerance and graft rejection.

VI. Practical

Purification of immunoglobulin classes, Subclasses, Fragmentation of antibody by enzyme digestion to F (ab)2 and Fc fragments, Affinity chromatography techniques. Separation of protein by SDS PAGE under reducing condition.Western blot experiment to detect the immunogenic protein, ELISPOT, cytotoxic T cell assay, morphological and functional assays of blood monocytes. FACS and MACS.

I. Course Title : Cytokines and Chemokines

II. Course Code : VMC 612

III. Credit Hours : 2+0

IV. Aim of the course

To study recent advances in cytokines and chemokines**.**

V. Theory

Unit I

Properties of cytokines. General structure and function of classification of cytokines family's, Cytokine secretion by Th1 and Th2 subsets. Cytokines cross regulation. Cytokine receptors:general structure of cytokine receptors, Immunoglobulin superfamily receptors, class 1 and class 2 cytokine receptor families. TNF receptor families and cytokine antagonists.

Unit II

Cytokine related diseases. Therapeutic uses of cytokines and their receptors. Chemokines: subgroups of chemokines and their structures and functions, chemokine receptor families.

Unit III

Immunomodulators: Types of immunomodulators and their mechanism of action. Adjuvants: classification, Mode of action, Adjuvants combination and safety. Cytokine as adjuvant, PLG and microparticle as adjuvant, TLR agonist as adjuvant. Antigen delivery system and mode of action. Immunostimulants: Bacterial product and synthetic Compound, Complex carbohydrates, Immune enhancing drugs, Vitamins and cytokines.

Unit IV

Immunosuppression, Neuroendocrine control of immunoregulation, Immunosuppressive agents and drugs, Corticosteroids, Cyclosporin's, Cyclophosphamide and other agents, Like irradiation and the mode of action.

I. Course Title : Immunoregulation
II. Course Code : VMC 613
III. Credit Hours : 1+0

IV. Aim of the course

To study recent advances in immunoregulation mechanisms.

V. Theory

Unit I

Molecular mediators of immune response: Lymphokines and monokines. Idiotypic networks. Epitope specific regulation. Th, Tc and Treg cells. MHC in immunoregulation, Immune response genes. Antigen specific suppressor molecules produced by T cells. Immunosuppressive agents and immune-stimulation. Immunoregulatory pathways.

I. Course Title : Advances in Vaccinology
II. Course Code : VMC 614
III. Credit Hours : 2+0

IV. Aim of the course

To learn about advances in vaccine research and modern approaches for the vaccine development.

V. Theory

Unit I

Different phases in vaccine development. Direct and indirect correlates of protection. Antigen identification and characterization employing emerging technologies such as microarrays, *in vivo* expression technology, Signature-tagged mutagenesis and phage display technology.

Unit II

Immuno-informatics applied to epitope mapping, T cell epitopes and identification of pathogenic epitopes. Novel vaccines: nucleic acids, Marker vaccines, Mucosal vaccines, Bacterial ghosts as vaccines and virus-like particles. Futuristic vaccines: anti-allergic, Anti-autoimmune diseases, De-addiction vaccines and transplant survival/ prolonging vaccines.

I. Course Title : Current Topics in Infection and Immunity

II. Course Code : VMC 615

III. Credit Hours : 2+0

IV. Aim of the course

Discussions on recent developments in the immunobiology of major viral, bacterial and fungal diseases of animals.

V. Theory

Unit I

Introduction and historical developments. Host-pathogen relationship.

Unit II

Effector mechanisms of specific and non-specific immunity to different groups of microbes.

Unit III

Immunobiology of major viral, Bacterial and fungal diseases of animals. Types of vaccines for infectious diseases; Current trends in vaccine development.

I. Course Title : Veterinary Microbial Biotechnology

II. Course Code : VMC 616

III. Credit Hours : 2+1

IV. Aim of the course

To understand as to how microbial processes and activities can be used for development of medically and industrially important products and processes.

V. Theory

Unit I

History of microbial biotechnology. Microbes in nature.Microbes as infectious agents of human and animals. Host-microbe relationships. Microbial metabolism and growth characteristics. Microbial genetics.

Unit II

Introduction to molecular biology of microorganisms: DNA, RNA and proteins structure and functions. DNA replication, RNA transcription, reverse transcription, protein translation and regulatory mechanisms. Bacterial extrachromosomal DNA elements.

Unit III

Genetic engineering: Restriction enzymes, DNA ligases, DNA polymerases, RNases and DNases and other enzymes. DNA sequencing. Plasmids and phage-derived vectors, Bacterial hosts for cloning and expression of transgenes. Genomic libraries and sequencing. Blotting of DNA, RNA and proteins. Polymerase chain reaction. An introduction to Microarrays and Metagenomics.

Unit IV

Expression of antigens and antibody fragments useful as diagnostic reagents and vaccines. PCR and blotting techniques in infectious disease diagnosis. Nucleic acid vaccines. Vectored viral and bacterial vaccines. Construction of defined mutants and marker vaccines using genetic manipulation techniques.Manipulation of microbial processes for production of industrially useful substances.

VI. Practical

Extraction of nucleic acids from viruses and bacteria. Restriction endonuclease digestion of DNA and resolution in agarose gel electrophoresis. PCR amplification of DNA. RT-PCR of RNA. Insertion of DNA fragments into plasmid/ phagemid/ phage vectors. Construction of competent *E. coli* host cells. Transformation and transfection of competent *E. coli* cells. Screening of transformants and isolation of clones. Sequence analysis of clones/ PCR amplicons. Expression of genes of bacterial/ viral antigens. Use of PCR for infectious disease diagnosis.

I. Course Title : Special Problem

II. Course Code : VMC 690

III. Credit Hours : 1+0

IV. Aim of the course

To provide expertise in handling practical research problem(s).

V. Practical

Short research problem(s) involving contemporary issues and research techniques.

Course Outline-cum-Lecture Schedule for Doctoral Degree Programme

VMC 601: Advances in Veterinary Bacteriology 2+1

S.No.	Topic of Syllabus	Lecture/ Practical
Theory		
1.	Recent advances in bacterial taxonomy and phylogeny	3
2.	Advanced studies on bacterial cytology	2
3.	Molecular structure and function of bacterial cell surface Peptidoglycans	2
4.	Walls of Gram-positive and Gram-negative bacteria	2
5.	Cell surface appendages: Flagella and Fimbriae	3
6.	Role of bacteria cell envelope in pathogenicity and immunogenicity	4
7.	Biochemical activities	4
8.	Antigenic structure	4
9.	Bacterial secretory and excretory system	4
10.	Bacterial whole genome sequence analysis and its application	4
	Total	**32**
Practical		
1.	Isolation of bacterial LPS	1
2.	Isolation of bacterial OMP	1
3.	Isolation of bacterial Peptidoglycans	1
4.	Isolation of bacterial Capsule	1
5.	Isolation of bacterial Flagellar antigen	1
6.	Genotyping of bacteria	2
7.	Phage typing of bacteria	2
8.	Serotyping of bacteria	3
9.	Studies on host pathogen interactions	4
	Total	**16**

VMC 602: Advances in Veterinary Mycology 2+1

S.No.	Topic of Syllabus	Lecture/ Practical
Theory		
1.	Advanced studies on taxonomy of pathogenic fungi	2
2.	Advanced studies on genetics of pathogenic fungi	4
3.	Advanced studies on physiology of pathogenic fungi	4
4.	Advanced studies on antigenic characterization of pathogenic fungi	6
5.	Advanced studies on molecular approaches for identification of fungi	4
6.	Immunology and serology of mycoses	4
7.	Antifungal therapy	4
8.	Fungal vaccines	2
9.	Fungal viruses	2
	Total	**32**

S.No.	Topic of Syllabus	Lecture/ Practical
Practical		
1.	Morphological, biochemical and physiological studies of various fungi	6
2.	*In vivo* pathogenicity study	5
3.	Molecular detection and characterization of fungi	5
	Total	**16**

VMC 603: Bacterial Genetics 2+0

S.No.	Topic of Syllabus	Lecture
Theory		
1.	Comparative studies of prokaryotic and eukaryotic genome and their replication	3
2.	Structure, classification and replication of plasmids	3
3.	Bacterial variations: Phenotypic and genotypic variations	3
4.	Mutations and mutagenesis, types of bacterial mutants and detection of mutants	4
5.	Gene mapping	3
6.	Mechanism of gene transfer: transduction, transformation and conjugation	4
7.	Types and mechanism of recombination: Reciprocal, non-reciprocal and illegitimate recombination's	4
8.	Mobile genetic elements	3
9.	Molecular mechanism of antibiotic resistance	3
10.	Regulation of gene expression	2
	Total	**32**

VMC 604: Microbial Toxins 2+1

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Classification of bacterial and fungal toxin on the basis of their structure and functions	4
2.	The role of microbial toxins in the pathogenesis of diseases	3
3.	Biochemical and biological characteristics of toxins	5
4.	Toxin producing Grams-positive and Grams-negative bacteria	2
5.	Properties and clinical conditions produced by different bacterial and fungal toxins	4
6.	Analytical methods for detection of bacterial and fungal toxins: Biological assays, immunological assays, Nucleic acid-based methods	8
7.	Application of microbial toxins	3
8.	Immuno-biological studies of toxins	3
	Total	**32**
Practical		
1.	Detection and identification of Mycotoxigenic fungi and mycotoxins	2
2.	Method of detection of bacterial endotoxin	3
3.	Production of toxins in suitable media	3
4.	Purification and characterization of toxins	3

S.No.	Topic of Syllabus	Lectures/ Practicals
5.	Biological characterization in animal and in tissue culture	3
6.	Toxin neutralization test	2
	Total	**16**

VMC 605: Bacterial Pathogenesis 2+0

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Molecular structure, production and mode of action of bacterial virulence factors	8
2.	Bacterial biofilms	4
3.	Advancee studies on pathogenesis of bacterial diseases of various systems	8
4.	Host-pathogen interaction	8
5.	Animal models for bacterial pathogens	4
	Total	32

VMC 606: Advances in Veterinary Virology 2+1

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Biology of RNA and DNA virus replication	2
2.	An introduction to bacteriophages and phage replication	2
3.	Current concepts in animal virus research with respect to viral structure and architecture	3
4.	viral virulence, viral pathogenesis, persistence and oncogenesis	4
5.	Viruses as bio-terror agents and viruses for pest management (Bio-control)	2
6.	Antiviral drugs: Scope, use and limitations	3
7.	Existing antiviral drugs and their mechanism of action	2
8.	Latest trends in antiviral drug development	2
9.	Preparation of plasmid backbone, preparation of viral genes for cloning and cloning in viral genome backbone	3
10.	Confirmation of cloned genes	2
11.	Development of positive marker and negative markers	2
12.	DIVA vaccine	2
13.	Different types of viral vectors (vaccinia, adenoviral, retroviral vectors)	3
	Total	**32**
Practical		
1.	Characterization of viral proteins and genome	8
2.	Problem oriented practical assignments aimed at development of bioreagents and relevant diagnostic tests	8
	Total	**16**

VMC 607: Molecular Viral Pathogenesis 2+1

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Study of virus host interactions: host specificity, tissue tropism and mechanism of virus spread in the body	3
2.	Host immune responses to viral infections	2
3.	Viral strategies to evade host immune responses	2
4.	Viral interference and interferons	2
5.	Pathogenesis of viral diseases of various systems	3
6.	Animal models for studying viral pathogenesis	3
7.	Molecular and genetic determinants of viral virulence	3
8.	Mechanisms of viral virulence	3
9.	Molecular and genetic determinants of viral persistence	3
10.	Viral oncogenesis	4
11.	Viral immunosuppression and immunopathology	4
	Total	**32**
Practical		
1.	Pathotyping of animal viruses using Newcastle disease virus as model	4
2.	Determination of immunosuppressive potential of animal viruses using infectious bursal disease virus/ Marek's disease virus/ chicken anaemia virus	8
3.	Characterization of molecular determinants of viral virulence using variants, recombinants and reassortants	4
	Total	**16**

VMC 608: Structure Function Relationship of DNA and RNA Viruses 2+0

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Methods of studying virus structure and architecture	3
2.	Methods of amplification of viral nucleicacids	2
3.	Molecular characterization of viral protein and nucleic acids	3
4.	Nucleotide sequencing and its analysis by software programmes	6
5.	Detailed study of virus replication in various groups of animal viruses	6
6.	Understanding the relationship between structure and function of animal DNA and RNA viruses	6
7.	Development of modern vaccines and antivirals using the relationship between structure and function of animal DNA and RNA viruses	6
	Total	**32**

VMC 609: Oncogenic Viruses 2+0

S.No.	Topic of Syllabus	Practical
Theory		
1.	General features of cell transformation and characterization of transformed cells	4
2.	Oncogenic RNA and DNA viruses	4

S.No.	Topic of Syllabus	Practical
3.	Oncolytic viruses	5
4.	Viral and cellular oncogenes	5
5.	Mechanisms of viral oncogenesis	8
6.	Diagnosis of viral oncogenesis	6
	Total	**32**

VMC 610: Slow Viral Infections and Prions 1+0

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Epidemiology of slow viral infections	1
2.	Pathogenesis of slow viral infections	1
3.	Diagnosis and control of slow viral infections	2
4.	Properties, replication and epidemiology of prions	2
5.	Scrapies	2
6.	Bovine spongiform encephalopathy	2
7.	Chronic wasting disease of dear	2
8.	Transmissible mink encephalopathy	2
9.	Recent trends in prion research	2
	Total	**16**

VMC 611: Advances in Veterinary Immunology 2+1

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	Significance of HSC l and Origin of myeloid cells	1
2.	Lymphoid cells (T and B cells), NK cells and NKT cell	1
3.	Apoptosis and its role in homeostatic mechanism	1
4.	Ontogeny of the lymphoid tissue in mammals and birds	1
5.	Cell adhesion molecules, recirculation and trafficking, cell homing receptor	2
6.	Antigen presenting cells and their functions at cellular level	1
7.	Cytokines, chemokines and cytokine receptors	2
8.	Early development of T and B cells and its differentiation and maturation in primary lymphoid organ	1
9.	B cell development and T cell development	2
10.	Lineage commitment and memory generation	2
11.	Organization of expression of lymphocyte receptors gene	2
12.	Multiagenic organization of immunoglobulin gene	1
13.	Thymic selection of T cell repertoire.	1
14.	Concept of extrathymic origin of T cells	1
15.	Effector and memory T and B cells	1
16.	Mechanism of recombination of immunoglobulin genes and T cell receptor genes	2
17.	Clonal expansion	1
18.	Role of T cell help in B cell response	1
19.	Affinity maturation of B cells and class switching and T cell activation	1

S.No.	Topic of Syllabus	Lectures/ Practicals
20.	MHC class-I and II structure and gene arrangement, polymorphism, antigen processing and presentation mechanism	2
21.	Effector mechanisms of CTL, NK cells and NK T cell activation	2
22.	Regulation of immune response	2
23.	Role of T reg-cells, immunological tolerance and graft rejection	1
	Total	**32**
Practical		
1.	Purification of immunoglobulin classes, subclasses, fragmentation of antibody by enzyme digestion to F (ab)2 and Fc fragments, affinity chromatography techniques	2
2.	Separation of protein by SDS PAGE under reducing condition	2
3.	Western blot experiment to detect the immunogenic protein	2
4.	ELISPOT	2
5.	Cytotoxic T cell assay	2
6.	Morphological and functional assays of blood monocytes	2
7.	FACS	2
8.	MACS	2
	Total	**16**

VMC 612: Cytokines and Chemokines 2+ 0

S.No.	Topic of Syllabus	Lectures
Theory		
1	Properties of cytokines	2
2	General structure and function of classification of cytokines family's, cytokine secretion by Th1 and Th2 subsets	3
3	Cytokines cross regulation	2
4	Cytokine receptors:general structure of cytokine receptors, immunoglobulin superfamily receptors, class 1 and class 2 cytokine receptor families	3
5	TNF receptor families and cytokine antagonists	2
6	Cytokine related diseases	2
7	Therapeutic uses of cytokines and their receptors	2
8	Chemokines: subgroups of chemokines and their structures and functions, chemokine receptor families	3
9	Types of immunomodulators and their mechanism of action	2
10	Adjuvants: classification, mode of action, adjuvants combination and safety	2
11	Cytokine as adjuvant, PLG and microparticle as adjuvant, TLR agonist as adjuvant	2
12	Antigen delivery system and mode of action	3
	Immunostimulants: bacterial product and synthetic compound, complex carbohydrates, immune enhancing drugs, vitamins and cytokines	3
13	Immunosuppression, Neuroendocrine control of immunoregulation, Immunosuppressive agents and drugs, corticosteroids, cyclosporin's, cyclophosphamide and other agents, like irradiation and the mode of action	3
	Total	**32**

VMC 613: Immunoregulation 1+0

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Molecular mediators of immune response:lymphokines and monokines	2
2.	Idiotypic networks	2
3.	Epitope specific regulation	2
4.	Th, Tc and Treg cells	2
5.	MHC in immunoregulation, immune response genes	2
6.	Antigen specific suppressor molecules produced by T cells	2
7.	Immunosuppressive agents and immune-stimulation	2
8.	Immunoregulatory pathways	2
	Total	**16**

VMC 614: Advances in Vaccinology 2+0

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Different phases in vaccine development	4
2.	Direct and indirect correlates of protection	2
3.	Antigen identification and characterization employing emerging technologies such as microarrays, in vivo expression technology, signature-tagged mutagenesis and phage display technology	6
4.	Immuno-informatics applied to epitope mapping, T cell epitopes and identification of pathogenic epitopes	8
5.	Nucleic acids, marker vaccines, mucosal vaccines, bacterial ghosts as vaccines and virus-like particles	6
6.	Futuristic vaccines: anti-allergic, anti-autoimmune diseases, de-addiction vaccines and transplant survival/ prolonging vaccines	6
	Total	**32**

VMC 615: Current topics in Infection and Immunity 2+0

S.No.	Topic of Syllabus	Lectures
Theory		
1.	Introduction and historical developments	5
2.	Host-pathogen relationship	6
3.	Effector mechanisms of specific and non-specific immunity to different groups of microbes	6
4.	Immunobiology of major viral, bacterial and fungal diseases of animals	6
5.	Types of vaccines for infectious diseases	5
6.	Current trends in vaccine development	6
	Total	**32**

VMC 616: Veterinary Microbial Biotechnology 2+1

S.No.	Topic of Syllabus	Lectures/ Practicals
Theory		
1.	History of microbial biotechnology	1
2.	Microbes in nature	1
3.	Microbes as infectious agents of human and animals	1
4.	Host-microbe relationships	1
5.	Microbial metabolism and growth characteristics	1
6.	Microbial genetics	1
7.	Introduction to molecular biology of microorganisms: DNA, RNA and proteins structure and functions	2
8.	DNA replication, RNA transcription, reverse transcription, protein translation and regulatory mechanisms	2
9.	Bacterial extrachromosomal DNA elements	1
10.	Genetic engineering: restriction enzymes, DNA ligases, DNA polymerases, RNases and DNases and other enzymes	2
11.	DNA sequencing	2
12.	Plasmids and phage-derived vectors, bacterial hosts for cloning and expression of transgenes	2
13.	Genomic libraries and sequencing	1
14.	Blotting of DNA, RNA and proteins	2
15.	Polymerase chain reaction	1
16.	An introduction to Microarrays and Metagenomics	1
17.	Expression of antigens and antibody fragments useful as diagnostic reagents and vaccines	2
18.	PCR and blotting techniques in infectious disease diagnosis	2
19.	Nucleic acid vaccines	1
20.	Vectored viral and bacterial vaccines	1
21.	Construction of defined mutants and marker vaccines using genetic manipulation techniques	2
22.	Manipulation of microbial processes for production of industrially useful substances	2
	Total	**32**
Practical		
1.	Extraction of nucleic acids from viruses and bacteria	2
2.	Restriction endonuclease digestion of DNA and resolution in agarose gel electrophoresis	1
3.	PCR amplification of DNA	1
4.	RT-PCR of RNA	1
5.	Insertion of DNA fragments into plasmid/ phagemid/ phage vectors	2
6.	Construction of competent E. coli host cells	2
7.	Transformation and transfection of competent E. colicells	1
8.	Screening of transformants and isolation of clones	1
9.	Sequence analysis of clones/ PCR amplicons	2
10.	Expression of genes of bacterial/ viral antigens	2
11.	Use of PCR for infectious disease diagnosis	1
	Total	**16**

VMC 690: Special Problem 0+1

Practical

Short research problem(s) involving contemporary issues and research techniques. Planning a short research problem or working on a published research paper or new developments.

Suggested Reading

- AM Lesk. 2002. *Introduction to Bioinformatics*. Oxford University press.
- Abbas AH. Lichtman and S. Pillai. 2017. *Cellular and Molecular Immunology: Functions and Disorders of the Immune System*, 7th Ed., Elsevier.
- B Detrick and RG Hamilton and JH Schimitz. 2016. *Manual of Molecular and Clinical Laboratory Immunology*. 8th Ed. American Society for Microbiology.
- B Markey, F Leonard, M Archambault, A Cullinane and D Maguire. 2013. *Clinical Veterinary Microbiology* 2nd Ed. MOSBY- Elsevier.
- BD Singh. 2012. *Biotechnology: Expanding Horizons*, 4thEd.Kalyani Pub.
- C Hirsh, NJ MacLachlan and RL Walker. 2004. *Veterinary Microbiology*, 2ndEdn., Wiley-Blackwell Pub.
- CC Kibbler, R Barton, Neil AR Gow, S Howell, DM MacCallum and RJ Manuel. 2018. *Oxford Textbook of Medical Mycology*, 1st Ed., Oxford University Press.
- CM Fraser, T Read and KE Nelson. 2010. *Microbial Genomes (Infectious Disease)*. 1st Edition, Humana Press.
- D Balasubramanian, CFA Bryce, K Jayaraman, J Green and K Dharmalingam. 2004. *Concepts in Biotechnology*, Revised edition, Universities Press Pub.
- DW Mount. 2001. *Bioinformatics: Sequence and genome analysis*. Cold Spring Harbor, N.Y: Cold Spring Harbor Laboratory Press.
- FA Murphy, EPJ Gibbs, MK Holzmek and MJ Studdert. 1999. *Veterinary Virology*. 3rd Ed. Academic Press.
- GJ Tortora, BR Funke, CL Case, D Weber and W Bair. 2018. *Microbiology: An Introduction*, 13th Ed., Pearson Pub.
- GM Callahan and RM Yates. 2014. *Basic Veterinary Immunology*. 1stEdn., University Press of Colorado.
- JB Carter and VA Saunders. 2013. *Virology: Principles and Applications*, 2nd Ed., John Wiley and Sons Pub.
- J Glenn Songer and KW Post. 2004. *Veterinary Microbiology: Bacterial and Fungal Agents of Animal Diseases*. 1st Ed., Saunders Pub.
- J Punt, S Stranford, P Jones and J Owen. 2019. *Kuby Immunology*, 8th Ed., W.H. Freeman Pub.
- J Willey, K Sandman and D Wood. 2019. *Prescott's Microbiology*, 11thEdn., McGraw-Hill Education Pub.
- J Mestecky, W Strober, MW Russell, H Cheroutre, BN Lambrecht and BL Kelsall. 2015. *Mucosal Immunology* 4th Edn., Academic Press.
- JE Coligan, AM Kruisbeek, DH Margulies, EM Shevach and W Strober. 2003. *Current Protocols in Immunology*. 3rd Edn. John Wiley and Sons.
- L Gyles, JF Prescott, J Glenn Songer and CO Thoen. 2010. *Pathogenesis of Bacterial Infections in Animals*, 4thEdn., Wiley-Blackwell Pub.
- MJ Dey and RM Schultz. 2014. *Veterinary Immunology: Principles and Practice*, 2nd Edn., CRC Press/ Taylor and Francis.
- MM Levine, JB Kaper, R Rappuoli, MA Liu and MF Good. 2004. *New Generation Vaccines*. 3rd Ed. Marcel-Dekker.
- NJ Maclachlan and EJ Dubovi. 2016. *Fenner's Veterinary Virology*. 5thEdn., Academic Press.
- PJ Quinn, BK Markey, FC Leonard, P Hartigan, S Fanning and ES Fitzpatrick. 2011. *Veterinary Microbiology and Microbial Disease*, 2nd Ed., Wiley-Blackwell Pub.
- PJ Delves, SJ Martin, DR Burton and IM Roitt. 2017. *Roitt's Essential Immunology* 13th Edition, Wiley Blackwell.

- R Tizard. 2017. *Veterinary Immunology*, 10th Edn., Saunders Publ.
- S Giguère, JF Prescott and PM Dowling. 2013. *Antimicrobial Therapy in Veterinary Medicine*, 5th Ed., John Wiley and Sons, Inc.
- SJ Flint, V Racaniello, G Rall and A Skalka. 2015. *Principles of Virology*, 4th Edition (2 volume set). ASM press
- S Jameel and L Villarreal. 2000. *Advances in Animal Virology*. Science Pub.
- Samanta. 2015. *Veterinary Mycology*. Springer, India, Private Ltd Pub.
- WJW Morrow, NA Sheikh, CS Schmidt and D Huw Davies. 2012. *Vaccinology: Principles and Practice*1 edition Wiley-Blackwell.
- TA Brown. 2016. *Gene Cloning and DNA Analysis*. 7th Edition., Wiley Blackwell
- WJ Dodds and R Schulz. 1999. *Veterinary Vaccines and Diagnostics*. Vol. 41 (Advances in Veterinary Medicine) 1st Ed. Academic Press.
- For Ph.D. Courses: Selected articles and reviews from journals

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Para-Clinical Subjects
– Veterinary Pathology

Course Title with Credit Load
M.V.Sc. in Veterinary Pathology

Course Code	Course Title	Credit Hours
VPL 501	General Pathology*	2+1
VPL 502	Techniques in Pathology*	0+2
VPL 503	Animal Oncology	1+1
VPL 504	Clinical Pathology*	1+1
VPL 505	Necropsy Procedures and Interpretations*	1+1
VPL 506	Necropsy Conference*	0+1
VPL 507	Systemic Pathology*	2+1
VPL 508	Pathology of Infectious Diseases of Domestic Animals*	2+1
VPL 509	Toxicopathology	2+1
VPL 510	Avian Pathology*	2+1
VPL 511	Pathology of Wild/ Zoo and Aquatic Animal Diseases	2+1
VPL 512	Pathology of Laboratory Animal Diseases	2+1
VPL 591	Master's Seminar*	1+0
VPL 599	Master's Research	30

*Core Courses

Course Contents
M.V.Sc. in Veterinary Pathology

I. Course Title : General Pathology
II. Course Code : VPL 501
III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with different types of degenerations, cell injuries caused by different types of irritants and inflammation.

V. Theory

Unit I

Introduction and principles of Pathology including genetic basis of disease; Cellular responses to injury: Causes and mechanisms of reversible and irreversible cell injury; Morphologic characteristics, Significance and fate of various intracellular (lipids, glycogen, proteins) and extracellular (hyaline material, amyloid, fibrinoid change, gout) accumulations/ degenerations, Endogenous and exogenous pigmentations, Cell death (necrosis, apoptosis and gangrene), Pathologic calcifications and cellular adaptive changes.

Unit II

Inflammation and repair: Introduction to inflammation, Acute inflammation-cellular and molecular events including mediators and heat shock proteins of acute inflammation; Cellular components, Morphologic classification and outcomes of acute inflammation, Chronic inflammation-causes, Morphologic features and cellular components of chronic inflammation, Healing and repair, Systemic effects of inflammation.

Unit III

Disturbances in circulation: Causes, mechanisms, Morphologic features, Significance and fate of hyperemia, Oedema, Haemorrhage, Thrombosis, Embolism, Ischaemia, infarction and shock.

Unit IV

Immune mediated reactions: Introduction to autoimmunity and immune mediated diseases, mechanisms of hypersensitivity reactions.

VI. Practical

- To study the morphologic descriptions of lesions and nomenclature of a morphologic diagnosis based on gross and/ or microscopic lesions of variety of conditions (degenerations, infiltrations, pigmentations, necrosis, circulatory and growth disturbances and different types of inflammation) in the preserved specimens/ slides. Demonstration of post-mortem changes.
- Continuous assessment of students for their skills in the diagnosis of gross lesions during post-mortem examination of different tissues of domestic animals.

Preparation of histopathology slides on the selected cases followed by interaction in the student seminars/ group discussions.

VII. Suggested Reading

- McGavin MD and Zachary JF. 2017. *Pathologic Basis of Veterinary Diseases*. 6th Ed. Elsevier.
- Vegad JL. 2007. *Text Book of Veterinary General Pathology*. 2nd Ed. International Book Distr.

I. Course Title : Techniques in Pathology

II. Course Code : VPL 502

III. Credit Hours : 0+2

IV. Aim of the course

To acquaint the students with different techniques used frequently in Veterinary Pathology.

V. Practical

- Basic histopathological techniques-Collection of tissues, fixation, processing, section cutting and H and E staining of tissue sections. Collection and fixation of tissues for scanning electron microscopy, transmission electron microscopy, histochemical, toxicological, bacteriological and virological examinations. Application of micrometry and special staining techniques. Demonstration of different inclusions, bacteria and fungi in tissues.
- Principles of dark field, phase contrast and fluorescent microscopy; introduction to scanning electron microscopy and transmission electron microscopy.
- Histochemical techniques for demonstration of fat, glycogen, connective tissue, mucopolysaccharides and common enzymes, pigments and minerals Cryosectioning and application of immunohistochemical techniques–immunoperoxidase and immunofluorescence.
- Principles and applications of PCR and its variants.
- Museum specimen preparation and maintenance.

VI. Suggested Reading

- Culling CFA. 1969. *Handbook of Histological Techniques*. Butterworths.
- Lillie RD. 1965. *Histopathologic Techniques and Practical Histo-chemistry*. 3rd Ed. McGraw-Hill.
- Culling CFA. 2013. *Handbook of Histopathological and Histochemical Techniques: Including Museum Techniques* PDF, eBook (http://mbooknom.men/go/best.php?id=B01DRY52U8)

I. Course Title : Animal Oncology

II. Course Code : VPL-503

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with different types of neoplasms of domestic animals, their nature, cause, pathology and diagnosis.

V. Theory

Unit I

Tumour-Etiology, Carcinogens and oncogenesis, Nomenclature and classification, characteristics of benign and malignant tumours, Molecular mechanisms, Pathways of spread of tumors and tumor immunology

Unit II

Effects of tumour, Grading, Staging and laboratory diagnosis of tumours. Animal tumour models–experimental induction of neoplasms

Unit III

Pathology of different types of epithelial and connective tissue tumours with their characteristic identification features and epidemiology. Commonly encountered tumours of respiratory, haemopoietic, integumentary, musculoskeletal, gastrointestinal, hepatobiliary, uro-genital, nervous, ocular, ear and endocrine system.

VI. Practical

- Cytological diagnosis of tumours via impression smears and Fine Needle Aspiration Cytology.
- To study the gross and microscopic changes in different types of neoplasms.

VII. Suggested Reading

- Meuten DJ. 2016. *Tumors in Domestic Animals*. 5th Ed. Wiley-Blackwell

I. Course Title : Clinical Pathology
II. Course Code : VPL 504
III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with clinical alterations in blood, urine, CSF and other body fluids due to different diseases.

V. Theory

Unit I

Study of changes in blood/ plasma/ serum including biochemical profile for organ function tests, Cytological examination and examination of urine, Faeces, Cerebrospinal fluid and biopsy specimens and their interpretation.

VI. Practical

Analysis of clinical samples (blood/ serum/ plasma, urine, faeces, Biopsy samples (exfoliative/ FNAC) including biochemical profile for organ function tests in different disease conditions in animals/ poultry and their interpretations.

VII. Suggested Reading

- Amy C. Valenciano, Rick L. Cowell. 2013. *Cowell and Tyler's Diagnostic Cytology and Hematology of the Dog and Cat*, 4^{th} Ed, Elsevier
- Benzamin MM. 1985. *Outline of Veterinary Clinical Pathology*. 3rd Ed. Ludhiana, Kalyani Publishers.
- Coles EH. 1986. *Veterinary Clinical Pathology*. 4^{th} Ed, WB Saunders.
- Douglas J., Weiss, K and Jane Wardrop. 2010. *Schalm's Veterinary Haematology*, Wiley.

I. Course Title : Necropsy Procedures and Interpretations
II. Course Code : VPL 505
III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with necropsy procedures in large and small animals and study of PM lesions in different diseases and to educate the students about common veterolegal problems and technically simple and legal writing of PM reports.

V. Theory

Unit I

General knowledge about the laws relating to veterinary practice, professional discipline and professional etiquettes.

Unit II

Regulations dealing with diseases of animals in India regarding epidemiology, quarantine certificate, issue of soundness certificate, etc.

Unit III

Different manners/ modes of death such as criminal assault, Cruelty to animals, malicious poisoning, Snake bite, Death due to drowning, Lightning strokes during thunderstorms; Veterolegal wounds like electrocution, Gunshot wounds, Automobile accidents, and violent death; Legal implications in animals in above conditions, doping in horses, etc.

VI. Practical

- Detailed necropsy examination of various species of large and small animals including poultry, laboratory animals and wildlife**.** Systematic examination of brain, lungs, heart, endocrine glands, lymph nodes, liver, gastro-intestinal tract, urinary and genital systems for gross pathological and histopathological studies and correlation of the observations to diagnose the disease conditions.
- Necropsy case presentation and report writing/ protocol preparation. Collection, preservation and dispatch of morbid materials for diagnosis of viral, bacterial, protozoan, parasitic diseases, toxic/ poisoning and for histochemistry/ histopathology.

VII. Suggested Reading

- Albert C Strafuss.1988. *Necropsy: Procedures and Basic Diagnostic Methods for Practicing Veterinarians*, Charles C. Thomas Publisher Springfield
- Benjamin Lucio-Martinez and Jodi A Korich. 2010. *Illustrated guide to Poultry Necropsy and diagnosis*, Cornell University (https://www.slideshare.net/heshamkotb/illustrated-guide-to-poultry-necropsy-and-diagnosis)
- D Gopala Krishna Rao. 2005. *Textbook on necropsy and histopathological techniques*, 1st Ed. Academa
- Donald B Feldman and John Curtis Seely. 1988. *Necropsy Guide: Rodents and the Rabbit*, 1st Ed. CRC Press
- Gahlot AK, Sharma SN and Tanwar RA. 2003. *Veterinary Jurisprudence*. 5th Ed. NBS Publishers, Bikaner.
- John M King, David C Dodd and Lois Roth. 2006. *The Necropsy Book,* Fifth Edition, C L Davis Foundation
- Jones TC and Gleiser CA. 1954. *Veterinary Necropsy Procedures*. JB Lippincott
- Lincoln PJ and Thomson J. 1998. *Forensic DNA Profiling Protocols*. Humana Press.
- Majó Masferrer, Natàlia, Dolz Pascual, Roser and Shivaprasad HL. 2011. *Atlas of Avian Necropsy: Macroscopic Diagnosis Sampling,* SERVET Publishers
- Rudin N and Inman K. 2002. *An Introduction to Forensic DNA Analysis*. CRC Press

I. Course Title : Necropsy Conference

II. Course Code : VPL 506

III. Credit Hours : 0+1

IV. Aim of the course

To promote self learning of the students in different necropsy procedures of animals including poultry and description of post-mortem lesions in different diseases/ disease conditions.

V. Practical

- Continuous assessment of students on detailed necropsy examination of various species of large and small animals including poultry; Necropsy associated cytological examinations; Systematic examination of different organs for morphologic description of gross lesions; gross photography; Collection of tissues for histopathology and based on nature of gross lesions, if possible further collection for investigation of viral/ bacterial/ protozoan/ fungal/ parasitic diseases/ toxic or poisoning, etc.
- Morphologic description of microscopic lesions; microscopic photography; correlation of gross and microscopic observations with the results of other parallel investigations to diagnose the disease conditions; presentation of select case(s) in the monthly seminars followed by report writing and final morphologic/ etiologic diagnosis, classification and preservation of microscopic slides.

VI. Suggested Reading

- Albert C Strafuss. 1988. *Necropsy: Procedures and Basic Diagnostic Methods for Practicing Veterinarians*, Charles C. Thomas Publisher Springfield.
- Benjamin Lucio-Martinez and Jodi A Korich. 2010. *Illustrated guide to Poultry Necropsy and diagnosis,* Cornell University (https://www.slideshare.net/heshamkotb/illustrated-guide-to-poultry-necropsy-and-diagnosis)
- D Gopala Krishna Rao. 2005. *Textbook on necropsy and histopathological techniques,* 1st Ed. Academa.
- Donald B Feldman, John Curtis Seely. 1988. *Necropsy Guide: Rodents and the Rabbit*, 1st Ed. CRC Press.
- Jones TC and Gleiser CA. 1954. *Veterinary Necropsy Procedures*. JB Lippincott.
- John M King, David C Dodd and Lois Roth. 2006. *The Necropsy Book*, Fifth Edition, C L Davis Foundation.
- Majó Masferrer, Natàlia, Dolz Pascual, Roser and Shivaprasad HL. 2011. *Atlas of Avian Necropsy: Macroscopic Diagnosis Sampling*, SERVET Publishers.

I. Course Title : Systemic Pathology

II. Course Code : VPL 507

III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about different disease conditions of haemopoietic, circulatory, respiratory, digestive, urinary and genital systems, nervous, musculoskeletal, endocrine glands and special senses.

V. Theory

Unit I

Advanced study of pathological conditions in relation to their etiology, Pathology and pathogenesis including examples of specific infectious or non-infectious diseases affecting cardiovascular (heart, blood vessels and lymph vessels), Respiratory (nasal cavity, Larynx, Trachea, Bronchi, Lungs and pleura) and haemopoietic (bone marrow, blood, spleen, lymph node) systems.

Unit II

Advanced study of pathological conditions in relation to their etiology, Pathology and pathogenesis including examples of specific infectious or non-infectious diseases affecting different organs of digestive (buccal cavity, pharynx, oesophagus, stomach and intestines), Urinary (kidneys, ureter, urinary bladder and urethra) and genital (male and female organs including mammary gland) systems.

Unit III

Advanced study of pathological conditions in relation to their etiology, Pathology and pathogenesis including examples of specific infectious or non-infectious diseases affecting different organs of nervous (brain and spinal cord), endocrine (pituitary, thyroid, parathyroid, pancreas) musculo-skeletal systems (muscles and bones) and organs of special senses (eye, ear), skin and its appendages (hoof, tail).

VI. Practical

- To study the morphologic description of lesions and nomenclature of a morphologic diagnosis based on gross and/ or microscopic lesions in variety of organs in the preserved specimens/ slides.
- Continuous assessment of students for their skills in the morphologic description of lesions and nomenclature of a morphologic diagnosis based on gross and/ or microscopic lesions in variety of organs during post-mortem examination of domestic animals followed by interaction in the student seminars/ group discussions.

VII. Suggested Reading

- Grant Maxie. 2015. Jubb, Kennedy & Palmer's *Pathology of Domestic Animals*, 6th Ed. Saunders Ltd.
- Vegad JL and Madhu Swamy. 2010. *A text book of Veterinary Systemic Pathology*, 2nd Ed. Publisher IDBC, Lukhnow

I. Course Title : Pathology of Infectious Diseases of Domestic Animals

II. Course Code : VPL 508

III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about important infectious disease conditions of domestic animals.

V. Theory

Unit I

Study of etiology, Pathology and pathogenesis of various viral diseases-Foot and mouth disease, Vesicular stomatitis, Vesicular exanthema, Vesicular disease, Rinderpest, Bovine viral diarrhoea-Mucosal disease, Bovine malignant catarrhal fever, Infectious bovine rhinotracheitis, Parainfluenza-3, Bovine respiratory syncytial virus infection, Pox diseases, Blue tongue, Contagious ecthyma, PPR, Rabies, Canine distemper, Parvovirus infections, Infectious canine hepatitis, Pseudorabies, Classical swine fever, Swine and Equine influenza, Equine infectious anaemia, African horse sickness, Equine viral arteritis, Equine viral encephalomyelitis, Equine herpesvirus infections, Papillomatosis, Rift Valley fever, Japanese encephalitis, Ovine encephalomyelitis (Louping ill) and Prion diseases.

Unit II

Study of etiology, pathology and pathogenesis of various bacterial diseases-Tuberculosis, Johne's disease, Actinobacillosis, Actinomycosis, Brucellosis, Listeriosis, Pasteurellosis, Leptospirosis, Anthrax, Clostridial group of diseases, Streptococcal and Staphylococcal infections, Campylobacter infections, Swine erysipelas, Glasser's disease, Foot rot, Colibacillosis and Salmonellosis, Glanders, Melioidosis, Nocardiosis, Cutaneous strepthricosis, Corynebactrium infections, Chlamydial and Mycoplasma infections.

Unit III

Study of etiology, Pathology and pathogenesis of various fungal, Rickettsial and parasitic diseases-Aspergillosis, Blastomycosis, Coccidioidomycosis, Histoplasmosis, Epizootic lymphangitis, Rhinosporidiosis, Sporotrichosis, Candidiasis, Crytococcosis, Dermatomycoses;Diseases due to commonly occurring mycotoxins; Important rickettsial diseases-Q-fever, Heart water disease, Ehrlichiosis, Anaplasmosis, Haemobartonellosis; Important protozoan diseases-Coccidiosis, Toxoplasmosis, Babesiosis, Theilariosis, Cryptosporidiosis, Trypanosomiasis and Pathology of important diseases caused by helminths.

VI. Practical

Morphologic description of lesions based on gross and/ or microscopic lesions and the study of their correlation with a specific disease in the preserved specimens/ slides.

VII. Suggested Reading

- Jones TC, Hunt RD & King NW. 1997. *Veterinary Pathology*. Blackwell Publishing.
- Grant Maxie. 2015. Jubb, Kennedy & Palmer's *Pathology of Domestic Animals*, 6th Ed. Saunders Ltd.
- Gary Procop and Bobbi Pritt. 2014. *Pathology of Infectious Diseases*, 1st Ed. Saunders

I. Course Title : Toxicopathology

II. Course Code : VPL 509

III. Credit Hours : 2+1

IV. Aim of the course

To teach student about toxicity in livestock due to plants and extraneous poisons.

V. Theory

Unit I

Introduction, classification and mode of action of different poisons.

Unit II

Study of pathogenesis, symptoms, gross and microscopic pathology of diseases caused by toxic plants, Organic and inorganic poisons commonly taken or administered maliciously to different species of domestic animals.

Unit III

Various regulatory bodies and regulatory processes, Protocols in conducting toxicopathological trials; Chronology for conducting preclinical toxicology. OECD-

Good Laboratory Practices, Toxicopathological profile including battery of tests for pharmaceutical/ toxic agents.

Unit IV

In-vitro and *In vivo* models for toxicity studies and evaluation parameters.

VI. Practical

- To study gross and histopathological alterations as a result of ingestion of toxic plants and extraneous poisons in domestic animals.
- Assignments on commonly occurring toxic plants of the region; Diagnosis of commonly taken or maliciously administered poisonous substances.

VII. Suggested Reading

- Jones TC, Hunt RD and King NW. 1997. *Veterinary Pathology*. Blackwell Publishing.

I. Course Title : Avian Pathology

II. Course Code : VPL 510

III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about the different disease conditions of poultry.

V. Theory

Unit I

Avian inflammation and immunology, Study of etio-pathology, symptoms, transmission, and diagnosis of infectious diseases of chickens, turkeys, ducks and other birds caused by Bacteria: Salmonella, *Escherichia coli* and Clostridial infections, Infectious coryza, Fowl cholera, Tuberculosis and Spirochaetosis; Chlamydial and Mycoplasmal infections; Viruses: Ranikhet disease, Infectious bursal disease, Infectious bronchitis, Infectious laryngotracheitis, Marek's disease, Leukorsarcoma group of diseases, Reticuloendotheliosis, Fowl pox, Avian influenza, Avian encephalomyelitis, Inclusion body hepatitis, Hydropericardium syndrome, Egg drop syndrome-76, Chicken infectious anaemia, Avian nephritis, Reovirus infections- Viral arthritis and Infectious stunting syndrome, Duck plague, Duck viral hepatitis, Coronaviral enteritis and Haemorrhagic enteritis of turkeys: Fungi and mycotoxins; Parasites-Coccidiosis, Histomoniasis, Round worm and Tape worm infections; Ecto-parasites of birds.

Unit II

Study of etio-pathology, clinical symptoms, and diagnosis of nutritional deficiencies - Vitamin and Mineral deficiencies; Metabolic diseases-Ascites, Gout, Fatty liver and kidney syndrome, Fatty liver haemorrhagic syndrome, Cage layer fatigue, etc.; Miscellaneous conditions of poultry-Heat stress, Blue comb, Breast blister, Bumble foot, Cannibalism, False layer, Internal layer, Pendulous crop, Round heart disease etc.

Unit III

Emerging and re-emerging diseases of poultry: Introduction to an emerging and a re-emerging pathogen, mechanisms of poultry pathogen's emergence, co-evolution of poultry pathogens with their vaccines and medications, common diseases of poultry susceptible to point mutations and their pathology.

VI. Practical

- Necropsy examination of the different species of poultry; morphologic description of gross and/ or microscopic lesions in the preserved specimens/ slides.
- Continuous assessment of students for their skills in the diagnosis of gross lesions in different organs of various systems during post-mortem examination of poultry. Preparation of histopathology slides on the select cases followed by interaction in the student seminars/ group discussions.

VII. Suggested Reading

- Saif YM, Barnes FJ, Glisson JR, Fadly AM, Mc Dougald LR & Swayne D. 2008. *Diseases of Poultry*. 12th Ed. Blackwell Publishing.
- Randall CJ. 1984. *A Colour Atlas of Diseases of the Domestic Fowl and Turkey,* Mosby International.
- Majó Masferrer, Natàlia, Dolz Pascual, Roser and Shivaprasad HL. 2011. *Atlas of Avian Necropsy: Macroscopic Diagnosis Sampling*, SERVET Publishers.
- Benjamin Lucio-Martinez and Jodi A Korich. 2010. *Illustrated guide to Poultry Necropsy and diagnosis*, Cornell University (https://www.slideshare.net/heshamkotb/illustrated-guide-to-poultry-necropsy-and-diagnosis)

I. Course Title : Pathology of Wild/ Zoo and Aquatic Animal Diseases

II. Course Code : VPL 511

III. Credit Hours : 2+1

IV. Aim of the course

To teach the pathology and diagnosis of different disease conditions of wild and aquatic animals particularly fish.

V. Theory

Unit I: Wild/ Zoo Animal diseases

Etiology, transmission, gross and microscopic pathology of some commonly occurring infectious diseases of wild animals: West Nile fever, Rabies, Foot and mouth disease, Pox, Kyasanaur forest disease, Infectious hepatitis virus, Infectious feline peritonitis, Anthrax, Tuberculosis, Colibacillosis, Clostridial infections Trypanosomosis, Babesiosis, Theileriosis; Etiology, gross and microscopic pathology of commonly occurring non-infectious diseases of Wild/ Zoo animals.

Unit II: Infectious diseases of fish

Study of etiology, gross and microscopic pathology of Bacterial diseases- Bacterial cold water disease, Bacterial fin disease, Fill rot, Furunculosis, Aeromonas septicemia, Epizootic ulcerative syndrome, Yersiniosis, Pseudomoniasis, Alteromoniasis, Pasteurellosis, Enteric septicemia of catfish, Edwardsiellosis, Vibriosis, Streptococcosis, Bacterial kidney disease, Mycobacteriosis, Nocardiosis, Epitheliocystis: Salmonid rickettsialsepticaemia, Columnaris disease; Viral diseases-Spring viremia of carp, Infectious pancreatic necrosis, Viral hemorrhagic septicaemia, Koi herpes virus disease, Infectious spleen and kidney necrosis, Carp pox, Virus nervous necrosis, Lymphocystis disease, Infectious salmon anemia, Salmon alpha virus infections, Infectious hematopoietic necrosis, Herpes viral hematopoeitic necrosis, Chinese grass carp reovirusdisease, Viral hemorrhagic necrosis, Epizootic hemorrhagic necrosis; Fungal diseases- Saprolegniasis, Branchiomycosis (Gill rot), Ichthyosporidiosis, Exophiala infection, Aphanomyces and Fusarium infection; Parasitic and Protozoal diseases-Ich or White spot disease, Costiasis, Trichodiniasis, Velvet disease, Coral fish disease, Epistylis, Red sore disease, Glossatella, Myxosporidiosis, Whirling disease, Microsporidiosis (Glugea, Pleistophora, Loma), Coccidiosis, Proliferative kidney disease, Cryptosporidiosis.

Unit III: Other diseases of Fish

Nutritional diseases-Nutritional deficiency of protein, lipid, carbohydrate, vitamins and minerals; Neoplastic conditions- Melanoma in Platyfish/ Swordtail hybrids, Hepatoma and hepatocellular carcinoma in rainbow trout, Stomatopapilloma of eels (Cauliflower disease), Papilloma of the brown bullhead, Lip Fibroma (Fibropapilloma) of Angel fish, Dermal fibrosarcomas of walleye pike, Lymphosarcoma of pike, Schwannoma/ Neurofibromas of the bicoloured damselfish; Environmental stress-Gas bubble disease, Acidosis/ Alkalosis, Thermal shock, Sun burn disease, Anoxia, Increased in dissolved CO_2 or H_2S or Ammonia concentration in water, Increased in turbidity of pond water, Algal toxicosis disease.

VI. Practical

Post-mortem examination of wild animals including wild birds. Study of gross and microscopic lesions of important infectious and non-infectious diseases of fish and wild animals

VII. Suggested Reading

- Arora BM. 1984. *Wildlife Diseases in India*. Periodical Expert Book Agency.
- Fowler ME. 1978. *Zoo and Wild Animal Medicine.* WB Saunders. Roberts RJ. 1979. *Fish Pathology*. Bailliere Tindall, London

I. Course Title : Pathology of Laboratory Animal Diseases

II. Course Code : VPL 512

III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about pathology and diagnosis of different disease conditions of laboratory animals.

V. Theory

Unit I

Etiology, transmission, gross and microscopic pathology of some commonly occurring diseases of Rabbits: Pasteurellosis, Bordetellosis, Colibacillosis, Tyzzer’s disease, Staphyloccal infections, Venereal spirochetosis, (rabbit syphilis, cuniculosis), Proliferative ileotyphilitis, Salmonellosis, Tularemia, Clostridium infections, Myxomatosis, Rabbit fibroma/ shope fibroma, Rabbit papillomatosis, Viral hemorrhagic disease, Coccidiosis, Enephalotozoonoses, Baylisascarisprocyonis, Cestode, Mites, Fleas and lice, miscellaneous and neoplastic diseases of rabbits.

Unit II

Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Rats: Bacterial diseases-Staphylococcal dermatitis, Pasteurellosis, Streptococcal diseases, Helicobacter infection, CAR bacillus, Mycoplasma pulmonis, Pseudotuberculosis (corynobacteriosis), Tyzzers disease, Salmonellosis, Rat bite fever; Viral diseases- Rat theilo virus (RTV-1), Parvovirus, coronavirus, pneumonia virus of mice, Hantaan virus, Sendai virus, Reovirus-3, Protozoan diseases

(Trichomonads, Chilomastixbettencorti, Spironucleusmuris, Giardia muris, Rat sarcodines, Rat enteric coccidian), Arthropods (Mesostigmated mites, lice of rats), Helminths (rat pinworms, Hymenolepid tapeworm, Cestodes with a rat intermediate host, rat threadworms); fungal disease (*Pneumocystis carinii*), other miscellaneous and neoplastic diseases

Unit III

Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Mice: Bacterial diseases- Helicobacter infection, Pasteurellosis, Staphylococcal furunculosis, *Mycoplasma pulmonis*, Cilia associated respiratory bacillus, *Corynebacterium bovis*, *Pseudomonas aeruginosa*, *Citrobacter rodentium*, Tyzzer's disease, Salmonellosis; Viral diseases- Mouse norovirus, Mouse hepatitis virus, Mouse encephalomyelitis virus, Epizootic diarrhoea of infant mice, Parvovirus, Murine cytomegalovirus, Mouse adenovirus, Ectromelia virus, Lymphocytic choriomengitis virus, Pneumonia virus of mice, Lactate dehydrogenase elevating virus, Sendai virus, Mouse thymic virus, Mouse polyoma viruses, Reo-3 virus; Parasitic diseases-Pin worms, Fur mites of mice, Mange mites, Mesostigmatid mites, Lice of mice, Trichomonads, *Chilomastixbettencorti*, *Spironucleusmuris*, *Giardia muris,* Mouse sarcodines, Mouse enteric coccidian, Mouse parentral coccidian, Mouse sporozoans, Hymenolepid tapeworms, Encysted tape worm; Fungal disease (*Pneumocystis* pneumonia) and other miscellaneous and neoplastic diseases

Unit IV

Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Guinea pigs: Bacterial diseases- Antibiotic-induced enterotoxemia/ haemorrhagic typhlitis, *Bordetella* pneumonia, Streptococcal pneumonia, Cervical lymphadenitis, Pododermatitis, Mastitis, Tyzzer's disease, Salmonellosis; Viral diseases- Guinea pig cytomegalovirus, Adenovirus, Parainfluenza virus, Corona-like virus, Lymphocytic choriomeningitis virus; Parasitic diseases- Coccidia, Fur mites, Helminthes, Lice of guinea pigs, Mange mites, Cryptosporidiosis, Microsporidium parasites and other miscellaneous conditions

Unit V

Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Hamsters, Gerbills and primates

VI. Practical

Post-mortem examination of laboratory animals. Study of gross and microscopic lesions of important infectious and non-infectious diseases of laboratory animals

VII. Suggested Reading

- Beninchka K, Garner FM and Jones TC. 1978. *Pathology of Laboratory Animals.* Vols. I, II. Springer Verlag.

Course Outline-cum-Lecture Schedule for Master Degree Programme

I. Course Title : General Pathology
II. Course Code : VPL 501
III. Credit hours : 2+1

IV. Aim of the course

To acquaint the students with different types of degenerations, cell injuries caused by different types of irritants and inflammation

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction and principles of Pathology including genetic basis of disease	3
2.	Cellular responses to injury: Causes and mechanisms of reversible and irreversible cell injury; morphologic characteristics, significance and fate of various intracellular (lipids, glycogen, proteins) and extracellular (hyaline material, amyloid, fibrinoid change, gout) accumulations/ degenerations, endogenous and exogenous pigmentations, cell death (necrosis and apoptosis), pathologic calcifications and cellular adaptive changes	9
3.	Inflammation and repair: Introduction to inflammation, acute inflammation-cellular and molecular events including mediators and heat shock proteins of acute inflammation; cellular components, morphologic classification and outcomes of acute inflammation	5
4.	Chronic inflammation-causes, morphologic features and cellular components of chronic inflammation, healing and repair, systemic effects of inflammation	5
5.	Disturbances in circulation: Causes, mechanisms, morphologic features, significance and fate of hyperemia, oedema, haemorrhage, thrombosis, embolism, ischaemia, infarction and shock	6
6.	Immune mediated reactions: Introduction to autoimmunity and immune mediated diseases, mechanisms of hypersensitivity reactions.	4
Practical		
1.	To study the morphologic descriptions of lesions and nomenclature of a morphologic diagnosis based on gross and/ or microscopic lesions of variety of conditions (degenerations, infiltrations, pigmentations, necrosis, circulatory and growth disturbances and different types of inflammation) in the preserved specimens/ slides.	6
2.	Demonstration of post-mortem changes.	2
3.	Continuous assessment of students for their skills in the diagnosis of gross lesions during post-mortem examination of different tissues of domestic animals.	4

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
4.	Preparation of histopathology slides on the select cases followed by interaction in the student seminars/ group discussions.	4

I. Course Title : Techniques in Pathology

II. Course Code : VPL 502

III. Credit hours : 0+2

IV. Aim of the course

To acquaint the students with different techniques used frequently in Veterinary Pathology

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Practical		
1.	Basic histopathological techniques-Collection of tissues, fixation, processing, section cutting and H and E staining of tissue sections. Collection and fixation of tissues for scanning electron microscopy, transmission electron microscopy, histochemical, toxicological, bacteriological and virological examinations. Application of micrometryand special staining techniques. Demonstration of different inclusions, bacteria and fungi in tissues	10
2.	Principles of dark field, phase contrast and fluorescent microscopy; introduction to scanning electron microscopy and transmission electron microscopy	5
3.	Histochemical techniques for demonstration of fat, glycogen, connective tissue, mucopolysaccharides and common enzymes, pigments and minerals	7
4.	Cryosectioning and application of immunohistochemical techniques–immunoperoxidase and immunofluorescence	3
5.	Principles and applications of PCR and its variants	2
6.	Museum specimen preparation and maintenance	5

I. Course Title : Animal Oncology

II. Course Code : VPL 503

III. Credit hours : 1+1

IV. Aim of the course

To acquaint the students with different types of neoplasms of domestic animals, their nature, cause, pathology and diagnosis.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Tumour-Etiology, carcinogens and oncogenesis, nomenclature and classification, characteristics of benign and malignant tumours, molecular mechanisms, pathways of spread of tumors and tumor immunology	4
2.	Effects of tumour, grading and staging and laboratory diagnosis of tumours. Animal tumour models–experimental induction of neoplasms	4
3.	Pathology of different types of epithelial and connective tissue tumours with their characteristic identification features and epidemiology	2
4.	Tumours of respiratory, haemopoietic, integumentary, musculoskeletal, gastrointestinal, hepatobiliary, uro-genital, nervous, ocular, ear and endocrine system	6
Practical		
1.	Cytological diagnosis of tumours via impression smears and Fine Needle Aspiration Cytology.	8
2.	To study the gross and microscopic changes in different types of neoplasms.	8

I. Course Title : Clinical Pathology

II. Course Code : VPL 504

III. Credit hours : 1 + 1

IV. Aim of the course

To acquaint the students with clinical alterations in blood, urine, CSF and other body fluids due to different diseases.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Study of changes in blood/ plasma/ serum including biochemical profile for organ function tests	8
2.	Cytological examination and examination of urine, faeces, cerebrospinal fluid and biopsy specimens and their interpretation	8
Practical		
1.	Analysis of clinical samples (blood/ serum/ plasma) and their interpretations	4
2.	Analysis of clinical samples (urine) and their interpretations	2
3.	Analysis of clinical samples (faeces) and their interpretations	2
4.	Analysis of biopsy samples (exfoliative/ FNAC) and their interpretations	4
5.	Analysis of biochemical profile for organ function tests in different disease conditions in animals	4

I. Course Title : Necropsy Procedures and Interpretations

II. Course Code : VPL 505

III. Credit hours : 0+1

IV. Aim of the course

To acquaint the students with necropsy procedures in large and small animals and study of PM lesions in different diseases.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Practical		
1.	Detailed necropsy examination of various species of large and small animals including poultry, laboratory animals and wildlife.	4
2.	Systematic examination of brain, lungs, heart, endocrine glands, lymph nodes, liver, gastro-intestinal tract, urinary and genital systems for gross pathological and histopathological studies and correlation of the observations to diagnose the disease conditions.	8
3.	Necropsy case presentation and report writing/ protocol preparation. Collection, preservation and dispatch of morbid materials for diagnosis of viral, bacterial, protozoan, parasitic diseases, toxic/ poisoning and for histochemistry/ histopathology.	4

I. Course Title : Necropsy Conference

II. Course Code : VPL 506

III. Credit hours : 0 + 1

IV. Aim of the course

To promote self-learning of the students in different necropsy procedures of animals including poultry and description of post-mortem lesions in different diseases/ disease conditions.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Practical		
1.	Continuous assessment of students on detailed necropsy examination of various species of large and small animals including poultry; necropsy associated cytological examinations; systematic examination of different organs for morphologic description of gross lesions; gross photography; collection of tissues for histopathology and based on nature of gross lesions, if possible further collection for investigation of viral/ bacterial/ protozoan/ fungal/ parasitic diseases/ toxic or poisoning, etc.	8
2.	Morphologic description of microscopic lesions; microscopic photography; correlation of gross and microscopic observations with the results of other parallel investigations to diagnose the disease conditions; presentation of select case(s) in the monthly	

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
	seminars followed by report writing and final morphologic/ etiologic diagnosis, classification and preservation of microscopic slides.	8

I. Course Title : Systemic Pathology

II. Course Code : VPL 507

III. Credit hours : 2 + 1

IV. Aim of the course

To teach the students about different disease conditions of haemopoitic, circulatory, respiratory, digestive, urinary and genital systems, nervous, musculoskeletal, endocrine glands and special senses.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Advanced study of pathological conditions in relation to their etiology, pathology and pathogenesis including examples of specific infectious or non-infectious diseases affecting cardiovascular (heart, blood vessels and lymph vessels) and respiratory (nasal cavity, larynx, trachea, bronchi, lungs and pleura).	8
2.	Advanced study of pathological conditions in relation to their etiology, pathology and pathogenesis including examples of specific infectious or non-infectious diseases affecting digestive (buccal cavity, pharynx, oesophagus, stomach and intestines) and haemopoietic (bone marrow, blood, spleen, lymph node) systems.	8
3.	Advanced study of pathological conditions in relation to their etiology, pathology and pathogenesis including examples of specific infectious or non-infectious diseases affecting urinary (kidneys, ureter, urinary bladder and urethra) and genital (male and female organs including mammary gland) systems.	8
4.	Advanced study of pathological conditions in relation to their etiology, pathology and pathogenesis including examples of specific infectious or non-infectious diseases affecting nervous (brain and spinal cord), endocrine (pituitary, thyroid, parathyroid, pancreas) musculo-skeletal systems (muscles and bones) and organs of special senses (eye, ear), skin and its appendages (hoof, tail).	8
Practical		
1.	To study the morphologic description of lesions and nomenclature of a morphologic diagnosis based on gross and/ or microscopic lesions in variety of organs in the preserved specimens/ slides.	8
2.	Continuous assessment of students for their skills in the morphologic description of lesions and nomenclature of a morphologic diagnosis based on gross and/ or microscopic lesions in variety of organs during post-mortem examination of domestic animals followed by interaction in the student seminars/ group discussions.	8

I. Course Title : Pathology of infectious diseases of domestic animals

II. Course Code : VPL 508

III. Credit hours : 2 + 1

IV. Aim of the course

To teach the students about important infectious disease conditions of domestic animals.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Study of etiology, pathology and pathogenesis of various viral diseases- Foot and mouth disease, Vesicular stomatitis, Vesicular exanthema, Vesicular disease, Rinderpest, Bovine viral diarrhoea-Mucosal disease, Bovine malignant catarrhal fever, Infectious bovine rhinotracheitis, Parainfluenza-3, Bovine respiratory syncytial virus infection, Pox diseases, Blue tongue, Contagious ecthyma, PPR	7
2.	Study of etiology, pathology and pathogenesis of various viral diseases- Rabies, Canine distemper, Parvovirus infections, Infectious canine hepatitis, Pseudorabies, Classical swine fever, Swine and Equine influenza, Equine infectious anaemia, African horse sickness, Equine viral arteritis, Equine viral encephalomyelitis, Equine herpesvirus infections, Papillomatosis, Rift Valley fever, Japanese encephalitis, Ovine encephalomyelitis (Louping ill) and Prion diseases.	5
3.	Study of etiology, pathology and pathogenesis of various bacterial diseases- Tuberculosis, Johne's disease, Actinobacillosis, Actinomycosis, Brucellosis, Listeriosis, Pasteurellosis, Leptospirosis, Anthrax, Clostridial group of diseases, Streptococcal and Staphylococcal infections.	5
4.	Study of etiology, pathology and pathogenesis of various bacterial diseases- Campylobacter infections, Swine erysipelas, Glasser's disease, Foot rot, Colibacillosis and Salmonellosis, Glanders, Melioidosis, Nocardiosis, Cutaneous strepthricosis, Corynebactrium infections, Chlamydial and Mycoplasma infections.	5
5.	Study of etiology, pathology and pathogenesis of various fungal diseases-Aspergillosis, Blastomycosis, Coccidioidomycosis, Histoplasmosis, Epizootic lymphangitis, Rhinosporidiosis, Sporotrichosis, Candidiasis, Crytococcosis, Dermatomycoses; Diseases due to commonly occurring mycotoxins	5
6.	Important rickettsial diseases- Q-fever, Heart water disease, Ehrlichiosis, Anaplasmosis, Haemobartonellosis; Important protozoan diseases-Coccidiosis, Toxoplasmosis, Babesiosis, Theilariosis, Cryptosporidiosis, Trypanosomiasis and Pathology of important diseases caused by helminthes	5
Practical		
1.	Morphologic description of lesions based on gross and/ or microscopic lesions and the study of their correlation with a specific disease in the preserved specimens/ slides.	16

I. Course Title : Toxicopathology
II. Course Code : VPL 509
III. Credit Hours : 2 + 1

IV. Aim of the course

To teach student about toxicity in livestock due to plants and extraneouspoisons.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction, classification and mode of action of different poisons.	4
2.	Study of pathogenesis, symptoms, gross and microscopic pathology of diseases caused by toxic plants, organic and inorganic poisons commonly taken or administered maliciously to different species of domestic animals	12
3.	Various regulatory bodies and regulatory processes, porticos in conducting toxicopathological trials. Chronology for conducting preclinical toxicology. OECD-Good Laboratory Practices, toxicopathological profile including battery of tests for pharmaceutical/ toxic agents	8
4.	*In-vitro* and *in-vivo* models for toxicity studies and evaluation parameters	8
Practical		
1.	To study gross and histopathological alterations as a result of ingestion of toxic plants and extraneous poisons in domestic animals.	8
2.	Assignments on commonly occurring toxic plants of the region; Diagnosis of commonly taken or maliciously administered poisonous substances.	8

I. Course Title : Avian Pathology
II. Course Code : VPL 510
III. Credit hours : 2 + 1

IV. Aim of the course

To teach the students about the different disease conditions of poultry.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Avian inflammation and immunology, Study of etio-pathology, symptoms, transmission, and diagnosis of infectious diseases of chickens, turkeys, ducks and other birds caused by Viruses: Ranikhet disease, Infectious bursal disease, Infectious bronchitis, Infectious laryngotracheitis, Marek's disease, Leukorsarcoma group of diseases, Reticuloendotheliosis, Fowl pox, Avian influenza, Avian encephalomyelitis, Inclusion body hepatitis, Hydropericardium syndrome, Egg drop syndrome-76, Chicken infectious anaemia, Avian nephritis,	

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
	Reovirus infections- Viral arthritis and Infectious stunting syndrome, Duck plague, Duck viral hepatitis, Coronaviral enteritis and Haemorrhagic enteritis of turkeys	12
2.	Study of etio-pathology, symptoms, transmission, and diagnosis of infectious diseases of chickens, turkeys, ducks and other birds caused by Bacteria: *Salmonella*, *Escherichia coli* and Clostridial infections, Infectious coryza, Fowl cholera, Tuberculosis and Spirochaetosis; Chlamydial and Mycoplasmal infections; Fungi and mycotoxins; Parasites-Coccidiosis, Histomoniasis, Round worm and Tape worm infections; Ecto-parasites of birds	10
3.	Study of etio-pathology, clinical symptoms, and diagnosis of nutritional deficiencies -Vitamin and Mineral deficiencies; Metabolic diseases-Ascites, Gout, Fatty liver and kidney syndrome, Fatty liver haemorrhagic syndrome, Cage layer fatigue, etc.; Miscellaneous conditions of poultry-Heat stress, Blue comb, Breast blister, Bumble foot, Cannibalism, False layer, Internal layer, Pendulous crop, Round heart disease, etc.	6
4.	Emerging and re-emerging diseases of poultry: Introduction to an emerging and a re-emerging pathogen, mechanisms of poultry pathogen's emergence, co-evolution of poultry pathogens with their vaccines and medications, common diseases of poultry susceptible to point mutations and their pathology	4
Practical		
1.	Necropsy examination of the different species of poultry; morphologic description of gross and/ or microscopic lesions in the preserved specimens/ slides.	8
2.	Continuous assessment of students for their skills in the diagnosis of gross lesions in different organs of various systems during post-mortem examination of poultry. Preparation of histopathology slides on the select cases followed by interaction in the student seminars/ group discussions.	8

I Course Title : Pathology of Wild/ Zoo and Aquatic Animal Diseases

II. Course Code : VPL 511

III. Credit hours : 2 + 1

IV. Aim of the course

To teach the pathology and diagnosis of different disease conditions of wild and aquatic animals particularly fish

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Wild/ Zoo Animal diseases: Etiology, transmission, gross and microscopic pathology of commonly occurring infectious diseases of wild animals: West Nile fever, Rabies, Foot and mouth disease, Pox,	

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
	Kyasanaur forest disease, Infectious hepatitis virus, Infectious feline peritonitis, Anthrax, Tuberculosis, Colibacillosis, Clostridial infections Trypanosomosis, Babesiosis, Theileriosis; Etiology, gross and microscopic pathology of commonly occurring non-infectious diseases of Wild/ Zoo animals.	7
2.	Infectious diseases of Fish: Study of etiology, gross and microscopic pathology of Viral diseases-Spring viremia of carp, Infectious pancreatic necrosis, Viral hemorrhagic septicaemia, Koi herpes virus disease, Infectious spleen and kidney necrosis, Carp pox, Virus nervous necrosis, Lymphocystis disease, Infectious salmon anemia, Salmon alpha virus infections, Infectious hematopoietic necrosis, Herpes viral hematopoeitic necrosis, Chinese grass carp reovirus disease, Viral hemorrhagic necrosis, Epizootic hemorrhagic necrosis; Fungal diseases- Saprolegniasis, Branchiomycosis (Gill rot), Ichthyosporidiosis, Exophiala infection, Aphanomyces and Fusarium infection.	7
3.	Infectious diseases of Fish: Study of etiology, gross and microscopic pathology of Bacterial diseases- Bacterial cold water disease, Bacterial fin disease, Fill rot, Furunculosis, Aeromonas septicemia, Epizootic ulcerative syndrome, Yersiniosis, Pseudomoniasis, Alteromoniasis, Pasteurellosis, Enteric septicemia of catfish, Edwardsiellosis, Vibriosis, Streptococcosis, Bacterial kidney disease, Mycobacteriosis, Nocardiosis, Epitheliocystis: Salmonidrickettsialsepticaemia, Columnaris disease; Parasitic and Protozoal diseases-Ich or White spot disease, Costiasis, Trichodiniasis, Velvet disease, Coral fish disease, Epistylis, Red sore disease, Glossatella, Myxosporidiosis, Whirling disease, Microsporidiosis (Glugea, Pleistophora, Loma), Coccidiosis, Proliferative kidney disease, Cryptosporidiosis.	6
4.	Other diseases of Fish: Nutritional diseases- Neoplastic conditions- Melanoma in Platyfish/ Swordtail hybrids, Hepatoma and hepatocellular carcinoma in rainbow trout, Stomatopapilloma of eels (Cauliflower disease), Papilloma of the brown bullhead, Lip Fibroma (Fibropapilloma) of Angel fish, Dermal fibrosarcomas of walleye pike, Lymphosarcoma of pike, Schwannoma/ Neurofibromas of the bicoloured damselfish.	6
5.	Other diseases of Fish: Nutritional diseases- Nutritional deficiency of protein, lipid, carbohydrate, vitamins and minerals; Environmental stress- Gas bubble disease, Acidosis/ Alkalosis, Thermal shock, Sun burn disease, Anoxia, Increased in dissolved CO_2 or H_2S or Ammonia concentration in water, Increased in turbidity of pond water, Algal toxicosis disease.	6
Practical		
1.	Post-mortem examination of wild animals including wild birds. Study of gross and microscopic lesions of important infectious and non-infectious diseases of fish and wild animals.	16

I. Course Title : Pathology of Laboratory Animal Diseases

II. Course Code : VPL 512

III. Credit hours : 2 + 1

IV. Aim of the course

To teach the students about pathology and diagnosis of different disease conditions of laboratory animals.

Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Etiology, transmission, gross and microscopic pathology of some commonly occurring diseases of Rabbits: Pasteurellosis, Bordetellosis, Colibacillosis, Tyzzer's disease, Staphyloccal infections, Venereal spirochetosis, (rabbit syphilis, cuniculosis), Proliferative ileotyphilitis, Salmonellosis, Tularemia, Clostridium infections, Myxomatosis, Rabbit fibroma/ shope fibroma, Rabbit papillomatosis, Viral hemorrhagic disease, Coccidiosis, Enephalotozoonoses, Baylisascarisprocyonis, Cestode, Mites, Fleas and lice, miscellaneous and neoplastic diseases of rabbits	5
2.	Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Rats: Bacterial diseases-Staphylococcal dermatitis, Pasteurellosis, Streptococcal diseases, Helicobacter infection, CAR bacillus, Mycoplasma pulmonis, Pseudotuberculosis (corynobacteriosis), Tyzzers disease, Salmonellosis, Rat bite fever; Protozoan diseases (Trichomonads, *Chilomastix bettencorti*, Spironucleusmuris, Giardia muris, Rat sarcodines, Rat enteric coccidian), Arthropods (Mesostigmated mites, lice of rats), Helminths (rat pinworms, Hymenolepid tapeworm, Cestodes with a rat intermediate host, rat threadworms).	5
3.	Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Rats: Viral diseases- Rat theilo virus (RTV-1), Parvovirus, coronavirus, pneumonia virus of mice, Hantaan virus, Sendai virus, Reovirus-3 fungal disease (*Pneumocystis carinii*), other miscellaneous and neoplastic diseases	5
4.	Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Mice: Bacterial diseases- Helicobacter infection, Pasteurellosis, Staphylococcal furunculosis, *Mycoplasma pulmonis*, Cilia associated respiratory bacillus, *Corynebacterium bovis*, *Pseudomonas aeruginosa*, Citrobacter rodentium, Tyzzer's disease, Salmonellosis; Parasitic diseases-Pin worms, Fur mites of mice, Mange mites, Mesostigmatid mites, Lice of mice, Trichomonads, *Chilomastix bettencorti*, *Spironucleus muris*, *Giardia muris,* Mouse sarcodines, Mouse enteric coccidian, Mouse parentral coccidian, Mouse sporozoans, Hymenolepid tapeworms, Encysted tape worm	5
5.	Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Mice: Viral diseases- Mouse norovirus, Mouse hepatitis virus, Mouse encephalomyelitis virus, Epizootic diarrhoea of infant mice, Parvovirus, Murine cytomegalovirus, Mouse adenovirus, Ectromelia virus, Lymphocytic choriomengitis virus, Pneumonia virus of mice, Lactate dehydrogenase elevating virus,	

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
	Sendai virus, Mouse thymic virus, Mouse polyoma viruses, Reo-3 virus; Fungal disease (*Pneumocystis* pneumonia) and other miscellaneous and neoplastic diseases	5
6.	Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Guinea pigs: Bacterial diseases- Antibiotic-induced enterotoxemia/ haemorrhagic typhlitis, *Bordetella* pneumonia, Streptococcal pneumonia, Cervical lymphadenitis, Pododermatitis, Mastitis, Tyzzer's disease, Salmonellosis; Viral diseases- Guinea pig cytomegalovirus, Adenovirus, Parainfluenza virus, Corona-like virus, Lymphocytic choriomeningitis virus; Parasitic diseases- Coccidia, Fur mites, Helminthes, Lice of guinea pigs, Mange mites, Cryptosporidiosis, Microsporidium parasites and other miscellaneous conditions	5
7.	Etiology, transmission, gross and microscopic pathology of commonly occurring diseases of Hamsters, Gerbills and primates	2
Practical		
1.	Post-mortem examination of laboratory animals. Study of gross and microscopic lesions of important infectious and non-infectious diseases of laboratory animals.	16

Course Title with Credit Load
Ph.D. in Veterinary Pathology (VPL)

Course Code	Course Title	Credit Hours
VPL 601	Molecular and Ultrastructural Basis of Cell Injury*	2+1
VPL 602	Molecular Basis of Inflammation	1+1
VPL 603	Molecular Basis of Neoplasia	1+1
VPL 604	Immunopathology*	2+1
VPL 605	Advances in Diagnostic Pathology	1+2
VPL 606	Pathology of Nutritional and Metabolic Disturbances	2+1
VPL 607	Pathology of Important Emerging and Re-Emerging Diseases of Pets and Livestock	2+1
VPL 608	Research Methodology in Pathology*	1+0
VPL 609	Necropsy Conference I*	0+1
VPL 690	Special Problem	0+1
VPL 691	Doctoral Seminar-I*	1+0
VPL 692	Doctoral Seminar-II*	1+0
VPL 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Veterinary Pathology (VPL)

I. Course Title : Molecular and Ultrastructural Basis of Cell Injury
II. Course Code : VPL 601
III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about different molecular including ultrastructural changes in diseases conditions.

V. Theory

Unit I

Study of cells- cell morphology, interpretation of normal and abnormal cells.

Unit II

Overview of Cell injury, Targets of cell injury-Cell membranes, Aerobic respiration, structural proteins and enzymes and genetic apparatus of the cell; Mechanisms of cell injury-hypoxia, Injury by free radicals, Chemical injury, Infectious agents, other forms of cell injury-immune mediated reactions, Genetic derangements; Mechanisms of cell membrane damage; Mechanisms of DNA damage-base loss, Base modification, chemical modification, Replication errors, Inter-strand cross-links, DNA-protein cross-links, Strand breaks. Molecular and immunopathological changes associated with different types of cell injuries.

Unit III

Morphology of Reversible and irreversible cell injury with particular emphasis on ultra structural changes in the cells and organelles: Morphology of cell death-necrosis, Apoptosis and autolysis, Mechanism of apoptosis, Intracellular and extracellular accumulations, Pigment and tissue deposits, Consequences of cell injury Cellular adaptations-hyperplasia, Hypertrophy, Atrophy, Metaplasia and dysplasia.

Unit IV

Mechanism of other types of cell death, viz., Pyroptosis, Ferroptosis, Autophagy, ETOSIS, etc.

VI. Practical

Collection and preparation of specimens for electron microscopic studies. Interpretation of ultra-structural changes and their correlation with gross and histopathological findings

VII. Suggested Reading

- Selected articles from journals.

I. Course Title : Molecular Basis of Inflammation

II. Course Code : VPL 602

III. Credit Hours : 1+1

IV. Aim of the course

To teach the students about molecular mechanisms of inflammations.

V. Theory

Unit I

Cellular, molecular and immunopathological changes associated with different types of inflammation. Acute inflammation, Vascular events of acute inflammation, Cellular events in acute inflammation, Leucocyte-endothelial interactions, Leucocyte adhesion molecules, Endothelial adhesion molecule receptors, Leucocyte chemotactic factors, Microbicidal activity of leucocytes, Leucocyte activation.

Unit II

Plasma derived mediators of inflammation-Complement system, Kinin system, Coagulation system and Fibrinolytic system; Cell derived mediators of inflammation-vasoactive amines, lipid mediators, cytokines, chemokines, oxygen radicals and nitric oxide, Cellular components of inflammation, types of exudative inflammation.

Unit III

Chronic inflammation and its types, Elements of chronic inflammation, Healing and repair, Wound healing mediators and their functions, Repair of bone, Repair of nervous tissue and myocardium.

VI. Practical

Molecular alterations and their correlation with gross and microscopic inflammatory changes

VII. Suggested Reading

- Selected articles from journals.

I. Course Title : Molecular Basis of Neoplasia

II. Course Code : VPL 603

III. Credit Hours : 1+1

IV. Aim of the course

To teach the students about molecular mechanisms of neoplasia and diagnostic techniques.

V. Theory

Unit I

Tumour characteristics, differentiation and proliferation, molecular basis of cancer, tumour stromal interaction, molecular mechanisms of invasion and metastasis of tumours, molecular changes underlying tumour progression and heterogeneity, tumour biology and growth.

Unit II

Tumour genetics, immunohistochemical/ including markers associated tumour diagnosis.

Unit III

Application of cytological, histopathological, immunohistochemical and molecular techniques in diagnosis and prognosis of various tumour conditions.

VI. Suggested Reading

- Selected articles from journals.

I. Course Title : Immunopathology
II. Course Code : VPL 604
III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about immune mediated and autoimmune diseases of animals.

V. Theory

Unit I

Principles of immunopathology, Etiopathology of hypersensitivity reactions and immune complex diseases; Autoimmunity, mechanisms of autoimmunity, Genetic, microbial and environmental factors in autoimmunity.

Unit II

Study of etiology, pathology and pathogenesis of commonly encountered Immunoproliferative disorders (Multiple myeloma, lymphoma, leukemia), Hypersensitivity diseases, Autoimmune diseases and immune deficiencies in domestic animals.

VI. Practical

Immune complexes-quantification and determination by various techniques, Enumeration of various populations of lymphocytes by different techniques, Determination of C3 levels, Autoimmune reaction by demonstrating auto-antibodies, Gross and microscopic pathology of hypersensitivity reactions (class IV and others).

VII. Suggested Reading

- Selected articles from journals.

I. Course Title : Advances in Diagnostic Pathology
II. Course Code : VPL 605
III. Credit Hours : 1+2

IV. Aim of the course

To teach the students about current diagnostic techniques for diagnosis of different diseases.

V. Theory

Unit I

Principles and applications of Scanning electron microscopy, Transmission electron microscopy, Laser scanning confocal microscopy, Telemicroscopy-Virtual slide microscopy.

Unit II

Current techniques for diagnosis of animal diseases namely ELISA, PCR and its variants, Flow cytometry (FCM), *In-situ* hybridization, Bio chip techniques (DNA chip, Protein microarray, Tissue microarray), Chromatography, Spectrophotometry and Immunodiffusion technique, Biopsy techniques, Use of laboratory animals, etc.

Unit III

In-vitro cell culture techniques (commonly used cell lines, chicken embryo), cytopathic effect of different viruses and their interpretations.

VI. Practical

Principles and practice of advance techniques for the diagnosis of animal diseases.

VII. Suggested Reading

- Selected articles from journals.

I. Course Title : Pathology of Nutritional and Metabolic Disorders

II. Course Code : VPL 606

III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about nutritional and metabolic disorder of animals.

V. Theory

Unit I

Pathogenesis, gross and microscopic pathology of nutritional imbalances, viz., carbohydrate, protein, fats, vitamins and macro and microelements.

Unit II

Pathogenesis, gross and microscopic pathology of different metabolic diseases namely Milk fever, Ketosis, Pregnancy toxaemia, Tetany, Azoturia, Equine hyperlipidemia, downer's cow and rheumatism like syndrome and post parturient hemoglobinuria in domestic animals and diabetes mellitus in dogs.

VI. Practical

Estimation of certain minerals in sera of natural and experimentally induced deficiencies in domestic animals. To study the haematological, gross and microscopic pathological alterations caused by nutritional and metabolic disorders.

VII. Suggested Reading

- Selected articles from journals.

I. Course Title : Pathology of Important Emerging and Re-Emerging Diseases

II. Course Code : VPL-607

III. Credit Hours : 2+1

IV. Aim of the course

To teach the students about important emerging, re-emerging, exotic and transboundary diseases of pets and livestock.

V. Theory

Unit I

Advances in pathogenesis and pathology including molecular basis of important viral infections namely Foot and mouth disease, Vesicular stomatitis, Vesicular exanthema, Rinderpest, Bovine malignant catarrhal fever, Infectious bovine rhinotracheitis, Parainfluenza-3, Bovine respiratory syncytial virus infection, Blue tongue, Contagious ecthyma, Pox diseases, Peste des petits ruminants, Rabies, Canine distemper, parvovirus infections, Infectious canine hepatitis, Pseudorabies, Hog cholera/ swine fever, swine influenza, Rift valley fever, Scrapie, Bovine spongiform encephalopathy, Japanese encephalitis, Diseases caused by Nipah virus, Kyasanaur forest disease, West Nile fever, Hendravirus, Ebola virus, Crimean-Congo haemorrhagic fever, Chikungunya virus, Ganjam virus, Marburg virus, etc.

Unit II

Advances in pathogenesis and pathology including molecular basis of important bacterial infections namely Tuberculosis, Johne's disease, Actinobacillosis, Actinomycosis, Brucellosis, Listeriosis, Pasteurellosis, Leptospirosis, Anthrax, Clostridial group of diseases, Swine erysipelas, Glasser's disease, Colibacillosis and Salmonellosis, *Corynebactrium* infections, Chlamydial and Mycoplasmal infections.

Unit III

Advances in pathogenesis and pathology including molecular basis of important fungal infections namely Aspergillosis, Blastomycosis, Coccidioidomycosis, Histoplasmosis, Rhinosporidiosis, Sporotrichosis, Candidiasis, Crytococcosis, Dermatomycoses, diseases due to commonly occurring mycotoxins-Aflatoxins, Ochratoxin, Zearalenone, T-2 toxins, Rubratoxin, Fumonisin, Moniliformin, etc.

VI. Practical

Study of clinical and gross alterations and histopathology of some important emerging and enzootic diseases.

VII. Suggested Reading

- Selected articles from Journals.

I. Course Title : Research Methodology in Pathology

II. Course Code : VPL 608

III. Credit Hours : 1+0

IV. Aim of the course

To provide exposure to the students on different methodologies indispensable in Pathology research through available scientific literature in world class journals.

V. Theory

Unit I

Literature based study: Use of various experimentation techniques in pathology research, Animal experimentation techniques, Planning and design of various types of experiments through study of literature for selection of appropriate methodology and evaluation parameters including scoring system, Data evaluation methods, etc.

Unit II

Introduction to OECD-GLP guidelines, Reference studies through literature for safety evaluation of drug/ plant/ plant molecules using *In-vitro* and *In vivo* techniques, Determination and calculation of LD_{50}, ID_{50}, MIC, MTD, etc., use of modern molecular techniques in experimental pathology research.

VI. Suggested Reading

- Selected articles from journals.

I. Course Title : Necropsy Conference-I

II. Course Code : VPL-609

III. Credit Hours : 0+1

IV. Aim of the course

To promote self learning of the students in different necropsy procedures of animals including poultry and description of post-mortem lesions in different diseases/ disease conditions.

V. Practical

- Continuous assessment of students on detailed necropsy examination of various species of large and small animals including poultry; necropsy associated cytological examinations; systematic examination of different organs for morphologic description of gross lesions; gross photography; collection of tissues for histopathology and based on nature of gross lesions, if possible further collection for investigation of viral/ bacterial/ protozoan/ fungal/ parasitic diseases/ toxic or poisoning, etc.
- Morphologic description of microscopic lesions; microscopic photography; correlation of gross and microscopic observations with the results of other parallel investigations to diagnose the disease conditions; presentation of select case(s) in the monthly seminars followed by report writing and final morphologic/ etiologic diagnosis, classification and preservation of microscopic slides.

VI. Suggested Reading

- D Gopala Krishna Rao. 2005. *Textbook on necropsy and histopathological techniques*, 1st Ed. Academa.
- Donald B Feldman, John Curtis Seely. 1988. *Necropsy Guide: Rodents and the Rabbit*, 1st Ed. CRC Press.
- Albert C Strafuss. 1988. *Necropsy: Procedures and Basic Diagnostic Methods for Practicing Veterinarians,* Charles C. Thomas Publisher Springfield.
- Jones TC and Gleiser CA. 1954. *Veterinary Necropsy Procedures*. JB Lippincott.
- John M King, David C Dodd and Lois Roth. 2006. *The Necropsy Book*, Fifth Edition, C L Davis Foundation.
- Majó Masferrer, Natàlia, Dolz Pascual, Roser and Shivaprasad HL. 2011. *Atlas of Avian Necropsy: Macroscopic Diagnosis Sampling*, SERVET Publishers.
- Benjamin Lucio-Martinez and Jodi A Korich. 2010. *Illustrated guide to Poultry Necropsy and diagnosis*, Cornell University (https://www.slideshare.net/heshamkotb/illustrated-guide-to-poultry-necropsy-and-diagnosis).

I. Course Title : Special Problem

II. Course Code : VPL 690

III. Credit Hours : 0+1

IV. Aim of the course

To provide expertise in handling practical research problems.

V. Practical

Short research problem(s) involving contemporary issues and research techniques.

VI. List of some selected Journals

- *American Journal of Veterinary Medical Association*
- *Annals of Nutrition and Metabolism*
- *Annual Review of Nutrition*
- *Avian Diseases*
- *Avian Pathology*
- *Cancer Research*
- *Cellular and Molecular Biology*
- *Current Contents*
- *European Journal of Nutrition*
- *Genomics, Proteomics and Bioinformatics*
- *Indian Journal of Animal Sciences*
- *Indian Journal of Poultry Science*
- *Indian Journal of Veterinary Pathology*
- *Indian Veterinary Journal*
- *Journal of Applied Toxicology*
- *Journal of Comparative Pathology*
- *Journal of Ethnopharmacology*
- *Journal of Immunology and Immunopathology*
- *Journal of Pathology*
- *Journal of Research in Veterinary Science*
- *Phytomedicine*
- *Toxicology Letters*
- *Toxicon*
- *Trends in Immunology*
- *Veterinary Bulletin*
- *Veterinary Immunology and Immunopathology*
- *Veterinary Pathology*

e-Resources

- www.iavp.org (Indian Journal of Veterinary Pathology)
- www.vetpathology.org (Veterinary Pathology)
- www.tandf.co.uk (Avian Pathology)
- www.avdi.allenpress.com (Avian Diseases)
- www.elsevier.com/locate/vetimm (Veterinary Immunology and Immuno- pathology).

Course Outline-cum-Lecture Schedule for Doctoral Degree Programme

I. Course Title : Molecular and Ultra structural Basis of Cell Injury
II. Course Code : VPL 601
III. Credit Hours : 2 + 1

IV. Aim of the course

To teach the students about different molecular including ultrastructural changes in diseases conditions.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Study of cells- cell morphology, interpretation of normal and abnormal cells	6
2.	Overview of Cell injury, Targets of cell injury-Cell membranes, aerobic respiration, structural proteins and enzymes and genetic apparatus of the cell; mechanisms of cell injury-hypoxia, injury by free radicals, chemical injury, infectious agents, other forms of cell injury-immune mediated reactions, genetic derangements; mechanisms of cell membrane damage; mechanisms of DNA damage-base loss, base modification, chemical modification, replication errors, inter-strand cross-links, DNA-protein cross-links, strand breaks. Molecular and immunopathological changes associated with different types of cell injuries	10
3.	Morphology of Reversible and irreversible cell injury with particular emphasis on ultra structural changes in the cells and organelles: Morphology of cell death-necrosis, apoptosis and autolysis, mechanism of apoptosis, intracellular and extracellular accumulations, pigment and tissue deposits, consequences of cell injury	10
4.	Cellular adaptations-hyperplasia, hypertrophy, atrophy, metaplasia and dysplasia	4
5.	Mechanism of other types of cell death, viz., pyroptosis, ferroptosis, autophagy, ETOSIS, etc.	2
Practical		
1.	Collection and preparation of specimens for electron microscopic studies. Interpretation of ultra-structural changes and their correlation with gross and histopathological findings	16

I. Course Title : Molecular Basis of Inflammation
II. Course Code : VPL 602
III. Credit Hours : 1 + 1
IV. Aim of the course

To teach the students about molecular mechanisms of inflammations.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Cellular, molecular and immunopathological changes associated with different types of inflammation. Acute inflammation, Vascular events of acute inflammation, Cellular events in acute inflammation, Leucocyte-endothelial interactions, Leucocyte adhesion molecules, Endothelial adhesion molecule receptors, Leucocyte chemotactic factors, Microbicidal activity of leucocytes, Leucocyte activation.	6
2.	Plasma derived mediators of inflammation-Complement system, Kinin system, Coagulation system and Fibrinolytic system; Cell derived mediators of inflammation-vasoactive amines, lipid mediators, cytokines, chemokines, oxygen radicals and nitric oxide, Cellular components of inflammation, types of exudative inflammation.	6
3.	Chronic inflammation and its types, Elements of chronic inflammation, Healing and repair, Wound healing mediators and their functions, Repair of bone, Repair of nervous tissue and myocardium.	4
Practical		
1.	Molecular alterations and their correlation with gross and microscopic inflammatory changes.	16

I. Course Title : Molecular Basis of Neoplasia
II. Course Code : VPL 603
III. Credit Hours : 1 + 1
IV. Aim of the course

To teach the students about molecular mechanisms of neoplasia and diagnostic technique.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Tumour characteristics, differentiation and proliferation, molecular basis of cancer, tumour stromal interaction, molecular mechanisms of invasion and metastasis of tumours, molecular changes underlying tumour progression and heterogeneity, tumour biology and growth.	8

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
2.	Tumour genetics, immunohistochemical/ including markers associated tumour diagnosis.	8
Practical		
1.	Application of cytological, histopathological, immunohistochemical and molecular techniques in diagnosis and prognosis of various tumour conditions.	16

I. Course Title : Immunopathology

II. Course Code : VPL 604

III. Credit Hours : 2 + 1

IV. Aim of the course

To teach the students about immune mediated and autoimmune diseases of animals.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Principles of immunopathology, Etiopathology of hypersensitivity reactions and immune complex diseases; Autoimmunity, mechanisms of autoimmunity, Genetic, microbial and environmental factors in autoimmunity.	16
2.	Study of etiology, pathology and pathogenesis of commonly encountered Immunoproliferative disorders (Multiple myeloma, lymphoma, leukemia), hypersensitivity diseases, autoimmune diseases and immune deficiencies in domestic animals.	16
Practical		
1.	Immune complexes-quantification and determination by various techniques, enumeration of various populations of lymphocytes by different techniques, determination of C3 levels.	8
2.	Autoimmune reaction by demonstrating auto-antibodies, gross and microscopic pathology of hypersensitivity reactions (class IV and others).	8

I. Course Title : Advances in Diagnostic Pathology

II. Course Code : VPL 605

III. Credit Hours : 1 + 2

IV. Aim of the course

To teach the students about current diagnostic techniques for diagnosis of different diseases.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Principles and applications of Scanning electron microscopy, Transmission electron microscopy, Laser scanning confocal microscopy, Telemicroscopy-Virtual slide microscopy	4
2.	Current techniques for diagnosis of animal diseases namely ELISA, PCR and its variants, Flow cytometry (FCM), *In-situ* hybridization, Bio-chip techniques (DNA chip, Protein microarray, Tissue microarray), Chromatography, Spectrophotometry and Immunodiffusion technique, Biopsy techniques, Use of laboratory animals, etc.	8
3.	*In-vitro* cell culture techniques (commonly used cell lines, chicken embryo), cytopathic effect of different viruses and their interpretations	4
Practical		
1.	Principles and practice of advance techniques for the diagnosis of animal diseases	32

I. Course Title : Pathology of Nutritional and Metabolic Disorders

II. Course Code : VPL 606

III. Credit Hours : 2 + 1

IV. Aim of the course

To teach the students about nutritional and metabolic disorder of animals.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Pathogenesis, gross and microscopic pathology of nutritional imbalances, viz., carbohydrate, protein, fats, vitamins and macro and microelements	16
2.	Pathogenesis, gross and microscopic pathology of different metabolic diseases namely milk fever, ketosis, pregnancy toxaemia, tetany, azoturia, equine hyperlipidemia, downer's cow and rheumatism like syndrome and post parturient hemoglobinuria in domestic animals and diabetes mellitus in dogs	16
Practical		
1.	Estimation of certain minerals in sera of natural and experimentally induced deficiencies in domestic animals	8
2.	To study the haematological, gross and microscopic pathological alterations caused by nutritional and metabolic disorders	8

I. Course Title : Pathology of Important Emerging and Re-Emerging diseases

II. Course Code : VPL 607

III. Credit Hours : 2 + 1

IV. Aim of the course

To teach the students about important emerging, re-emerging, exotic and transboundary diseases of pets and livestock.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Advances in pathogenesis and pathology including molecular basis of important viral infections namely Foot and mouth disease, Vesicular stomatitis, Vesicular exanthema, Rinderpest, Bovine malignant catarrhal fever, Infectious bovine rhinotracheitis, Parainfluenza-3, Bovine respiratory syncytial virus infection, Blue tongue, Contagious ecthyma, Pox diseases, Peste des petits ruminants, Rabies, Canine distemper, parvovirus infections, Infectious canine hepatitis, Pseudorabies	8
2.	Advances in pathogenesis and pathology including molecular basis of important viral infections namely Hog cholera/ swine fever, swine influenza, Rift valley fever, Scrapie, Bovine spongiform encephalopathy, Japanese encephalitis, Diseases caused by Nipah virus, Kyasanaur forest disease, West Nile fever, Hendravirus, Ebola virus, Crimean-Congo haemorrhagic fever, Chikungunya virus, Ganjam virus, Marburg virus, etc.	8
3.	Advances in pathogenesis and pathology including molecular basis of important bacterial infections namely Tuberculosis, Johne's disease, Actinobacillosis, Actinomycosis, Brucellosis, Listeriosis, Pasteurellosis, Leptospirosis, Anthrax, Clostridial group of diseases, Swine erysipelas, Glasser's disease, Colibacillosis and Salmonellosis, Corynebactrium infections, Chlamydial and Mycoplasmal infections	8
4.	Advances in pathogenesis and pathology including molecular basis of important fungal infections namely Aspergillosis, Blastomycosis, Coccidioidomycosis, Histoplasmosis, Rhinosporidiosis, Sporotrichosis, Candidiasis, Crytococcosis, Dermatomycoses, diseases due to commonly occurring mycotoxins-Aflatoxins, Ochratoxin, Zearalenone, T-2 toxins, Rubratoxin, Fumonisin, Moniliformin, etc.	8
Practical		
1.	Study of clinical and gross alterations and histopathology of some important emerging and enzootic diseases.	16

I. Course Title : Research Methodology in Pathology

II. Course Code : VPL 608

III. Credit Hours : 1+0

IV. Aim of the course

To provide exposure to the students on different methodologies indispensable in Pathology research through available scientific literature in world class journals

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Literature based study: Use of various experimentation techniques in pathology research, animal experimentation techniques, Planning and design of various types of experiments through study of literature for selection of appropriate methodology and evaluation parameters including scoring system, data evaluation methods, etc.	8
2.	Introduction to OECD-GLP guidelines, Reference studies through literature for safety evaluation of drug/ plant/ plant molecules using *In-vitro* and *In vivo* techniques, Determination and calculation of LD_{50}, ID_{50}, MIC, MTD, etc., use of modern molecular techniques in experimental pathology research	8

I. Course Title : Necropsy Conference I

II. Course Code : VPL 609

III. Credit Hours : 0 + 1

IV. Aim of the course

To promote self-learning of the students in different necropsy procedures of animals including poultry and description of post-mortem lesions in different diseases/ disease conditions.

Lecture/ Practical schedule

Sr. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Practical		
1.	Continuous assessment of students on detailed necropsy examination of various species of large and small animals including poultry; necropsy associated cytological examinations; systematic examination of different organs for morphologic description of gross lesions; gross photography; collection of tissues for histopathology and based on nature of gross lesions, if possible further collection for investigation of viral/ bacterial/ protozoan/ fungal/ parasitic diseases/ toxic or poisoning, etc.	8
2.	Morphologic description of microscopic lesions; microscopic photography; correlation of gross and microscopic observations with the results of other parallel investigations to diagnose the disease conditions; presentation of select case(s) in the monthly seminars followed by report writing and final morphologic/ etiologic diagnosis, classification and preservation of microscopic slides	8

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Para-Clinical Subjects
– Veterinary Parasitology

Course Title with Credit Load
M.V.Sc. in Veterinary Parasitology

Course Code	Course Title	Credit Hours
VPA 501	Platyhelminthes-I*	1+1
VPA 502	Platyhelminthes-II*	1+1
VPA 503	Nemathelminthes and Acanthocephala*	2+1
VPA 504	Arthropod Parasites*	2+1
VPA 505	Parasitic Protozoa*	2+1
VPA 506	Diagnostic Parasitology	0+2
VPA 507	Clinical Parasitology	1+1
VPA 508	Management of Parasitic Diseases	1+1
VPA 509	Immunoparasitology	2+1
VPA 510	Parasitic Zoonoses	2+0
VPA 511	Parasites of Wildlife	1+1
VPA 591	Master's Seminar*	1+0
VPA 599	Master Research	30

*Core Courses

Course Contents
M.V.Sc. in Veterinary Parasitology

I. Course Title : Platyhelminthes-I
II. Course Code : VPA 501
III. Credit Hours : 1+1
IV. Aim of the course

To study the morphology, biology, pathogenesis and control measures for trematode parasites of veterinary importance.

V. Theory

Unit I

Introduction, classification, general account and economic importance of trematodes.

Unit II

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, Treatment and control measures of trematodes belonging to families: Dicrocoeliidae, Opisthorchiidae and Fasciolidae.

Unit III

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of trematodes belonging to families: Echinostomatidae, Heterophyidae, Plagiorchiidae, Troglotrematidae, Prosthogonimidae, Nanophyetidae and Paragonimidae.

Unit IV

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of trematodes belonging to families: Notocotylidae, Brachylemidae, Cyclocoelidae, Paramphistomatidae and Schistosomatidae.

Unit V

Classification, characters of snails and control strategies of molluscs of veterinary importance.

VI. Practical

- Collection, preservation/ processing and identification of trematode parasites; their eggs and intermediate hosts.
- Observation on parasitic stages in host tissues and associated pathological lesions.
- Identification of molluscs of veterinary importance and examination of molluscs for various developmental stages of trematode parasites.

I. Course Title : Platyhelminthes-II
II. Course Code : VPA 502
III. Credit Hours : 1+1
IV. Aim of the course

To study the morphology, biology, pathogenesis and control measures for cestode parasites of veterinary importance.

Unit I

Introduction, classification, general account and economic importance of cestodes

Unit II

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of cestodes belonging to families: Diphyllobothriidae, Mesocestoididae and Taeniidae.

Unit III

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of cestodes belonging to families: Davaineidae, Hymenolepididae, Dipylidiidae and Dilepididae.

Unit IV

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, Treatment and control measures of cestodes belonging to families: Anoplocephalidae and Thysanosomidae.

V. Practical

Collection, preservation/ processing and identification of cestode parasites; their eggs, larval stages and intermediate hosts. Parasitic stages in host tissues and associated pathological lesions.

I. Course Title : Nemathelminthes and Acanthocephala

II. Course Code : VPA 503

III. Credit Hours : 2+1

IV. Aim of the course

To study the morphology, biology, pathogenesis, diagnosis and control of nematodes and thorny-headed worms of veterinary importance.

V. Theory

Unit I

Introduction, classification, general account and economic importance of nematodes and thorny-headed worms.

Unit II

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of nematodes belonging to families: Ascarididae, Anisakidae, Oxyuridae, Heterakidae and Subuluridae.

Unit III

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment, and control measures of nematodes belonging to families: Rhabditidae, Strongyloididae and Strongylidae.

Unit IV

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment, and control measures of nematodes belonging to families: Trichonematidae, Amidostomidae, Stephanuridae, Syngamidae and Ancylostomatidae.

Unit V

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of nematodes belonging to families: Filaroididae, Trichostrongylidae, Ollulanidae, Dictyocaulidae and Metastrongylidae.

Unit VI

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of nematodes belonging to families: Spiruridae, Thelaziidae, Acuariidae, Tetrameridae, Physalopteridae, Gnathostomatidae, Filariidae, Setariidae, Onchocercidae and Dracunculidae.

Unit VII

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of nematodes belonging to families: Trichinellidae, Trichuridae, Capillariidae and Dioctophymatidae.

Unit VIII

Morphology, Epidemiology, Life cycle, Pathogenesis, Clinical signs, Diagnosis, treatment and control measures of thorny headed worms belonging to families: Polymorphidae, Oligacanthorhynchidae and Gnathobdellidae.

V. Practical

Collection, preservation/ processing and identification of nematode parasites and thorny headed worms; their eggs and larvae and associated pathological lesions.

I. Course Title : Arthropod Parasites

II. Course Code : VPA 504

III. Credit Hours : 2+1

IV. Aim of the course

To study the morphology, biology, vector potential of the arthropods of veterinary importance and their control measures

V. Theory

Unit I

Introduction, Classification, Harmful effects and Economic importance of arthropod parasites.

Unit II

Distribution, Morphology, Life cycle, Seasonal pattern, Pathogenesis, Vector potentiality, Economic significance and control of arthropods belonging to the families: Culicidae, Ceratopogonidae, Simuliidae and Psychodidae.

Unit III

Distribution, Morphology, Life cycle, Seasonal pattern, Pathogenesis, Vector potentiality, Economic significance and control of arthropods belonging to the families: Tabanidae, Gasterophilidae, Muscidae, Cuterebridae and Glossinidae.

Unit IV

Distribution, Morphology, Life cycle, Seasonal pattern, Pathogenesis, Vector potentiality, Economic significance and control of arthropods belonging to the families: Oestridae, Sarcophagidae, Calliphoridae and Hippoboscidae. Importance of blow flies in forensic entomology and treatment of wounds.

Unit V

Distribution, Morphology, Life cycle, Seasonal pattern, Pathogenesis, Economic significance and control of arthropods belonging to the families: Pediculidae, Haematopinidae, Linognathidae, Menoponidae, Philopteridae and Trichodectidae.

Unit VI

Distribution, Morphology, Life cycle, Seasonal pattern, Pathogenesis, Economic significance and control of arthropods belonging to the Orders- Siphonaptera and Hemiptera, Cimicidae and Reduviidae.

Unit VII

Distribution, Life cycle, Seasonal pattern, Vector potentiality, Pathogenesis economic significance and control of acarines belonging to the families: Argasidae and Ixodidae.

Unit VIII

Distribution, Morphology, Life cycle, Seasonal pattern, Pathogenesis, Economic significance and control of acarines belonging to the families: Sarcoptidae, Psoroptidae, Demodicidae, Trombiculidae, Dermanyssidae. Cytoditidae and Linguatulidae.

Unit IX

Chemical, Biological, Immunological control measures and integrated pest management. Detection and mechanisms of acaricidal resistance.

V. Practical

Collection, preservation/ processing, identification, differentiation of arthropod parasites and their developmental stages; associated lesions and skin scraping examination.

I. Course Title : Parasitic Protozoa

II. Course Code : VPA 505

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the morphology, Life cycle, Pathogenesis, Diagnosis and control of protozoan parasites of veterinary importance.

V. Theory

Unit I

Introduction, classification, general account and economic importance of protozoan parasites.

Unit II

Morphology, Epidemiology, Pathogenesis, Clinical signs, Diagnosis, and control measures of protozoan parasites belonging to the families: Trypanosomatidae, Monocercomonadidae, Trichomonadidae, Hexamitidae and Endamoebidae.

Unit III

Morphology, Epidemiology, Pathogenesis, Clinical signs, Diagnosis and control measures of protozoan parasites belonging to the families: Eimeriidae, Cryptosporidiidae and Sarcocystidae.

Unit IV

Morphology, Epidemiology, Pathogenesis, Clinical signs, Diagnosis, Treatment and control measures of protozoan parasites belonging to the families: Plasmodiidae, Babesiidae, Theileriidae, Haemogregarinidae and Balantidiidae.

Unit V

Morphology, Epidemiology, Pathogenesis, Clinical signs, Diagnosis and control measures of Rickettsiales in relation to haemoprotozoans.

VI. Practical

Collection, Preservation/ Processing, Identification of parasitic protozoa in clinical material and host tissues. Special techniques for certain protozoans such as coccidia and Cryptosporidia.

I. Course Title : Diagnostic Parasitology
II. Course Code : VPA 506
III. Credit Hours : 0+2

IV. Aim of the course

To learn the techniques associated with isolation, Identification and preservation of the endo and ectoparasites of veterinary importance and their vectors.

V. Practical

Microscopy and micrometry, Preparation of Romanowsky stains. Collection, preservation, Processing and examination of faecal and blood samples; Lymph node biopsy, Skin scrapings, Nasal washings, Sputum, genital discharges/ washings and urine samples from animals for parasitological examinations. Quantitative faecal examination, Maintenance of fly and tick colonies in laboratory for experimental purposes and testing of drugs; tick dissection for vector potential. Collection of aquatic snails from field and their examination for the presence of different parasitic stages. Collection, fixation, staining, whole mounts and identification of parasites. Culturing techniques for important parasites, pasture larval count, worm count and assessment of worm burden.

Remote Sensing (RS) and Geographic Information System (GIS) as tools for mapping parasitic diseases.

I. Course Title : Clinical Parasitology
II. Course Code : VPA 507
III. Credit Hours : 1+1

IV. Aim of the course

Collection, preservation and examination of clinical material for parasitological investigations and interpretations.

V. Theory

Unit I

Collection, preservation and dispatch of clinical material to laboratory for diagnosis

Unit II

History, clinical signs, gross and microscopic examination of diagnostic material.

Unit III

Animal sub-inoculation technique; blood and lymph node biopsy smear examination; histopathology of affected organs.

VI. Practical

Identification, observation of parasitic stages in host tissues, excretions, secretions and associated pathological lesions. Special techniques for haemoparasites and coccidians.

I. Course Title : Management of Parasitic Diseases

II. Course Code : VPA 508

III. Credit Hours : 1+1

IV. Aim of the course

To study the integrated approach for the control of helminths, arthropods and protozoan parasites of veterinary importance.

V. Theory

Unit I

Conventional and novel methods for control of helminth infections in livestock – anthelmintics, their mode of action, characteristic of an ideal anthelmintic drug, Anthelmintic resistance, Spectrum of activity, Delivery devices and integrated control method. Immunological control, Deworming schedule, Snail and other intermediate host control. Ethno veterinary practices.

Unit II

Conventional and novel methods of control of protozoan parasites–antiprotozoal drugs, Their mode of action, Integrated control method including immunological control.

Unit III

Conventional and novel methods of control with insecticides/ acaricides. Methods of application, their mode of action, insecticide resistance, biological control, integrated control method, genetic control and immunological control.

VI. Practical

In vivo and *in-vitro* detection of efficacy of control agents and resistance to anthelmintics, anticoccidials, insecticides and acaricides.

I. Course Title : Immunoparasitology

II. Course Code : VPA 509

III. Credit Hours : 2+1

IV. Aim of the course

To study the host immune response against endo and ectoparasites of veterinary importance with special reference to immunoprophylaxis and immunodiagnosis.

V. Theory

Unit I

Introduction, types of parasite-specific antigens and their characterization.

Unit II

Types of immunity in parasitic infections.

Unit III

Invasive and evasive mechanisms, immunomodulators and their uses.

Unit IV

Immune responses in helminths, arthropods and protozoa of veterinary importance.

Unit V

Immunological control against parasitic diseases.

VI. Practical

Preparation of various antigens (somatic, excretory-secretory) and their fractionation and characterization and demonstration of various immunodiagnostic methods for the diagnosis of parasitic infections.

I. Course Title : Parasitic Zoonoses

II. Course Code : VPA 510

III. Credit Hours : 2+0

IV. Aim of the course

To study important parasites of zoonotic significance.

Unit I

Introduction to the concept of Zoonotic infections, Definitions, Various classifications of zoonoses, Host-parasite relationships, Modes of infections and factors influencing prevalence of zoonoses.

Unit II

A detailed study of Transmission, Epidemiology, Diagnosis and Control of common protozoa of zoonotic importance.

Unit III

A detailed study of Transmission, Epidemiology, Diagnosis and Control of common helminths of zoonotic importance.

Unit IV

A detailed study of Transmission, Epidemiology, Diagnosis and Control of common arthropods of zoonotic importance.

I. Course Title : Parasites of Wildlife

II. Course Code : VPA 511

III. Credit Hours : 1+1

IV. Aim of the course

To study the biology and control measures for major parasitic diseases of zoo and wild animals.

V. Theory

Unit I

A detailed study of protozoa of zoo and wild animals with particular emphasis on morphological features, Geographical distribution Epidemiology, Diagnosis and management.

Unit II

A detailed study of arthropod parasites of zoo and wild animals with particular emphasis on morphological features, Geographical distribution, Epidemiology, diagnosis and management.

Unit III

A detailed study of helminth parasites of zoo and wild animals with particular emphasis on morphological features, Geographical distribution, Epidemiology, diagnosis and management.

VI. Practical

Methods for investigating parasitic diseases of captive and wild animals. Collection and identification of parasites. Visits to zoos and biological parks/ sanctuaries for collection of samples.

Course Outline-cum-Lecture Schedule for Master Degree Programme

I. Course Title : Platyhelminthes-I
II. Course Code : VPA 501
III. Credit Hours : 1+1

IV. Aim of the course

To study the morphology, biology, pathogenesis and control measures for trematode parasites of veterinary importance

Lecture	Topic
Theory	
1-2	Introduction, history, classification, general account and economic importance of trematodes
3-4	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of trematodes belonging to families: Dicrocoeliidae and Opisthorchiidae
5-6	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of trematodes belonging to families: Strigeidae and Fasciolidae
7-8	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of trematodes belonging to families: Echinostomatidae, Heterophyidae, Plagiorchiidae and Troglotrematidae
9-10	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of trematodes belonging to families: Prosthogonimidae, Nanophyetidae and Paragonimidae
11-12	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of trematodes belonging to families: Notocotylidae, Brachylemidae, and Paramphistomatidae
13-14	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of trematodes belonging to families: Cyclocoelidae and Schistosomatidae
15-16	Classification and characters of snails and Control strategies of molluscs of veterinary importance
Practicals	
1-5	Collection, preservation/ processing and identification of trematode parasites; their eggs and intermediate hosts
6-11	Observation on parasitic stages in host tissues and associated pathological lesions caused by treamtodes
12-16	Identification of molluscs of veterinary importance and examination of molluscs for various developmental stages of trematode parasites.

I. Course Title : Platyhelminthes-II
II. Course Code : VPA 502
III. Credit Hours : 1+1

IV. Aim of the course

To study the morphology, biology, pathogenesis and control measures for cestode parasites of veterinary importance

Lecture	Topic
Theory	
1-2	Introduction, history, classification, general account and economic importance of cestodes
3-4	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of cestodes belonging to family: Diphyllobothriidae
5	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of cestodes belonging to family: Mesocestoididae
6-8	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of cestodes belonging to family: Taeniidae
9-10	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of cestodes belonging to families: Davaineidae and Hymenolepididae
11-12	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of cestodes belonging to families: Dipylidiidae and Dilepididae
13-14	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of cestodes belonging to family: Anoplocephalidae
15-16	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of cestodes belonging to family: Thysanosomidae
Practicals	
1-8	Collection, preservation/ processing and identification of cestode parasites; their eggs, larval stages and intermediate hosts.
9-16	Observation on parasitic stages in host tissues and associated pathological lesions

I. Course Title : Nemathelminthes and Acanthocephala
II. Course Code : VPA 503
III. Credit Hours : 2+1

IV. Aim of the course

To study the morphology, biology, pathogenesis and control measures of nematodes and thorny-headed worms of veterinary importance

Lecture	Topic
1-2	Introduction, history, classification, general account and economic importance of nematodes and thorny-headed worms
2-4	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to family: Ascarididae
5-6	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Anisakidae and Oxyuridae
7-8	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Heterakidae and Subuluridae

Lecture	Topic
9-10	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Rhabditidae and Strongyloididae
11-12	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to family: Strongylidae.
13-14	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Trichonematidae and Amidostomidae
15-16	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Stephanuridae and Syngamidae
17-18	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to family: Ancylostomatidae.
19-20	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Filaroididae and Trichostrongylidae
21-22	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Ollulanidae, Dictyocaulidae and Metastrongylidae
23-24	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Spiruridae, Thelaziidae, Acuariidae, Tetrameridae, Physalopteridae, and Gnathostomatidae
25-26	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Filariidae, Setariidae, Onchocercidae and Dracunculidae.
27-28	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Trichinellidae and Trichuridae
29-30	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Capillariidae and Dioctophymatidae
31-32	Morphology, epidemiology, life cycle, pathogenesis, clinical signs, diagnosis and control measures of nematodes belonging to families: Polymorphidae, Oligacanthorhynchidae and Gnathobdellidae.
Practicals	
1-16	Collection, preservation/ processing and identification of nematode parasites and thorny headed worms; their eggs and larvae and associated pathological lesions.

I. Course Title : Arthropod Parasites

II. Course Code : VPA 504

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the morphology, biology, vector potential of the arthropods of veterinary importance and their control measures.

Lecture	Topic
1-2	Introduction, classification harmful effects and economic importance of arthropod parasites.

Lecture	Topic
3-4	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, vector potential, economic significance and control of arthropods belonging to the family: Culicidae
5-6	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, vector potential, economic significance and control of arthropods belonging to the family: Ceratopogonidae
7-8	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, vector potential, economic significance and control of arthropods belonging to the families: Simuliidae and Psychodidae.
8-9	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, vector potential, economic significance and control of arthropods belonging to the families: Tabanidae and Gasterophilidae
10-11	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, vector potential, economic significance and control of arthropods belonging to the families: Muscidae, and Glossinidae
12-14	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, vector potential, economic significance and control of arthropods belonging to the families: Oestridae, Sarcophagidae, Calliphoridae and Hippoboscidae. Importance of blow flies in forensic entomology and treatment of wounds
15-18	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, economic significance and control of arthropods belonging to the families: Pediculidae, Haematopinidae, Linognathidae, Menoponidae, Philopteridae and Trichodectidae
19-20	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, economic significance and control of arthropods belonging to the order: Siphonaptera and families: Cimicidae and Reduviidae
21-25	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, vector potential, economic significance and control of arthropods belonging to the families: Argasidae and Ixodidae
26-30	Distribution, morphology, life cycle, seasonal pattern, pathogenesis, economic significance and control of acarines belonging to the families: Sarcoptidae, Psoroptidae, Demodicidae, Trombiculidae, Dermanyssidae. Cytoditidae and Linguatulidae.
31-32	Chemical, biological, immunological control measures and integrated pest management. Detection and mechanisms of acaricidal resistance
Practicals	
1-16	Collection, preservation/ processing, identification, differentiation of arthropod parasites and their developmental stages; associated lesions and skin scraping examination

I. Course Title : Parasitic Protozoa

II. Course Code : VPA 505

III. Credit Hours : 2+1

IV. Aim of the course

To study the morphology, life cycle, pathogenesis, diagnosis and control of protozoan parasites of veterinary importance.

Lecture	Theory
1-3	Introduction, History, Classification and General account and economic importance of protozoan parasites.

Lecture	Topic
4-7	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Trypanosomatidae
8-10	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Monocercomonadidae and Trichomonadidae
11-12	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Hexamitidae and Endamoebidae
13-14	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Endamoebidae
15-16	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Eimeriidae.
17-18	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Cryptosporidiidae.
19-22	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Sarcocystidae.
23	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Plasmodiidae.
24-26	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Babesiidae.
27-28	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Theileriidae.
29-30	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of protozoan parasites belonging to the family Haemogregarinidaeand Balantidiidae
31-32	Morphology, epidemiology, pathogenesis, clinical signs, diagnosis and control measures of Rickettsiales like *Anaplasma*, *Ehrlichia*, *Haemobartonella* and others.
Practicals	
1-4	Collection, preservation/ processing, identification of protozoan parasites based on faecal examination.
5-8	Collection, preservation/ processing, identification of protozoan parasites based on blood examination.
9-12	Observations on parasite stages in host tissues and the attendant pathological lesions.
13-16	Diagnosis of protozoan parasites of Veterinary importance.

I. Course Title : Diagnostic Parasitology

II. Course Code : VPA 506

III. Credit Hours : 0+2

Aim of the course

To learn the techniques associated with isolation, identification and preservation of the endo and ectoparasites of veterinary importance and their vectors.

Lecture	Topic
Practical	
1-2	Microscopy and micrometry, Preparation of Romanowsky stain.
3-8	Collection, preservation, processing and examination of faecal and blood samples; lymph node biopsy, skin scrapings, nasal washings sputum, genital discharges/ washings and urine samples from animals for parasitological examinations.

Lecture	Topic
9-12	Quantitative faecal examination.
13-16	Maintenance of fly and tick colonies in laboratory for experimental purposes and testing of drugs; tick dissection for vector potential.
17-20	Collection of aquatic snails from field and their examination for the presence of different parasitic stages.
21-24	Collection, fixation, staining, whole mounts and identification of parasites.
25-28	Culturing techniques for important parasites, pasture larval count, worm count and assessment of worm burden.
29-32	Remote Sensing (RS) and Geographic Information System (GIS) as tools for mapping parasitic diseases.

I. Course Title : Clinical Parasitology

II. Course Code : VPA 507

III. Credit Hours : 1+1

IV. Aim of the course

Collection of clinical material, examination/ investigation and its preservation for interpretations.

Lecture	Topic
Theory	
1-3	Unit I: Collection, preservation and dispatch of clinical material to laboratory for diagnosis.
4-8	Unit II: History, clinical signs, gross and microscopic examination of diagnostic material.
9-10	Unit III: Animal sub-inoculation tests.
11-13	Unit III: Blood and biopsy smear examination.
14-16	Unit III: Histopathology of affected organs.
Practical	
1-12	Identification, observation of parasitic stages in host tissues, excretions, secretions and associated pathological lesions.
7-12	Special techniques for *Cryptosporidium* oocysts in faecal samples. Sporulation of coccidial oocysts.

I. Course Title : Management of Parasitic Diseases

II. Course Code : VPA 508

III. Credit Hours : 1+1

IV. Aim of the course

To study the integrated approach for the control of helminths, arthropods and protozoan parasites of veterinary importance.

Lecture	Topic
Theory	
1-6	Unit I: Conventional and novel methods of control of helminth infection in livestock – anthelmintics, their mode of action, characteristic of an ideal anthelmintic drug, anthelmintic resistance, spectrum of activity, delivery devices, integrated

Lecture	Topic
	control method. Immunological control. Deworming schedule. Snail and other intermediate host control.
7-11	Unit II: Conventional and novel methods of control of protozoan parasites–antiprotozoal drugs, their mode of action, integrated control method including immunological control.
12-16	Unit III Conventional and novel methods of control with insecticides/ acaricides. Methods of application, their mode of action, insecticide resistance, biological control, integrated control method, genetic control and immunological control.
Practical	
1-6	*In vivo* detection of efficacy of and resistance to parasiticidal agents.
7-16	*In-vitro* detection of efficacy of and resistance to parasiticidal agents

I. Course Title : Immunoparasitology

II. Course Code : VPA 509

III. Credit Hours : 2+1

IV. Aim of the course

To study the host immune response against the endo and ectoparasites of veterinary importance with special reference to immunoprophylaxis and immunodiagnosis.

Lecture	Topic
Theory	
1-7	Unit I: Introduction, types of parasite-specific antigens and their characterization.
8-13	Unit II: Types of immunity in parasitic infections.
14-18	Unit III: Invasive and evasive mechanisms, immunomodulators and their uses.
19-27	Unit IV: Immune responses in helminths, arthropods and protozoa of veterinary importance.
28-32	Unit V: Immunological control against parasitic diseases
Practical	
1-9	Preparation of various antigens (somatic, excretory-secretory) and their fractionation and characterization and
10-16	Demonstration of various immunodiagnostic methods for the diagnosis of parasitic infections

I. Course Title : Parasitic Zoonoses

II. Course Code : VPA 510

III. Credit Hours : 2+0

IV. Aim of the course

To study important parasites of zoonotic significance.

Lecture	Topic
Theory	
1-3	Unit I: Introduction to the concept of zoonotic infections
4-6	Unit I:Definition and various classifications of zoonoses.

Lecture	Topic
7-10	Unit I: Host-parasite relationships, modes of infections, factors influencing prevalence of zoonoses.
11-18	Unit II: A detailed study of transmission, epidemiology, diagnosis and control of major protozoa of zoonotic importance.
19-25	Unit III: A detailed study of transmission, epidemiology, diagnosis and control of major helminths of zoonotic importance.
26-32	Unit IV: A detailed study of transmission, epidemiology, diagnosis and control of major arthropods of zoonotic importance.

I. Course Title : Parasites of Wildlife

II. Course Code : VPA 511

III. Credit Hours : 1+1

IV. Aim of the course

To study the biology and control measures for major parasitic diseases of zoo and wild animals.

Lecture	
Theory	
1-6	Unit I: A detailed study of protozoa of zoo and wild animals with particular emphasis on morphological features, geographical distribution epidemiology, diagnosis and management.
7-12	Unit II: A detailed study of arthropod parasites of zoo and wild animals with particular emphasis on morphological features, geographical distribution, epidemiology, diagnosis and management.
13-16	Unit III: A detailed study of helminth parasites of zoo and wild animals with particular emphasis on morphological features, geographical distribution, epidemiology, diagnosis and management
Practical	
1-6	Methods for investigating parasitic diseases of captive and wild animals.
7-16	Collection and identification of parasites. Visits to zoos and biological parks/ sanctuaries for collection of samples.

Course Title with Credit Load
Ph.D. in Veterinary Parasitology

Course Code	Course Title	Credits Hours
VPA 601	Advances in Helminthology-I	2+1
VPA 602	Advances in Helminthology-II	2+1
VPA 603	Entomology and Acarology	2+1
VPA 604	Advances in Protozoology	2+1
VPA 605	Immunology of Parasitic Diseases*	1+2
VPA 606	Molecular Diagnostics and Vaccine Development in Parasitology*	2+1
VPA 607	Host Parasite Interactions	2+0
VPA 608	*In-vitro* Cultivation of Parasites	1+2
VPA 609	Emerging and Re-Emerging Parasitic Diseases	2+0
VPA 610	Biology and Ecology of Parasites	3+0
VPA 611	Molecular Veterinary Parasitology	2+0
VPA 612	Parasite Epidemiology *	2+0
VPA 690	Special Problem	0+1
VPA 691	Doctoral Seminar-I *	1+0
VPA 692	Doctoral Seminar-II*	1+0
VPA 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Veterinary Parasitology

I. Course Title : Advances in Helminthology-I
II. Course Code : VPA 601
III. Credit Hours : 2+1

IV. Aim of the course

Developments in the area of molecular biology, pathogenesis, diagnosis and control of trematodes and cestodes.

V. Theory

Unit I

Advanced studies on Taxonomy, Molecular biology, Pathogenesis and Immunology of trematodes and their larval stages.

Unit II

Advanced studies on Taxonomy, Molecular biology, Pathogenesis and Immunology of cestodes and larval stages.

VI. Practical

Morphological, Pathological and Immunological studies of trematode and cestode parasites.

I. Course Title : Advances in Helminthology-II
II. Course Code : VPA 602
III. Credit Hours : 2+1

IV. Aim of the course

To study the recent developments in the area of molecular biology, pathogenesis, diagnosis of nematode parasites and thorny headed worms with an objective of better control.

V. Theory

Unit I

Advanced studies on Taxonomy, Molecular biology, Pathogenesis and Immunology of nematode parasites and their larval stages.

Unit II

Advanced studies on Taxonomy, Molecular biology, Pathogenesis and Immunology of thorny-headed worms.

VI. Practical

Morphological, Pathological and Immunological studies of various nematodes and thorny-headed worms.

I. Course Title : Entomology and Acarology
II. Course Code : VPA 603
III. Credit Hours : 2+1

IV. Aim of the course

To study the recent scientific developments on biology and control measures for arthropods of veterinary importance.

V. Theory

Unit I

Origin, Evolution, Regional/ Seasonal distribution and Forecasting of insect and acarine population.

Unit II

Population dynamics of insects and acarines in relation to biotic and abiotic factors

Unit III

Recent developments pertaining to insects of veterinary importance.

Unit IV

Recent developments pertaining to arachnids of veterinary importance.

Unit V

Chemical, Biological, Herbal and Immunological control measures and integrated pest management. Modulation of vector competence to transmit parasitic infections using molecular genetics by developing transgenic vectors.

VI. Practical

Collection and identification of arthropods; Demonstration of the infective stages in vectors. Immuno pathological changes produced in the host tissues due to the infestation of arthropods.

I. Course Title : Advances in Protozoology
II. Course Code : VPA 604
III. Credit Hours : 2+1

IV. Aim of the course

To study the recent developments in molecular biology, pathogenesis, diagnosis and control of protozoan parasites of veterinary importance

V. Theory

Unit I

Advanced studies on Taxonomy, Molecular biology, Pathogenesis and Immunology of intestinal protozoa.

Unit II

Advanced studies on Taxonomy, Molecular biology, Pathogenesis and Immunology of haemoprotozoans.

Unit III

Advanced studies on Taxonomy, Molecular biology, Pathogenesis and Immunology of tissue and other protozoa.

VI. Practical

Morphological, pathological and immunodiagnosis of protozoan diseases

I. Course Title : Immunology of Parasitic Diseases

II. Course Code : VPA 605

III. Credit Hours : 1+2

IV. Aim of the course

To study the immune mechanisms operating in different parasitic infections and to identify the immunodominant/ immunoprotective antigens for diagnosis and control of parasitic diseases.

Unit I

To study the salient features of immune responses in relation to trematode, cestode, nematode and protozoan infections in livestock. Immune responses to arthropod infestations.

Unit II

Principles and applications of immunodiagnostic methods for parasitic diseases.

Unit III

Standardization of immunodiagnostic methods for parasitic diseases.

Unit IV

Identification of candidate antigens for diagnosis and vaccine development.

V. Practical

Methods for purification of antigens, fractionation and characterization of antigens, identification of candidate antigens as drug targets, raising of hyperimmune sera, development and standardization of immunodiagnostic methods for the diagnosis and control of parasitic infections.

I. Course Title : Molecular Diagnostics and Vaccine Development for Parasitic Diseases

II. Course Code : VPA 606

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles of development of sensitive molecular tools for rapid and field oriented tests. Identification of diagnostic and vaccine targets for detection and control of parasites of livestock and pets.

V. Theory

Unit I

Introduction to molecular taxonomy of parasites.

Unit II

Genome organisation in parasites of veterinary importance. Structure and function of nucleic acids.

Unit III

Basic plan of gene cloning, and expression in heterologous host. Production of recombinant protein and downstream processing for diagnostic/ prophylactic applications.

Unit IV

General concept of protein synthesis. Identification and molecular characterization of proteins of diagnostic/ prophylactic relevance of parasitic origin.

Unit V

Nucleic acid based techniques for genetic characterization and sensitive diagnosis of parasitic infections; PCR, LAMP, Nucleic acid hybridization technique, pyrosequencing, Real Time PCR, DNA Microarray, Microsatellite analysis, RNAi, Reverse Genetic Approaches and their applications.

Unit VI

Hybridoma technology. Principle of production of monoclonal antibody. The diagnostic application of monoclonal antibodies of parasitic infection.

Unit VII

DNA vaccine, Vector vaccine, Recombinant protein based vaccine, Subunit vaccine, Principle and Application.

VI. Practical

Identification, Characterization, and Purification of Recombinant Protein Antigens; SDS-PAGE and Western Blotting, Extraction and quantification of nucleic acid and PCR and related techniques.

I. Course Title : Host Parasite Interactions

II. Course Code : VPA 607

III. Credit Hours : 2+0

IV. Aim of the course

To study different level of host-parasite interactions/ association with an objective of efficient control.

V. Theory

Unit I

Introduction, Distribution of parasites on/ in the host, Morphological adaptation for better survival in/ on the host.

Unit II

Behavioural defences, Host immune responses and Genetic resistance to parasites.

Unit III

Establishment of parasites in immune competent, Susceptible, Intermediate and Abnormal hosts, Chronicity of parasitic infections, Immuno evasive strategies of the parasites and host-parasite equilibrium.

Unit IV

Pathological consequences of host parasite interactions in relation to malnutrition and micronutrient metabolism.

I. Course Title : *In-vitro* Cultivation of Parasites
II. Course Code : VPA 608
III. Credit Hours : 1+2

IV. Aim of the course

Development and standardization of *in-vitro* techniques for parasite cultivation.

V. Theory

Unit I

Introduction, problems and goals of *in-vitro* cultivation of parasites.

Unit II

In-vitro cultivation of genital, Intestinal flagellates and Intestinal ciliates.

Unit III

In-vitro cultivation of intestinal protozoa.

Unit IV

In-vitro cultivation of haemoprotozoa.

Unit V

In-vitro techniques, media and tissue culture for cultivation of helminths and their larval stages.

Unit VI

In-vitro mass rearing and colonization of ticks, flies and other insects.

VI. Practical

Preparation of media, sterilization methods and cultivation of different parasites.

I. Course Title : Emerging and Re-Emerging Parasitic Diseases
II. Course Code : VPA 609
III. Credit Hours : 2+0

IV. Aim of the course

To study the emerging and re- emerging parasitic diseases.

V. Theory

Unit I

Emerging and re-emerging helminthic diseases.

Unit II

Emerging and re-emerging protozoan diseases.

Unit III

Emerging and re-emerging vector- borne diseases.

I. Course Title : Biology and Ecology of Parasites
II. Course Code : VPA 610
III. Credit Hours : 3+0

IV. Aim of the course

Study of the bionomics and ecology of the parasites.

V. Theory

Unit I

Ultrastructure, Physiology, Biochemistry and Bionomics of trematodes and cestodes of veterinary importance.

Unit II

Ultrastructure, Physiology, Biochemistry and Bionomics of nematodes of veterinary importance.

Unit III

Ultrastructure, Physiology, Biochemistry and Bionomics of important arthropod parasites.

Unit IV

Ultrastructure, Physiology, Biochemistry and Bionomics of important protozoan parasites.

Unit V

Ecology related definitions, Environmental changes and ecological disturbances due to natural phenomenon and human interventions (demographic, societal and agricultural changes global warming, floods, hurricanes and pollution.

Unit VI

Principles of Remote Sensing, GIS and their role in Veterinary Parasitology.

I. Course Title : Molecular Veterinary Parasitology

II. Course Code : VPA 611

III. Credit Hours : 2+0

IV. Aim of the course

To give an insight into molecular biology of parasites of veterinary importance, their transmission and control. Molecular, immunological and genetic aspects of common parasites of veterinary importance and vector-host-parasite interaction.

V. Theory

Unit I

Introduction to molecular biology of parasites-Biological molecules (carbohydrate, protein and nucleic acid)- Eukaryotic cell structure, cell membrane and organelles-kinetoplast, apicoplast, cilia, flagella biology-Eukaryotic cell metabolism and cell respiration-Oxidative phosphorylation-anaerobic metabolism in parasites-fatty acid metabolism of parasites-cellular reproduction mendelian genetics in parasites and vectors- Genome of parasites of veterinary importance, genome size- molecular taxonomy-DNA barcoding-phylogenetics.

Unit II

Genetic code- Gene expression-Transcription and Translation-post translational modifications- RNA interference in parasites-CRISPR/ Cas9 inparasites-metagenome-microbiome-transcriptome of parasites-transgenic and para transgenic approach in parasites-drug resistance mechanisms.

Unit III

Molecular biology of helminth parasites such as *Fasciola* spp, *Schistosoma* spp, *Taenia* spp, *Echinococcus* spp, *Toxocara* spp, *Haemonchus* spp., *Dictyocaulus* spp.

I. Course Title : Parasite Epidemiology

II. Course Code : VPA 612

III. Credit Hours : 2+0

IV. Aim of the course

To study the disease and transmission characteristics, descriptive epidemiology of infectious diseases.

V. Theory

Unit I: Introduction to epidemiological concepts

Definitions, aims and uses of epidemiological studies, Approaches of epidemiology (descriptive, analytical and experimental), Types of epidemiological studies along with their advantages and disadvantages, Features of parasitic disease epidemiology. Measures of disease frequency: Morbidity and mortality (Rate, Ratio, Proportional rate), Measures of morbidity (Cumulative incidence, Incidence rate, Attack rate, Prevalence-Point and Period) and mortality (Cumulative Mortality, Mortality rate, Death rate, Age/ Sex/ Breed death rate, Case fatality proportion, Cause specific death rate, etc.). The epidemiological triangle, iceberg concept, endemic stability, herd immunity concept, etc.

Unit II: Methods in epidemiology

Cross-sectional, case control and cohort studies. Techniques of epidemiological surveys.

Types of sampling- Non-probability sampling (target sampling, choice sampling, etc.), Probability sampling (Random samples, systemic sampling, stratified sampling. cluster sampling, etc.). Sample size calculation for different epidemiological and experimental studies.

Unit III: Advances in Epidemiological techniques

Sero-epidemiological methods used in important parasitic disease-Uses and limitations, Properties and Evaluation. Molecular epidemiology- Principles, laboratory methods, Bioinformatics in molecular epidemiology. Serological and molecular epidemiology of important parasites. Remote sensing and geographic information system- Scope and applications in Veterinary Parasitology.

Unit IV: Epidemiology of Important Parasitic Diseases

Epidemiological factors affecting distribution and transmission of important parasitic diseases of animals and birds- Agent Factors/ Disease Patterns, Environment and Disease Patterns, Social Factors and Disease Patterns, etc. Parasitic disease monitoring and evaluation, outbreak investigations and surveillance. Forecasting of parasitic diseases

VI. Suggested Reading

- Abubakar I, Stagg HR, Cohen T and Rodrigues LC. 2016. *Infectious Disease Epidemiology*, 1st Edn, Oxford University Press.
- Alan Gunn and Sarah Jane Pitt. 2012. *Parasitology: An integrated Approach*, 1st Edition, Wiley.
- Angela ER, Taylor and John R Baker. 1968. *In-vitro cultivation of parasites*, 1st Edition, Blackwell Scientific Pub.
- Atkinson CT, Thomas NJ and Hunter DB. 2009. *Parasitic diseases of wild birds*, 1st Edition, John Wiley and Sons, Inc

- Bhatia BB, Pathak KML and Juyal PD. 2014. *Textbook of Veterinary Parasitology*, 3rd Edition, Kalyani Publishers
- Boothroyd JC and Komuniecki R. 1995. *Molecular Approaches to Parasitology*. 1st Edition, Wiley-liss Publication, New York.
- Cohen S and Sadun EH. 1976. *Immunology of Parasitic Infections*, 1st Edition, Blackwell Scientific Publications
- David P Huges, Jacques Brodeur and Frederic Thomas. 2012. *Host manipulation by parasites*, Oxford University Press
- Elizabeth A Zeibeg. 2012. *Clinical Parasitology- A practical approach*. 2nd edition, Elsevier Health Sciences
- GW Krantz and DE Walter. 2009. *A manual of Acarology*, 3rdEdition, Texas Tech University Press
- Hendrix CM and Robinson E. 2017. *Diagnostic Parasitology for Veterinary Technicians*. 5th Edition. St. Louis, Missouri: Elsevier Inc
- Joanne P. 2009. *Advances in Parasitology Natural history of host- parasite interactions-* 1stedition, Vol 68 Academic Press
- Kennedy MW and Harnett W. 2001. *Parasitic nematodes: molecular biology, biochemistry, immunology*, 2nd Edition, CABI Publishing
- Kettle DS. 1995. *Medical and Veterinary Entomology*, 2nd Edition, CAB International
- Levine ND. 1999. *Veterinary Protozoology*, 1st edition, Wiley-Blackwell
- MA Taylor, RL Coop and RL Wall. 2015. *Veterinary Parasitology*, 3rd Edition, Wiley- Blackwell publishers.
- Marr JJ, Nilsen TW and Komuniecki RW. 2003. *Molecular Medical Parasitology*, 1st Edition, Elsevier
- Mehlhorn H. 2016. *Animal Parasites: Diagnosis, Treatment, Prevention*. 1st Edition, . Springer International Publishing
- Pittaway AR. 1991. *Arthropods of Medical and Veterinary Importance*, 1st Edition, CAB International
- Richard Wall and David Shearer. 1997. *Veterinary Entomology*, 1stEdition, Springer, Dordrecht
- Samuel W, Pybus M and Kocan A. 2001. *Parasitic Diseases of Wild Mammals*, 2nd Edition, Iowa State Univ. Press.
- Smyth JD. 1995. *Introduction to Animal Parasitology*, 3rdEdn., Cambridge University Press
- Soulsby EJL. 1982. *Helminths, Arthropods and Protozoa of Domesticated Animals* 7th Edition, Baillière Tindall, London
- Taylor MA, Coop RL and Wall RL. 2015. *Veterinary Parasitology*, 3rdEdn, Wiley- Blackwell Publishers
- Tibor Kassai. 1999. *Veterinary Helminthology*, 1stEdition, Butterworth-Heinemann publishers
- Urquhart GM, Armour J, Duncan JL, Dunn AM and Jennings FW. 1996. *Veterinary Parasitology,* 2nd Edition, Blackwell Science, London, UK
- Wakelin D. 1996. *Immunity to Parasites*. 2nd Edition, Cambridge University Press
- Walker A. 1994. *Arthropods of Humans and Domestic Animal: A Guide to Preliminary Identification*, 1st Edition, Springer Netherlands
- Zajac AM and Conboy GA. 2012. *Veterinary Clinical Parasitology*, 8th Edition, Wiley-Blackwell.
- Protozoological abstracts
- Advances in Parasitology
- Trends in Parasitology
- Experimental Parasitology
- Relevant Research/ Review articles

Course Outline-cum-Lecture Schedule Doctoral Degree Programme

I. Course Title : Advances in Helminthology-I
II. Course Code : VPA 601
III. Credit Hours : 2+1
IV. Aim of the course

Developments in the area of molecular biology, pathogenesis, diagnosis and control of trematodes and cestodes.

Lecture	Topics
Theory	
1-16	Unit I: Advanced studies on taxonomy, molecular biology, pathogenesis and immunology of trematodes and their larval stages.
17-32	Unit II: Advanced studies on taxonomy, molecular biology, pathogenesis and immunology of cestodes and larval stages.
Practicals	
1-9	Morphological, pathological and immunological studies of trematode parasites.
10-16	Morphological, pathological and immunological studies of cestode parasites.

I. Course Title : Advances in Helminthology-II
II. Course Code : VPA 602
III. Credit Hours : 2+1
IV. Aim of the course

To study the recent developments in the area of molecular biology, pathogenesis, diagnosis of nematode parasites and thorny headed worms with an objective of better control.

Lecture	Topics
Theory	
1-28	Unit I: Advanced studies on taxonomy, molecular biology, pathogenesis and immunology of nematode parasites and their larval stages.
30-32	Unit II: Advanced studies on taxonomy, molecular biology, pathogenesis and immunology of thorny-headed worms.
Practicals	
1-14	Morphological, pathological and immunological studies of various nematodes
15-16	Morphological, pathological and immunological studies of various thorny-headed worms

I. Course Title : Advances in Entomology and Acarology
II. Course Code : VPA 603
III. Credit Hours : (2+1)

IV. Aim of the course

To study the recent scientific developments on biology and control measures for arthropods of veterinary importance.

Lecture	Topics
Theory	
1-5	Unit I: Origin, evolution, regional/ seasonal distribution and forecasting of insect and acarine population
6-14	Unit II: Population dynamics of insects and acarines in relation to biotic and abiotic factors
15-21	Unit III: Recent developments pertaining to insects of veterinary importance.
22-27	Unit IV: Recent developments pertaining to arachnids of veterinary importance
28-32	Unit V: Chemical, biological, herbal and immunological control measures and integrated pest management. Modulation of vector competence to transmit parasitic infections using molecular genetics by developing transgenic vectors
Practicals	
1-11	Collection and identification of arthropods; demonstration of the infective stages in vectors
12-16	Immunopathological changes produced in the host tissues due to the infestation of arthropods

I. Course Title : Advances in Protozoology
II. Course Code : VPA 604
III. Credit Hours : (2+1)

IV. Aim of the course

To study the recent developments in molecular biology, pathogenesis, diagnosis and control of protozoan parasites of veterinary importance.

Lecture	Topics
Theory	
1-5	Unit I: Advanced studies on taxonomy, molecular biology, pathogenesis and immunology of intestinal protozoa
6-14	Unit II: Advanced studies on taxonomy, molecular biology, pathogenesis and immunology of haemoprotozoans
15-21	Unit III: Advanced studies on taxonomy, molecular biology, pathogenesis and immunology of tissue and other protozoa
Practicals	
1-16	Morphological, pathological and immunodiagnosis of protozoan diseases.

I. Course Title : Immunology of Parasitic Diseases
II. Course Code : VPA 605
III. Credit Hours : (1+2)

IV. Aim of the course

To study the immune mechanisms operating in different parasitic infections and to identify the immunodominant/ immunoprotective antigens for diagnosis and control of parasitic diseases.

Lecture	Topics
Theory	
1-4	Unit I: To study the salient features of immune responses in relation to trematode, cestode, and nematode infections in livestock
5-7	Unit I: To study the salient features of immune responses to protozoan infections in livestock
8-9	Unit I: To study the salient features of immune responses to arthropod infestations
10-11	Unit II: Principles and applications of immunodiagnostic methods for parasitic diseases
12-13	Unit III: Standardization of immunodiagnostic methods for parasitic diseases
14-16	Unit IV: Identification of candidate antigens for diagnosis and vaccine development
Practicals	
1-16	Methods for purification of antigens, fractionation and characterization of antigens, identification of candidate antigens as drug targets,
17-20	Raising of hyperimmune sera
21-32	Development and standardization of immunodiagnostic methods for the diagnosis and control of parasitic infections

I. Course Title : Molecular Diagnostics and Vaccine Development for Parasitic Diseases

II. Course Code : VPA 606

III. Credit Hours : (2+1)

IV. Aim of the course

To understand the principles of development of sensitive molecular tools for rapid and field oriented tests. Identification of vaccine targets for control of parasites of livestock and pets.

Lecture	Topics
Theory	
1-3	Unit I: Introduction. Molecular taxonomy of parasites
4-8	Unit II: Genome organisation in parasites of veterinary importance. Structure and function of nucleic acids
9-14	Unit III: Basic plan of gene cloning, and expression in heterologous host. Production of recombinant protein and downstream processing for diagnostic/ prophylactic applications
15-17	Unit IV: General concept of protein synthesis. Identification and molecular characterization of proteins of diagnostic/ prophylactic relevance of parasitic origin
18-26	Unit V: Nucleic acid based techniques for genetic characterization and sensitive diagnosis of parasitic infections; PCR, LAMP, nucleic acid hybridization technique, pyrosequencing, real time PCR, DNA microarray, microsatellite analysis, RNAi, reverse genetic approaches and their applications, etc.
27-28	Unit VI: Hybridoma technology. Principle of production of monoclonal antibody. The diagnostic application of monoclonal antibodies of parasitic infection
29-32	Unit VII: DNA vaccine, vector vaccine, recombinant protein based vaccine, subunit vaccine, principle and application

Lecture	Topics
Practicals	
1-11	Identification, characterization, and purification of recombinant protein antigens; SDS-PAGE and western blotting,
12-16	Extraction and quantification of nucleic acid and PCR

I. Course Title : Host Parasite Interactions

II. Course Code : VPA 607

III. Credit Hours : (2+0)

IV. Aim of the course

To study different level of host-parasite interactions/ association with an objective of efficient control.

Lecture	Topics
Theory	
1-6	Unit I: Introduction, distribution of parasites on/ in the host, morphological adaptation for better survival in/ on the host
7-14	Unit II: Behavioural defences, host immune responses and genetic resistance to parasites
15-26	Unit III Establishment of parasites in immune competent, susceptible, intermediate and abnormal hosts, chronicity of parasitic infections, immunoevasive strategies of the parasites and host-parasite equilibrium
27-32	Unit IV: Pathological consequences of host parasite interactions in relation to malnutrition and micronutrient metabolism

I. Course Title : *In-vitro* Cultivation of Parasites

II. Course Code : VPA 608

III. Credit Hours : (1+2)

IV. Aim of the course

Development and standardization of *in-vitro* techniques for parasite cultivation.

Lecture	Topics
Theory	
1-2	Unit I: Introduction, problems and goals of *in-vitro* cultivation of parasites
3-6	Unit II: *In-vitro* cultivation of genital, intestinal flagellates and intestinal ciliates
7-9	Unit III: *In-vitro* cultivation of intestinal protozoa
10-11	Unit IV: *In-vitro* cultivation of haemoprotozoa
12-13	Unit V: *In-vitro* techniques, media and tissue culture for cultivation of helminths and their larval stages
14-16	Unit VI: *In-vitro* mass rearing and colonization of ticks, flies and other insects
Practicals	
1-7	Preparation of media, sterilization methods and cultivation of genital, intestinal flagellates and intestinal ciliates
8-16	Preparation of media, sterilization methods and cultivation cultivation of intestinal and haemoprotozoa protozoa

Lecture	Topics
17-24	Preparation of media, sterilization methods and cultivation cultivation of helminths and their larval stages
25-32	Preparation of media, sterilization methods and cultivation cultivation of ticks, flies and other insects

I. Course Title : Emerging and Re-Emerging Parasitic Diseases

II. Course Code : VPA 609

III. Credit Hours : (2+0)

IV. Aim of the course

To study the emerging and re- emerging parasitic diseases.

Lecture	Topics
Theory	
1-10	Unit I: Emerging and re-emerging helminthic diseases
11-21	Unit II: Emerging and re-emerging protozoan diseases
22-32	Unit III: Emerging and re-emerging vector- borne diseases

I. Course Title : Biology and Ecology of Parasites

II. Course Code : VPA 610

III. Credit Hours : (3+0)

IV. Aim of the course

Study of the bionomics and ecology of the parasites.

Lecture	Topics
Theory	
1-5	Unit I: Ultrastructure, physiology, biochemistry and bionomics of trematodes of veterinary importance
6-10	Unit I: Ultrastructure, physiology, biochemistry and bionomics of cestodes of veterinary importance
11-20	Unit II: Ultrastructure, physiology, biochemistry and bionomics of nematodes of veterinary importance
21-30	Unit III: Ultrastructure, physiology, biochemistry and bionomics of important arthropod parasites
31-40	Unit IV: Ultrastructure, physiology, biochemistry and bionomics of important protozoan parasites
41-45	Unit V: Ecology related definitions, Environmental changes and ecological disturbances due to natural phenomenon and human interventions (demographic, societal and agricultural changes global warming, floods, hurricanes and pollution
46-48	Unit VI: Principles of Remote Sensing, GIS and their role in Veterinary Parasitology

I. Course Title : Molecular Veterinary Parasitology

II. Course Code : VPA 611

III. Credit Hours : (2+0)

IV. Aim of the course

To give a deep insight into molecular biology of parasites of veterinary importance, their transmission and control. Molecular, immunological and genetic aspects of selected parasites of veterinary importance and vector-host-parasite interaction.

Lecture	Topics
Theory	
1-2	Unit I: Introduction to molecular biology of parasites-Biological molecules (carbohydrate, protein and nucleic acid)
3-6	Unit I: Eukaryotic cell structure, cell membrane and organelles- kinetoplast, apicoplast, cilia, flagella biology
7-11	Unit I: Eukaryotic cell metabolism and cell respiration-Oxidative phosphorylation-anaerobic metabolism in parasites-fatty acid metabolism of parasites-cellular reproduction mendelian genetics in parasites and vectors
12-16	Unit I: Genome of parasites of veterinary importance, genome size- molecular taxonomy-DNA barcoding-phylogenetics
17-22	Unit II: Genetic code- Gene expression-Transcription and Translation-post translational modifications- RNA interference in parasites-CRISPR/ Cas9 in parasites
23-27	Unit II: Metagenome-microbiome-transcriptome of parasites-transgenic and para transgenic approach in parasites-drug resistance mechanism and genetics
28-32	Unit III: Molecular biology of selected helminth parasites (*Fasciola* spp, *Schistosoma* spp, *Taenia* spp, *Echinococcus* spp, *Toxocara* spp, *Haemonchus* spp, *Dictyocaulus* spp etc)

I. Course Title : Parasite Epidemiology

II. Course Code : VPA 612

III. Credit Hours : (2+0)

IV. Aim of the course

To study the disease and transmission characteristics, descriptive epidemiology of infectious agents.

Lecture	Topics
Theory	
1-4	Unit I: Introduction to epidemiological concepts-Definitions, aims and uses of epidemiological studies, approaches of epidemiology (descriptive, analytical and experimental), types of epidemiological studies along with their advantages and disadvantages, features of parasitic disease epidemiology
5-8	Unit I: Introduction to epidemiological concepts- Measures of disease frequency: Morbidity and mortality (Rate, Ratio, Proportional rate), Measures of morbidity (Cumulative incidence, Incidence rate, Attack rate, Prevalence-Point and Period) and mortality (Cumulative Mortality, Mortality rate, Death rate, Age/ Sex/ Breed death rate, Case fatality proportion, Cause specific death rate, etc.). The epidemiological triangle, iceberg concept, endemic stability, herd immunity concept, etc.
9-12	Unit II: Methods in epidemiology Cross-sectional, case control and cohort studies. Techniques of epidemiological surveys Types of sampling- Non-probability sampling (target sampling, choice sampling, etc.), Probability sampling (Random samples, systemic sampling, stratified sampling. cluster sampling, etc.). Sample size calculation for different epidemiological and experimental studies

Lecture	Topics
13-16	Unit II: Methods in epidemiology Epidemiological Measures of Association-Strength of association (Relative risk, odds ratio), Effect of association (Attributable rate), effect/ importance of association
17-20	Unit III: Advances in Epidemiological techniques Sero-epidemiological methods used in important parasitic disease-Uses and limitations, properties and evaluation. Molecular epidemiology- Principles, laboratory methods, bioinformatics in molecular epidemiology
21-24	Unit III: Advances in Epidemiological techniques Serological and molecular epidemiology of important parasites. Remote sensing and geographic information system- Scope and applications in Veterinary Parasitology
25-28	Unit IV: Epidemiology of Important Parasitic Diseases Epidemiological factors affecting distribution and transmission of important parasitic diseases of animals and birds- Agent Factors/ Disease Patterns, Environment and Disease Patterns, Social Factors and Disease Patterns, etc.
29-32	Unit IV: Epidemiology of Important Parasitic Diseases Parasitic disease monitoring and evaluation, outbreak investigations and surveillance Forecasting of parasitic diseases

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Para-Clinical Subjects
– Veterinary Public Health and Epidemiology

Course Title with Credit Load
M.V.Sc. in Veterinary Public Health and Epidemiology

Course Code	Course Title	Credit Hours
VPE 501	Concepts in Veterinary Public Health and One Health*	2+0
VPE 502	Zoonoses-I*	2+1
VPE 503	Zoonoses-II*	2+1
VPE 504	Principles of Epidemiology*	2+1
VPE 505	Hygiene and Safety of Foods of Animal and Aquatic Origin*	2+1
VPE 506	Food-borne Infections and Intoxications	2+1
VPE 507	Food Safety Standards, and Regulations	2+1
VPE 508	EnvironmentalHygiene and Safety	2+1
VPE 509	Applied Epidemiology	2+1
VPE 510	Biosecurity, Bioterrorism and Disaster Management	2+0
VPE 511	Laboratory Techniques in Veterinary Public Health*	0+3
VPE 591	Master’s seminar*	0+1
VPE 599	Master’s research	30

*Core courses

Course Contents
M.V.Sc. in Veterinary Public Health and Epidemiology

I. Course Title : Concepts in Veterinary Public Health and One Health
II. Course Code : VPE 501
III. Credit Hours : 2+0
IV. Aim of the course

To equip students with One Health concepts and advanced skills in public health aspects of infectious disease, intelligence, response, prevention and mitigation.

V. Theory

Unit I

VPH administration; organization, administration and implementation of VPH services/ programs; Structure and function of VPH agencies/ organizations of national and international importance. VPH team, administration and functions; responsibilities of veterinarians in public health team.

Unit II

Definition: One Health. Historical emergence of the concept. Scope, Objective and Area of activities of One Health. Strategic frame-work. Purpose for creation of Veterinary Public Health and Epidemiology –NET.

Unit III

Global burden of disease, Coordinated and systemic disease control response, Ecosystem, Urbanization intensive agriculture and animal husbandry practices, Host-pathogen interaction, Anti-microbial resistance and climate change.

VI. Suggested reading

- Calvin W Schwabe. 1984. *Veterinary Medicine and Human health*. Williams and Wilkins
- Sherikar AT, Bachhil VN and Thapliyal DC. 2013. *Text book of Elements of Veterinary Public Health*, ICAR, Govt. of India.
- Zinsstag J, Schelling E, Waltner-Toews D, Whittaker M and Tanner M. 2015. *One Health: the theory and practice of integrated health approaches*. CABI.

I. Course Title : Zoonoses-I
II. Course Code : VPE 502
III. Credit Hours : 2+1
IV. Aim of the course

To impart knowledge on Epidemiology, Etiology, Transmission pattern, Public health significance, Diagnosis and Management of important bacterial, Mycotic and Chlamydial zoonotic diseases.

V. Theory

Unit I

Definition and classification, Factors affecting the occurrence of zoonoses; Disease management strategies, Disease burden on population and socioeconomic impacts.

Unit II

History, Etiology, Epidemiology, Diagnosis and management of important Bacterial zoonoses, viz., Anthrax, Brucellosis, Tuberculosis, Leptospirosis, Salmonellosis, Borreliosis, Cat scratch disease, Glanders, Lyme disease, Malidiosis, Streptococcosis, Plague, Rat bite fever, Tetanus, Tularemia, Yersiniosis, Staphylococcosis, Vibriosis, Listeriosis, Campylobacteriosis and others.

Unit III

History, Etiology, Epidemiology, Diagnosis and Management of important Mycotic zoonoses, viz., Dermatophytosis, Blastomycosis, Coccidioidomycosis, Cryptococcosis, Histoplasmosis, Aspergillosis, Candidiasis, Rhinosporidiosis, Sporotrichosis and others.

Unit IV

History, Etiology, Epidemiology, Diagnosis and Management of Chlamydiosis (Psittacosis and Ornithosis) and Prions diseases, viz., Creutzfeldt-Jakob Disease (CJD); Variant Creutzfeldt-Jakob Disease (vCJD), Kuru. Bovine Spongiform Encephalopathy (BSE), Chronic Wasting Disease (CWD) and Scrapie.

VI. Practical

Isolation and identification of important Bacterial, Mycotic and Chlamydial agents of public health significance from host, Vehicle and environment.

VII. Suggested reading

- Bauerfeind R, Graevenitz AV, Kimmig P, Schiefer HG, Schwarz T, Slenczka W and Zahner H. 2016. *Zoonoses: infectious diseases transmissible from animals and humans* (No. Ed. 4). American Society for Microbiology (ASM).
- Mahendra Pal.Zoonoses.
- Narayan KG *Epidemiology, Diagnosis and Management of Zoonoses.*
- Pedro N Acha and Boris Szyfres. *Zoonoses and Communicable Diseases Common to Man and Animals.*
- Seyedmousavi S, De Hoog GS, Guillot J and Verweij PE. 2018. *Emerging and Epizootic Fungal Infections in Animals*. Springereds.
- Thapliyal DC. 1999. *Diseases of animals transmissible to man.* 1st ed. International Book Distributing Company, Lucknow.
- *Zoonoses: Recognition Control and Prevention* (Martin E, Jones EH, Hubbart WT and Hagstard HV)

I. Course Title : Zoonoses-II

II. Course Code : VPE 503

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on Epidemiology, Etiology, Transmission pattern, Public health significance, Diagnosis and Management of important Viral, Rickettsial and Parasitic zoonotic diseases.

V. Theory

Unit I

Disease burden, History, Etiology, Epidemiology, Transmission pattern, Diagnosis and management of important viral zoonoses, viz., Japanese encephalitis, Tick-borne encephalitis, Encephalomyelitis, Rabies, Influenza, KFD, Rift valley fever, Chickungunya, FMD, and Enteroviruses.

Unit II

Disease burden, History, Etiology, Epidemiology, Transmission pattern, Diagnosis and management of important viral zoonoses, viz., Crimean-Congo haemorrhagic fever, Dengue, West-Nile fever, Yellow fever, Rift-valley fever, Equine encephalitis, Louping ill, Ebola, Marburg, Hantavirus, Zika, Hendra, Nipah and Corona viruses.

Unit III

Disease burden, History, Etiology, Epidemiology, Transmission pattern, Diagnosis and Management of important Rickettsial zoonoses, viz., Q fever, Typhus fever group.

Unit IV

Disease burden, Etiology, Host range, Epidemiology, Transmission pattern, Diagnosis and Management of important Parasitic zoonoses, viz., Hydatidosis, Taeniosis, Trichinosis, Fascioliosis, Fasciolopsiosis, Toxoplasmosis, Trypanosomosis, Cryptosporidiosis, Cysticercosis, Leishmaniosis, Sarcocystosis, Dracunculosis, Paragonimosis and Diphylobothriosis.

VI. Practical

Isolation and identification methods for important viral and parasitic agents of public health significance from host, vehicle and environment.

VII. Suggested Reading

- Bauerfeind R, Graevenitz AV, Kimmig P, Schiefer HG, Schwarz T, Slenczka W and Zahner H. 2016. *Zoonoses: infectious diseases transmissible from animals and humans* (No. Ed. 4). American Society for Microbiology (ASM).
- Mackie and Mc. Cartney. *Practical Medical Microbiology*.
- Parija SC. *Text book of Medical Parasitology*.
- Pedro N Acha and Boris Szyfres. *Zoonoses and Communicable Diseases Common to Man and Animals*.
- Soulsby JL *Helminthes, Arthropods and Protozoa of Domesticated Animals*.
- Steele JL. *CRC Handbook series in Zoonoses*.
- Thapliyal DC. 1999. *Diseases of animals transmissible to man*. 1st ed. International Book Distributing Company, Lucknow.

I. Course Title : Principles of Epidemiology

II. Course Code : VPE 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the principles and concepts employed for epidemiological investigation of the diseases.

V. Theory

Unit I

Historical perspective and scope of veterinary epidemiology. Theories of disease causation and advancement in the concepts of disease causation, Iceberg concept. Koch's postulates of disease causation. Epidemiological tringles, Disease causing wheels, webs and pies.

Unit II

Definitions: Epidemic, Endemic, Pandemic and Sporadic diseases. Qualitative and quantitative approaches to epidemiology. Measurement of disease. Endemic stability and herd immunity, Basic reproductive ratio, Trends and spatial distribution of disease, Epidemic curve and their utility.

Unit III

Transmission of disease and role of ecology in maintenance of disease agents. Type of epidemiological methods. Landscape and molecular methods used in the epidemiological investigation.

Unit IV

Epidemiological Studies-Observational (Case-control, cohort and cross-sectional studies) and experimental studies (field and clinical trials). Disease surveys, monitoring and surveillance. Epidemiological data bases.

Unit V

Definition, scope and limitation of serological epidemiology and interpretation of results. Characteristics of ideal serological test, multiple testing and evaluation of tests. Investigation of disease outbreaks. Strategies of disease control and eradication.

VI. Practical

Data collection from various sources, analysis and interpretation. Serum collection method demonstration. Analytical diagnostic and relative sensitivity and specificity calculation. use of software for data analysis.

VII. Suggested Reading

- Elliot P, Wakefield JC, Best NG and Briggs DJ. 2000. *Spatial Epidemiology: methods and applications*; Oxford University Press.
- Martin SW, Meek AH and Willeberg P. 1986. *Veterinary Epidemiology: Principles and methods*. IOWA State University Press/ Ames, Iowa. USA.
- Pfeiffer D. 1998. *Veterinary Epidemiology. An Introduction. Institute of Veterinary, Animal and Biomedical Sciences*. Massey University, Palmerston, New Zealand.
- Salman M. 2008. *Animal disease surveillance and survey systems: methods and applications.* John Wiley and Sonsed.
- Thrusfield M. 1995. *Veterinary Epidemiology*: Blackwell Science Ltd. Oxford, UK.

I. Course Title : Hygiene and Safety of foods of Animal and Aquatic origin

II. Course Code : VPE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students about principles of food hygiene and quality improvement practices.

V. Theory

Unit I

Principles of food hygiene in relation to foods of animal and aquatic origin. Importance of food hygiene in public health. Impact of environmental sanitation and other factors on food quality. General principles of prevention of food-borne illnesses, risk analysis.

Unit II

Importance and objectives of milk hygiene. Hygienic production, Handling, Transportation, Storage and marketing of milk. Mastitis. Milk spoilage and preservation. Milk-borne diseases of public health significance. Milk allergy-lactose intolerance. Residues of pesticide and antibiotics in milk and its impact on human health. Milk spoilage. Milk adulteration, synthetic milk. Milk plant hygiene and sanitation.

Unit III

Objectives and importance of meat hygiene. Hygienic practices at farm and during transportation of food animals including poultry. Hygienic meat production-an overview. Adulteration. Speciation, spoilage and preservation of meat. Meat-borne diseases of public health significance. Treatment and safe disposal of slaughter-house by-products. Hygienic practices in abattoirs.

Unit IV

Fish, fisheries and ichthyology: an introduction. Environmental factors affecting aquatic food hygiene. Hygienic production, Handling, Preservation, Transportation and marketing of aquatic foods. Microbiology and Spoilage of aquatic foods. Safe disposal of fish byproducts. Fish-borne diseases of public health significance.

VI. Practical

Collection of meat/ milk/ egg/ fish samples for determination of physical as well as microbiological quality. Examination of meat/ milk samples for possible adulteration.

VII. Suggested reading

- FAO (Manual No. 79). *Manual on simple methods of Meat preservation.*
- Marriott NG, Schilling MW and Gravani RB. 2018. *Principles of Food sanitation*; Springer.
- Nollet LM and Toldrá F. 2016. *Safety Analysis of Foods of Animal origin*, CRC Press.ed.
- Norer R. 2016. *Genetic Technology and Food Safety*; Springer International Publishinged.
- Wro and Bruno. *Fish Disease and Disorders – Viral Bacterial and Fungal Infections.*

I. Course Title : Food-borne Infections and Intoxications

II. Course Code : VPE 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about illnesses arising due to consumption of contaminated foods.

V. Theory

Unit I

Definition: Food borne infection, Food intoxication, Bacterial toxins, Toxi-infection, etc. Classification, Epidemiology, Disease burden and Economics of food-borne diseases. Reservoirs of food-borne pathogens and its mode of transmission. Vehicles of pathogens. Measures employed for prevention and control of food-borne diseases. Food- poisoning outbreak investigation and management.

Unit II

Epidemiology, Economic, Diagnosis and Management of bacterial food-borne infections and intoxications due to *Salmonella*, *Campylobacter*, *Clostridium*, *Staphylococcus*, *Listeria monocytogenes*, *Vibrio parahaemolyticus*, *E.coli*, *Bacillus cereus*, *Shigella*, *Yersinia enterocolitica* and others. Types of bacterial toxins and its manifestations.

Unit III

Epidemiology, Economics, Diagnosis and Management of food-borne Viral pathogens: Hepatitis viruses, Entero-viruses, Noroviruses, Rotaviruses and other. Food- borne parasitic and rickettsial infections.

Unit IV

Illness due to food additives, seafood toxins, mycotoxins, biocides, plant origin toxins, heavy metals, veterinary drugs, hormones, etc. in foods. Anti-microbial resistance (AMR) in food-borne pathogens-definition, current status, factors responsible, mechanism of resistance, mode of transmission and control.

VI. Practical

Food-borne disease outbreak investigation. Detection, characterization and quantitation of food-borne pathogens, toxins, antibiotics, pesticides and additives in foods.

VII. Suggested reading

- Cliver DO, Potter M and Riemann HP. 2011. *Food borne Infections and Intoxications*; Elsevier.
- D'Mello JPF. *Food Safety-Contaminants and Toxins*.
- Jay JM, Loessner MJ and Golden DA. 2008. *Modern food microbiology*; Springer Science and Business Media.
- Hubbert WT. *Food Safety and Quality Assurance-Foods of Animal Origin*.
- Vernam AH. 1991. *Food-borne pathogens*; Wolfe Publishing Ltd, London.

I. Course Title : Food Safety Standards and Regulations

II. Course Code : VPE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with various parameters responsible for the production of hygienic and safe foods for human consumption.

V. Theory

Unit I

Indicators of food quality and spoilage (biological and others). Food plant hygiene and sanitation. Hurdle technique and its relevance. Microbiological criteria for food quality.

Unit II

Food standards- National, International, Private standards. GSP, GMP, HACCP and ISO 22000, etc. Genesis of food safety standards, Mechanism of food safety standards formulation, Agencies associated in food standard formulation, Role of WTO, FSSAI, BIS and others in standard formulation. National and international regulations and legislation enacted for quality food production.

Unit III

Food safety regulations in reference to the Pesticides, Veterinary drugs residues, Heavy metals, Hormones and others (MRLs, ADIs, etc.). Traceability system, Organic food production.

VI. Practical

Detection of Pesticides, Veterinary drug residues, Heavy metal in food samples. Visits to the various food processing units for examining the compliance of HACCP/ FSSAI regulations and other standards. Microbiological assessment of cleanliness of surface and equipment in abattoir/ meat/ milk plant

VII. Suggested Reading

- Fortin ND. 2016. *Food Regulation: law, science, policy, and practice*. John Wiley and Sons.
- Joint FAO. 2004. *Codex alimentarius: food hygiene basic texts* (No. Ed. 3). Food and Agriculture Organization of the United Nations.
- Josling TE, Roberts D and Orden D. 2004. *Food Regulation and Trade: toward a safe and open global system*; Peterson Institute Press.
- Van Der Meulen and Bernd. 2011. *Private Food Law: Governing food chains through contract law, self-regulation, private standards, audits and certification Schemes*. The Netherlands: Wageningen Academic Publishers.
- Vos E. 1999. *Institutional frameworks of community health and safety legislation: Committees, agencies, and private bodies*. Hart.

I. Course Title : Environmental Hygiene and Safety

II. Course Code : VPE 508

III. Credit Hours : 2+1

IV. Aim of the course

To impart education about environment, environmental pollutants and its manifestations on animal and human health.

V. Theory

Unit I

Introduction to environment, Environmental hygiene, Pollutants and its impact on animal/ human health. Green-house gasses and its effect. Microbial pollution. Environmental risk assessment and management.

Unit II

Nature and characteristics of various environmental pollutants. Pollutions of soil, air and water and its effects on health. Impact of noise pollution on health.

Unit III

Genetic risk from Environmental agents, Health problems due to nuclear energy, Microwave, Electro-magnetic and other radiation pollution, Environmental estrogens, Pesticides pollution. Industrial pollution as well as pollution due to plastic and petrochemical products.

Unit IV

Role of live-stock in environmental pollution, Dissemination of excreted pathogens, animal-waste and human risk, principles of safe disposal of bio-medical waste and recycling of wastes

Unit V

Contamination of environment with heavy metals, pesticides, veterinary drug residues and its impact on human health. National and international pollution control agencies and its role in management of environmental pollution. Regulations on control of environmental pollution.

VI. Practical

Determination of portability of drinking water, Estimation and detection of pathogenic microbes in water, air, soil, animal products, sewage, and animal waste; Visit of sewage and waste disposal plants/ sites.

VII. Suggested reading

- Fairman R, Mead CD and Williams WP. 1998. *Environmental risk assessment: approaches, experiences and information sources*.
- Frumkin H. 2016. *Environmental health: from global to local*. John Wiley and Sons.ed.
- Levy BS. 2006. *Occupational and environmental health: recognizing and preventing disease and injury*. Lippincott Williams and Wilkins. ed.
- Linkov I and Ramadan AB. 2004. *Comparative risk assessment and environmental decision making* (Vol. 38). Springer Science and Business Media.Ed.
- Ray M. *Environmental Pollution: Impact of technology on quality of life*.
- Richard B Philp. *Environmental Hazards and Human Health*

I. Course Title : Applied Epidemiology
II. Course Code : VPE 509
III. Credit Hours : 2+1

IV. Aim of the courses

To impart education on applied aspects of epidemiology.

V. Theory

Unit I

Introduction to applied epidemiology. Models, modelling and types of models. Epidemiological and economic models. Principles and classification of models. Deterministic and stochastic models. Empirical and explanatory models. Application of models in disease forecasting. Modelling in disease prevention and control.

Unit II

Disease occurrence, Ecology of disease, Monitoring and surveillance. Outbreak investigation protocol. Path, regression and discriminate analyses. Time series analysis and analysis of variance.

Unit III

Animal disease economics (cost-benefit analysis, internal rate of return, payback period, partial budgeting), decision analysis. Bayesian analysis. Monte-Carlo and Markovian processes and system evaluation. Uses of multivariate analysis.

Unit IV

Disease outbreaks, Participatory epidemiology, Disease reporting system, Tracing and notification. Disease control strategies, Risk assessment, Exotic diseases, Trans-boundary diseases, Vaccination.

Unit V

Definition; Disease intelligence. Tele-epidemiology. Remote sensing, Geographic information system, Disease surveillance and Early warning system.

VI. Practical

Survey, Sampling and Data presentation. Measurements of disease occurrence, Outbreak investigation and reporting. Use of epidemiological software.

VII. Suggested Reading

- Brownson RC and Petitti DB. 1998. *Applied Epidemiology: theory to practice*. Oxford University Press.
- Durr PA and Gatrell AC. 2004. *GIS and spatial analysis in veterinary science*. Cabi. Ed.
- Toma B, Dufour B, Sanaa M, Benet JJ, Moutou F, Louza A and Ellis P. 1999. *Applied Veterinary Epidemiology and the control of disease in populations*. 7 Avenue du Général de Gaulle.
- Twisk JW. 2013. *Applied longitudinal data analysis for epidemiology: a practical guide*. Cambridge university press.

I. Course Title : Bioterrorism and Disaster Management

II. Course Code : VPE 510

III. Credit Hours : 2+0

IV. Aim of the course

To equip the students with latest information of various types of disaster and its management, biological weapons used in bioterrorism, biological hazards and remedial measures, biomedical hazards and their prevention.

V. Theory

Unit I

Definition: Bioterrorism. Major agents used as biological weapons, Hazard analysis and combating bioterrorism. Bio-ethics and social ethics, Advisory role of veterinarians during such events.

Unit II

Definitions, Natural and man- made disaster, Impact analysis and classification of disaster scale, Essential preparations to manage disaster, Role of central, State and Local government bodies in disaster management, Role of veterinarians/ veterinary public health personnel during emergency/ Disaster and sequence of emergency medical services.

Unit III

Effect of natural disasters like floods, Prolonged draughts, Forest fires, Earthquakes, Tsunami and Tidal damages, Storms, etc. on human as well as animal population, post-disaster disease susceptibility and remedial measures.

Unit IV

Biosecurity– definition, importance, methods used for pathogen inventory, Food processing/ quarantine units/ animals/ poultry farms, etc. Biomedical hazards and biosafety in the laboratories. Occupational health risk and its management.

VI. Suggested Reading

- Antosia RE and Cahill JD. 2006. *Handbook of bioterrorism and disaster medicine*. Springer.ed.
- Hodgkinson PE and Stewart M. 1991. *Coping with catastrophe: A handbook of disaster management*. Taylor and Frances/ Routledge.
- Van De Walle B, Turoff M and Hiltz SR. 2014. *Information systems for emergency management*. Routledge.
- Van Oosterom P, Zlatanova S and Fendel E. 2006. *Geo-information for disaster management*. Springer Science and Business Media.Ed.

I. Course Title : Laboratory Techniques in Veterinary Public Health

II. Course Code : VPE 511

III. Credit Hours : 0+3

IV. Aim of the course

To impart practical exposure of laboratory techniques in Veterinary Public Health to the students.

V. Practical

Unit I

General practices: Use of PPE (Personal Protective Equipment) and biosafety cabinets, Preparation of glass-wares, cultural media, buffer solution, solutions of different molarity and other laboratory materials. Sampling methods for biological materials. Quality analysis of milk, meat, water and other food materials and others.

Unit II

Microbiological techniques: Plate counts, Enumeration and isolation of psychrophilic, Thermophilic and thermoduric organisms in food samples, Enumeration, isolation and identification of important food-borne pathogens, Detection of bacterial toxin involved in food-poisoning, Detection of viral pathogens in various samples. Isolation, identification and enumeration of yeast/ molds/ spores in food samples.

Unit III

Immunological/ Serological and electrophoretic techniques: AGPT, Precipitation tests, Agglutination test, Haem-agglutination test, Polyacrylamide gel electrophoresis, Counter immuno- gel electrophoresis, ELISA, FAT, Intra-dermal inoculation tests and others.

Unit IV

Detection and quantification of residues of pesticides and drugs using immunological and chromatographic methods.

Unit V

Methods for isolation and quantitation of genomic DNA/ RNA from bacterial and other biological specimens using Latest molecular techniques and others. Laboratory records and log books of equipment.

VI. Suggested Reading

- Bremner A and Jhonston M. *Poultry Meat Hygiene and Inspection*.
- Duncan JR and Prasse KW. 1986. *Veterinary Laboratory Medicine* (No. Ed. 2). Iowa State University Press.
- Garvin ML *Infectious Waste Management-A practical guide*.
- Gradwohls' *Clinical Lab Methods and Diagnosis*.
- Jerome KR. 2016. *Lennette's laboratory diagnosis of viral infections*. CRC (Sonnenwirth and Jarett) Press. ed.
- Prasad J and Neeraj. *Principles and Practice of Animal Health and Hygiene*.
- Rupprecht C and Nagarajan T. 2015. *Current laboratory techniques in rabies diagnosis, research and prevention* (Vol. 2). Academic Press.ed.

Course Outline-cum-Lecture Schedule for Master Degree Programme

I. Course Title : Concepts in Veterinary Public Health and One Health
II. Course Code : VPE 501
III. Credit Hours : 2+0

Lecture(s)	Topic
Theory	
1-2	VPH administration: organization, administration and implementation of VPH services/ programs
3-4	Structure and function of VPH agencies/ organizations at national and international levels
5-6	VPH team; administration and functions; responsibilities of veterinarians in the public health team
7	One Health: Definition, historical emergence of the concept. Scope, objectives and activities of One Health
8-9	One Health Umbrella, stewardship of VPH for the implementation of one health activities
10	Strategic framework of One Health activities
11-12	One Health approaches for control of zoonoses and ensuring food safety
13	One Health approaches for combating antimicrobial resistance
14	One health policies, legislations and research
15-16	Transdisciplinary approach of eco-health concepts; one health integrating policy, science and practices
17	Genesis ofveterinary public health and epidemiology as a discipline
18-19	Global burden of disease – need for inter-sectoral and inter-disciplinary collaboration
20-21	Coordinated and systemic disease control response
22	Ecosystems, urbanization, intensive agriculture and animal husbandry practices
23	Exploring host-pathogen interactions for better multi-sectoral responses at the human-animal-ecosystem interface addressing food safety, zoonoses, and other public health threats
24	Climate change and need for multi-sectoral and collateral/ multi-lateral collaborations
25	Sharing of epidemiological data and laboratory information on zoonoses and food safety problems across sectors
26	Integration of one health approaches for the promotion of ecosystem and wildlife health
27	Organizations and agencies working to mitigate health challenges based on ‘One Health Approach’
28	One Health Initiative as a union of human and veterinary medicine
29	Local, regional, national and international One Health networks
30	One Health in the paradigm of preventive health care and herd health management
31-32	Case study that integrate veterinary public health with one health

I. Course Title : Zoonoses-I
II. Course Code : VPE 502
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Definition and classification of zoonoses
2	Factors affecting occurrence of zoonoses
3	Disease management strategies
4	Zoonotic disease burden on population
5	Socioeconomic impact of zoonoses
6	Public health implications of bacterial zoonoses
7-9	History, etiology, epidemiology, diagnosis and management of anthrax, brucellosis and tuberculosis
10	History, etiology, epidemiology, diagnosis and management of leptospirosis
11-12	History, etiology, epidemiology, diagnosis and management of plague, rat bite fever, borreliosis and lyme disease
13-14	History, etiology, epidemiology, diagnosis and management of glanders, malidiosis, streptococcosis
15	History, etiology, epidemiology, diagnosis and management of salmonellosis
16	History, etiology, epidemiology, diagnosis and management of campylobacteriosis
17	History, etiology, epidemiology, diagnosis and management of yersiniosis and vibriosis
18-19	History, etiology, epidemiology, diagnosis and management of tetanus, listeriosis, staphylococcosis and tularemia, etc.
20	History, etiology, epidemiology, diagnosis and management of cat scratch disease,
21	History, etiology, epidemiology, diagnosis and management of mycotic zoonoses – General considerations
22-23	History, etiology, epidemiology, diagnosis and management of dermatophytosis, blastomycosis and coccidioidomycosis
24	History, etiology, epidemiology, diagnosis and management of cryptococcosis and histoplasmosis
25	History, etiology, epidemiology, diagnosis and management of aspergillosis and candidiasis
26	History, etiology, epidemiology, diagnosis and management of rhinosporidiosis, sporotrichosis and others
27	History, etiology, epidemiology, diagnosis and management of chlamydiosis (psittacosis and ornithosis)
28	History, etiology, epidemiology, diagnosis and management of prion diseases - Creutzfeldt-Jakob Disease (CJD) and variants
29-30	History, etiology, epidemiology, diagnosis and management of prion diseases - bovine spongiform encephalopathy (BSE), kuru, chronic wasting disease (CWD) and scrapie
31-32	Case studies pertaining to important zoonoses of India
Practical	
1.	Sampling and laboratory preparedness for handling zoonotic bacterial and fungal agents
2.	Isolation, identification and characterization of agents of *Bacillus anthracis* and zoonotic *Mycobacterium* species.
3.	Isolation, identification and characterization of zoonotic *Streptococcus* and *Staphylococcus* species.

Lecture(s)	Topic
4.	Isolation, identification and characterization of agents of *Clostridium tetani* and zoonotic *Listeria* species.
5.	Isolation, identification and characterization of zoonotic *Leptospira* and *Borrelia* species.
6.	Isolation, identification and characterization of *Burkholderia mallei* and *Burkholderia pseudomallei*
7.	Isolation, identification and characterization of zoonotic *Brucella* species
8.	Isolation, identification and characterization of food-borne and zoonotic *Salmonella* species including serotyping of isolates
9.	Isolation, identification and characterization of zoonotic *Yersinia* and *Vibrio* species
10.	Isolation, identification and characterization of zoonotic agents responsible for rat bite fever, cat scratch disease, tularemia, etc.
11.	Isolation and identification of zoonotic fungal agents of public health significance from the host, vehicle and environment associated with superficial mycozoonoses
12.	Isolation, identification and characterization of important mycotic agents of public health significance associated with systemic mycozoonoses – blastomycosis and coccidioidomycosis
13.	Isolation, identification and characterization of important mycotic agents of public health significance associated with systemic mycozoonoses – cryptococcosis and histoplasmosis
14.	Isolation, identification and characterization of important mycotic agents of public health significance associated with systemic mycozoonoses - aspergillosis, candidiasis, rhinosporidiosis and sporotrichosis
15.	Isolation, identification and characterization of important chlamydial agents of public health significance from host, vehicle and environment
16.	Laboratory detection of prion diseases

I. Course Title : Zoonoses-II
II. Course Code : VPE 503
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1-3	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of Japanese encephalitis, Tick-borne encephalitis and Encephalomyelitis
4-8	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of Rabies, Influenza, KFD, Rift valley fever andChikungunya
9	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of FMD and Enteroviruses
10	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of Crimean-Congo haemorrhagic fever
11-12	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of Dengue, West-Nile fever and Yellow fever
13	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of Rift-valley fever, Louping ill
14	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of equine encephalitis
15-16	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis

Lecture(s)	Topic
	and management of Ebola, Marburg and Hantavirus
17-18	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of Hendra Nepah and Zika virus
19	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of corona viruses
20	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of important rickettsial zoonoses
21	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of Q fever
22	Disease burden, history, etiology, epidemiology, transmission pattern, diagnosis and management of typhus fever group
23-25	Disease burden, etiology, host range, epidemiology, transmission pattern, diagnosis and management of hydatidosis, taeniosis/ cysticercosis and Trichinosis
26	Disease burden, etiology, host range, epidemiology, transmission pattern, diagnosis and management of fasciolosis and fasciolopsiosis
27	Disease burden, etiology, host range, epidemiology, transmission pattern, diagnosis and management of Toxoplasmosis
28-29	Disease burden, etiology, host range, epidemiology transmission pattern, diagnosis and management of Trypanosomosis and Leishmaniosis
30	Disease burden, etiology, host range, epidemiology, transmission pattern, diagnosis and management of Cryptosporidiosis
31	Disease burden, etiology, host range, epidemiology, transmission pattern, diagnosis and management of Sarcocystosis and Dracunculiosis
32	Disease burden, etiology, host range, epidemiology, transmission pattern, diagnosis and management of Paragonimiosis and Diphylobothriosis
Practical	
1.	Detection and characterization of zoonotic viral and parasitic agents from host, vehicle, environment, etc. - Sampling and laboratory preparations
2.	Detection and characterization of Japanese encephalitis, chikungunya and dengue viruses
3.	Detection and characterization of encephalomyelitis, Rift valley fever, West-Nile fever, yellow fever, louping ill and equine encephalitis viruses
4.	Detection and characterization of rabies and influenza viruses
5.	Detection and characterization of FMD and entero-viruses
6.	Detection and characterization of KFD, tick-borne encephalitis and Crimean-Congo haemorrhagic fever viruses
7.	Detection and characterization of zoonotic Ebola, Marburg, Hanta, Zika, corona, Hendra and Nipah viruses
8.	Isolation, identification and characterization of agents responsible for Q fever, typhus fever and other rickettsial zoonoses
9.	Detection and characterization of agents responsible for hydatidosis, taeniosis/ cysticercosis and trichinellosis
10.	Detection and characterization of agents responsible for fascioliosis and fasciolopsiosis
11.	Detection and characterization of *Toxoplasma gondii*
12.	Detection and characterization of zoonotic *Trypanosoma* species
13.	Detection and characterization of zoonotic *Cryptosporidium* species of health significance
14.	Detection and characterization of zoonotic *Leishmania* species
15.	Detection and characterization of zoonotic *Sarcocystis* species
16.	Detection and characterization of zoonotic agents responsible for dracunculiosis, paragonimiosis and diphylobothriosis

I. Course Title : Principles of Epidemiology
II. Course Code : VPE 504
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Historical perspective and scope of veterinary epidemiology
2	Disease causation -theories of disease causation, recent advancements and iceberg concept
3	Koch's postulates and Evan's rules
4	Epidemiological triangle
5	Epidemic, endemic, pandemic and sporadic diseases
6	Qualitative and quantitative approaches to epidemiology
7	Measurement of disease in populations
8	Endemic stability and herd immunity
9	Basic reproductive ratio
10	Trends in spatial and temporal distribution of disease
11	Epidemic curve and its applications
12	Transmission of disease
13	Role of ecology in maintenance of disease agents
14	Epidemiological methods
15	Landscape epidemiology
16	Molecular epidemiology
17	Epidemiological studies
18	Observational studies - case-control studies
19	Observational studies - cohort studies
20	Observational studies - cross-sectional studies
21	Experimental studies - field trials
22	Experimental studies - clinical trials
23	Disease surveys
24	Monitoring and surveillance
25	Epidemiological databases
26	Definition, scope and limitations of serological epidemiology and interpretation of results
27	Characteristics of ideal disease diagnostic tests
28	Multiple diagnostic testing
29	Evaluation of diagnostic tests
30	Investigation of disease outbreaks
31	Strategies of disease control
32	Disease eradication
Practical	
1.	Collection of data from various sources, analysis and interpretation
2.	Demonstration of sample (serum) collection
3.	Evaluation of diagnostic tests
4.	Analytical diagnostic and relative sensitivity and specificity calculation
5.	Use of software for data analysis
6.	Designing and interpretation of a case-control study
7.	Designing and interpretation of a cohort study
8.	Designing and interpretation of a cross-sectional study
9.	Designing and interpretation of a field trials
10.	Designing and interpretation of a clinical trials
11.	Determination of vaccines effectiveness
12.	Designing of a survey

Lecture(s)	Topic
13.	Spatio-temporal distribution of disease
14.	Outbreak investigation
15.	Case study on disease eradication
16.	Case study on disease monitoring and surveillance

I. Course Title : Hygiene and Safety of foods of Animal and Aquatic origin

II. Course Code : VPE 505

III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Importance of food hygiene in relation to the public health
2	Principles of food hygiene in relation to foods of animal origin (including aquatic origin foods)
3	Environmental sanitation in food establishments
4	Food quality - perspectives
5	Prevention of foodborne illnesses - principles
6	Risk analysis
7	Milk hygiene - importance and objectives
8	Hygienic production, handling, transportation, storage and marketing of milk and milk products
9	Mastitis in dairy animals and its public health significance
10	Spoilage of milk
11	Preservation of milk
12	Milk-borne diseases of public health significance
13	Epidemiology of milk allergy and lactose intolerance
14	Public health impact pesticide residues in milk supply chain
15	Antimicrobial residues in milk supply chain and their public health impact
16	Adulteration of milk and dairy products
17	Public health implications of synthetic milk
18	Milk plant hygiene and sanitation
19	Meat hygiene - importance and objectives
20	Hygienic meat production including hygienic practices at abattoirs
21	Hygienic practices at farm and during transportation of food animals including poultry
22	Adulteration of meat and meat speciation
23	Spoilage of meat and meat products
24	Preservation of meat
25	Meat-borne diseases of public health significance
26	Safe disposal of slaughter house byproducts
27	Fish, fisheries and ichthyology
28	Environmental factors affecting aquatic food hygiene
29	Hygienic production, handling, preservation, transportation and marketing of aquatic foods
30	Microbial profile and spoilage of aquatic foods
31	Disposal of fishery waste
32	Fish-borne diseases of public health significance

Lecture(s)	Topic
Practical	
1.	Collection of samples of meat, milk, egg and fish for physicochemical and microbial analysis
2.	Analysis of foods of animal origin for physicochemical quality
3.	Analysis of foods of animal origin for microbial quality
4.	Detection of adulteration, debasement, substitution and admixing of animal origin foods and products
5.	Recent methods of speciation of meat
6.	Determination of spoilage in foods of animal origin
7.	Extension of shelf life of perishable foods of animal origin
8.	Detection of mastitis in dairy animals and linking it to consumer's health
9.	Study of supply chains of milk, meat, egg and fish
10.	Evaluation of food plant, equipment and the environment for compliance
11.	Microbial risk analysis
12.	Risk analysis for residues of public health significance in foods of animal origin
13.	Source tracing of foodborne outbreaks using molecular, bioinformatics or epidemiological tools
14.	Evaluation of fish and aquatic harvest for quality and safety
15.	Visit to milk/ meat/ egg/ fish processing unit for the demonstration of food quality and safety checkpoints
16.	Study of databases, information communication tools (ICT) and dedicated websites related to quality and safety of animal origin foods

I. Course Title : Food-borne Infections and Intoxications
II. Course Code : VPE 506
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Definitions: Foodborne infections, Food intoxications, Toxi-infections, Bacterial toxins, etc.
2-3	Classification, epidemiology, disease burden and economics offoodborne diseases.
4	Fungal toxins
5	Plant, algal, and other toxins
6	Reservoirs of food-borne pathogens
7	Mode of transmission of food-borne pathogens
8	Vehicles of pathogens
9	Measures employed for prevention and control of food-borne diseases
10-11	Food- poisoning outbreak investigation
12	Management of food- poisoning outbreak
13-15	Epidemiology, economic, diagnosis and management of bacterial food-borne diseases
16-17	Foodborne disease due to *Salmonella* and *Campylobacter* species
18-19	Foodborne disease due to *Clostridium*, *Staphylococcus*, *Listeria* and *Bacillus* species
20-22	Foodborne diseases due to species of *Vibrio*, *Escherichia*, *Shigella*, *Yersinia*, etc.
23	Types of bacterial toxins and their manifestations
24-25	Epidemiology, economics, diagnosis and management of food-borne viral pathogens
26	Foodborne diseases due to hepatitis viruses and entero-viruses
27	Foodborne diseases due to noroviruses, rotaviruses, etc.
28	Food- borne rickettsial infections

Lecture(s)	Topic
29	Food- borne parasitic infections
30	Illness due to additives in foods, seafood toxins, mycotoxins, biocides and plant origin toxins
31	Illness due to food heavy metals, veterinary drugs, hormones, etc. in foods
32	Anti-microbial resistance (AMR) in food-borne pathogens-definition, current status, factors responsible, mechanism of resistance, mode of transmission and control

Practical

1. Food-borne disease outbreak investigation
2. Detection and characterization of food-borne bacterial pathogens in foods of animal origin
3. Detection and characterization of food-borne viral pathogens in foods of animal origin
4. Detection, quantification and characterization of microbial toxins in foods of animal origin
5. Detection of antimicrobial resistance in foodborne pathogens and their molecular and epidemiological characterization
6. Detection and characterization of rickettsial pathogens in foods of animal origin
7. Detection and characterization of parasites of public health in foods of animal origin
8. Detection, quantification and characterization of toxic compounds in the fish and aquatic food supply chain
9. Detection and quantification of antimicrobials in foods of animal origin
10. Detection and quantification of phytotoxins, biocides, etc. in foods of animal origin
11. Detection and quantification of pesticides residues in foods of animal origin
12. Detection and quantification of residues of metals and other environmental contaminants in foods of animal origin
13. Detection and quantification of additives in foods of animal origin
14. Detection and quantification of veterinary drugs in foods of animal origin
15. Case study on food-borne microbial disease relevant to the region
16. Case study on non-microbial hazard relevant to the region

I. Course Title : Food Safety Standards and Regulations
II. Course Code : VPE 507
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Indicators of food quality and safety
2	Food spoilage (biological, chemical, etc.)
3	Food plant hygiene
4	Sanitation program for the food plant
5	Hurdle technique and its relevance
6	Microbiological food quality criteria
7-8	National and international food standards
9	Private food standards
10	Prerequisite programs for food safety - GAP, GMP, etc.
11	Application of ISO 9000 series to food establishments
12-13	HACCP, ISO 22000

Lecture(s)	Topic
14	Genesis of food safety standards
15	Mechanisms of food safety standard formulation
16	Agencies associated in food standard formulation
17	Role of WTO and FSSAI in standard formulation
18	Role of BIS and other agencies in standard formulation
19	Role of EIC/ EIA
20	National regulations and legislations related to quality food production
21	International regulations related to quality food production
22-26	Food safety regulations in reference to pesticides, veterinary drug, heavy metals, hormones and other residues (MRL, ADI, etc.)
27	Traceability system for foods of animal origin
28	Organic food production
29	Packaging of foods of animal origin – specifications and standards
30	Public health implications of *in-vitro* and cultured meats as well as meat obtained from genetically modified and unconventional animals
31	SWOT analysis of emerging and novel technologies related to the quality and safety of foods of animal origin
32	Case study related to food standards
Practical	
1.	Detection of pesticide residues in foods of animal origin
2.	Detection of veterinary drug residues in foods of animal origin
3.	Detection of heavy metal residues in foods of animal origin
4.	Estimation of MRL/ MPL
5.	Estimation of NOEL, ADI, etc.
6.	Microbiological assessment of cleanliness of food plant surface
7.	Microbiological assessment of equipment in abattoir/ meat/ milk plant
8.	Visit to food processing units for examining compliance of HACCP/ FSSAI regulations and other standards
9.	Demonstration of traceability system for foods of animal origin
10.	Demonstration of compliance of organic production of foods of animal origin
11.	Demonstration of registration and licensing of food business operator (FBO) under FSSAI regime
12.	Evaluation of detergents and sanitizers used in the food plant
13.	Inventory management and hygiene audit of food plant
14.	Occupational safety at food plant
15.	Case study on HACCP
16.	Case study on ISO 22000

I. Course Title : Environmental Hygiene and Safety
II. Course Code : VPE 508
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Introduction to the environment and environmental hygiene
2	Impact of environmental pollutants on animal and human health
3	Characteristics of various environmental pollutants
4	Nature and impact of microbial pollution
5	Nature and impact of pollution due to chemical pollutants

Lecture(s)	Topic
6	Environmental risk assessment (microbial and non-microbial hazards)
7	Pollutions of soil, air and water and their effects on human, animal and environmental health
8	Dissemination of pathogens and pollutants in the environment
9	Global warming, enhanced green-house effect and climate change- impact on human, animal and environmental health
10	Impact of noise pollution on human and animal health
11	Management of environmental pollution
12	Industrial pollution including impact of plastic and petrochemical products
13	Genetic risk associated with environmental pollutants
14	Health problems due to nuclear energy, microwave, electro-magnetic and other radiation pollutions
15	Pollution due to agrochemicals and pesticides
16-17	Contamination and impact of heavy metals and veterinary drug residues
18	Role of livestock in environmental pollution
19	Public health impact of animal-waste
20	Recycling of wastes
21	Principles of safe disposal of bio-medical waste
22	Food chain consequences of environmental pollutants, contaminants and toxicants
23	Implications of genetically modified organisms on the animal, human and environmental health - regulations and compliance
24	Management of environmental pollution – conventions, treaties, agreements, etc.
25-26	Role of national and international pollution control agencies in the management of environmental pollution.
27	Regulations pertaining to environmental pollution and its control
28	Hygiene and safety at specialized laboratories
29	Designing and maintenance of laboratories that handle high risk pathogens
30	Environmental risk assessment of hazards of regional/ national importance
31	Case studies involving livestock and the environment
32	Case studies indicating human health impact associated livestock
Practical	
1.	Determination of potability of the drinking water
2.	Detection of pollutants in the water
3.	Detection of pollutants in the air
4.	Detection of pollutants in the soil
5.	Detection of pollutants in the animal products
6.	Detection of pollutants in the sewage
7.	Detection of pollutants in the animal waste
8.	Detection and quantification of environmental pollutants, toxicants and contaminants that affect animal, human and environmental health
9.	Sustainable methods for animal waste disposal/ economic utilization arising from intensive animal husbandry
10.	Cost-benefit analysis of environment friendly animal waste disposal approaches
11.	Detection and quantification of genetically modified organisms
12.	Structure and function of institutional biosafety committee (IBSC)
13.	Environmental monitoring of pollutants – markers and methods
14.	Preparation of feasibility report or projects pertaining to selected environmental pollutant(s) of regional importance
15.	Visit to sewage/ waste recycling/ disposal plant/ processing unit
16.	Case studies on risk mapping, environmental risk assessment, pollution mitigation, etc.

I. Course Title : Applied Epidemiology
II. Course Code : VPE 509
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	An introduction to applied epidemiology
2	Models, modeling and types of model
3	Epidemiological and economic models
4	Principles and classification of models
5	Deterministic and stochastic models
6	Empirical and explanatory models
7	Application of models in disease forecasting
8	Modeling in disease prevention and control
9-10	Disease occurrence and ecology of disease
11	Monitoring and surveillance
12	Outbreak investigation protocol
13	Path, regression and discriminate analyses
14	Time series analysis
15	Statistical analysis of the data - Analysis of variance
16	Animal disease economics - cost-benefit analysis, internal rate of return payback period, etc.
17	Animal disease economics - partial budgeting
18	Animal disease economics - decision analysis
19	Bayesian analysis
20	Monte-Carlo and Markovian processes and system evaluation
21	Multivariate analysis
22	Disease outbreaks and participatory epidemiology
23	Disease reporting system - tracing and notification
24	Disease control strategies
25	Risk assessment
26	Exotic diseases and trans-boundary diseases
27	Vaccination for the prevention of diseases
28	Disease intelligence
29	Tele-epidemiology
30	Application of remote sensing technology
31	Geographic information system
32	Disease surveillance and early warning system
Practical	
1.	Survey of animal diseases
2.	Biostatistics for establishing disease causality, association and measurements
3.	Profanity and non-probability sampling methods
4.	Presentation of disease data
5.	Measurements of disease occurrence in populations
6.	Outbreak investigation
7.	Disease reporting systems
8.	Demonstration of epidemiological software
9.	Estimation of disease burden and economics of animal/ zoonotic diseases
10.	Modeling of animal diseases
11.	Demonstration of cartography and disease mapping using computer software
12.	Demonstration of global positioning system (GPS), remote sensing technology and geographic information system (GIS)

Lecture(s)	Topic
13.	Working modality on disease surveillance and monitoring
14.	Demonstration of disease early warning system
15.	Disease modeling
16.	Case study on disease reporting and notifiable disease

I. Course Title : Biosecurity, Bioterrorism and Disaster Management
II. Course Code : VPE 510
III. Credit Hours : 2+0

Lecture(s)	Topic
Theory	
1.	Introduction and definitions related to the bioterrorism
2.	Potential biological weapons
3.	Categorization agents of bioterrorism
4.	Hazard analysis in bioterrorism
5.	Strategies for combating bioterrorism
6.	Bio-ethics, social ethics and advisory role of veterinarians during the event of bioterrorism
7.	Disaster – Definitions, categorization (natural and man-made disasters)
8.	Impact analysis of disasters
9.	Classification of disaster scale
10.	Essential preparations for the management of disasters
11.	Role of central, state and local government bodies in disaster management
12.	Role of veterinarians/ veterinary public health personnel during emergency/ disasters
13.	Sequence of emergency services
14.	Effect of natural disasters on human and animal populations
15.	Nature and characteristics of disasters - floods, tsunami, tides, etc.
16.	Nature and characteristics of disasters - prolonged draughts, forest fires, etc.
17.	Nature and characteristics of disasters - earthquakes, storms, etc.
18.	Post-disaster disease susceptibility and remedial measures
19.	Biosecurity– definition, importance, methods, pathogen inventory, etc.
20.	Biosecurity at food processing establishments
21.	Biosecurity at livestock/ poultry farms
22.	Biosecurity at specialized animal facilities
23.	Quarantine measures for disease prevention – structure and functions
24.	Biomedical hazards at hospitals, laboratories and special animal handling units
25.	Laboratory biosafety – principles, requirements and applications
26.	Biosafety at the specialized laboratories
27.	Occupational health risk and its management
28.	National and international laboratory safety compliance
29.	Prediction, early warning or forecasting systems for disasters
30.	Case study related to bioterrorism
31.	Case study related to biosafety
32.	Case study related to disaster

I. Course Title : Laboratory Techniques in Veterinary Public Health
II. Course Code : VPE 511
III. Credit Hours : 0+3

Class	Topic
Practical	
1	General laboratory practices – safety precautions, hazardous material disposal, maintenance and compliance with existing norms
2	Personal safety and use of PPE (personal protective equipment) in the laboratory
3	Laminar airflows– uses, types of cabinets, SOPs, applications, etc.
4	Biosafety cabinets – uses, types of cabinets, SOPs, applications, etc.
5	Preparation of glassware and plastic wares
6-8	Preparation of culture media
9-10	Preparation of buffers and solutions of different for laboratory use
11-12	Sampling methods
13-14	Techniques for quality analysis of milk and milk product
15-16	Techniques for quality analysis of meat and meat products (including poultry and egg)
17-18	Techniques for quality analysis of food/ feed and environmental samples
19	Analysis of water for quality and safety
20-21	Microbiological techniques: Plate counts - psychrophilic, mesophilic, thermophilic and thermoduric organisms
22-23	Microbiological techniques: enumeration techniques for psychrophilic, mesophilic, thermophilic and thermoduric organisms from samples of foods of animal origin
24-26	Techniques for isolation and identification of foodborne and zoonotic pathogens
27-28	Techniques for detection of microbial toxins associated with food-poisoning and outbreaks
29-30	Techniques for detection and confirmation of viral pathogens
31-32	Techniques for isolation, identification, enumeration, confirmation and characterization of fungi of public health significance
33-34	Immunological techniques used for the detection of zoonotic agents - hypersensitivity based tests
35-36	Serological techniques: precipitation and agglutination tests, counter immune-electrophoresis, ELISA, etc.
37-38	Electrophoresis (AGE, PAGE, SDS-PAGE, etc.) techniques
39-40	Chromatographic methods
41-42	Techniques for the detection and quantification of pesticides residues
43-44	Techniques for the detection and quantification of drugs using immunological and chromatographic methods
45	Methods for isolation and quantification of nucleic acids from pathogens from diverse biological specimens using latest molecular techniques
46-47	Molecular techniques for the detection and characterization of organisms of veterinary public health significance – PCR and other molecular techniques
48	Maintenance of laboratory records, log books of equipment and laboratory accreditation (NABL)

Course Title with Credit Load Ph.D. in Veterinary Public Health and Epidemiology

Course Code	Course Title	Credit Hours
VPE 601	Advances in Veterinary Public Health and Epidemiology*	2+1
VPE 602	Emerging, Re-emerging Zoonoses and One Health*	2+1
VPE 603	Advances in Food Safetyand Quality Control of Foods of Animal/ Aquatic origin*	2+1
VPE 604	Biosecurity and Occupational Health Safety	2+1
VPE 605	Recent Concepts in Epidemiology and Disease Forecasting	2+1
VPE 606	Risk Analysis and Predictive Modelling	2+1
VPE 607	Advances in Environmental Hygiene	2+1
VPE 608	Herd Health Management and Disease Economics	2+1
VPE 609	Epidemiology of Trans-boundary, Non-infectious and Chronic diseased	2+1
VPE 610	Ecology and Animal/ Human Health	2+0
VPE 611	Diagnostic Approaches in Epidemiology	2+1
VPE 612	Surveys, Surveillance and Data Management	2+1
VPE 613	Research Methodology and Publication Ethics in VPE*	2+0
VPE 690	Special Problem	0+1
VPE 691	Doctoral Seminar-I*	0+1
VPE 692	Doctoral Seminar-II*	0+1
VPE 699	Doctoral Research	75

*Core Courses

Course Contents
Ph.D. in Veterinary Public Health and Epidemiology

I. Course Title : Advances in Veterinary Public Health and Epidemiology

II. Course Code : VPE 601

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with current/ contemporary issues concerning the veterinary public health, veterinary epidemiology and the one health.

V. Theory

Unit I

Contemporary status of Veterinary Public Health in India and abroad. Public Health in the 21stCentury.Veterinary public health and its role in the society. Role of veterinary public health professionals in prevention and control of zoonoses. Organization and administration of veterinary public health agencies structure and functions. Data analysis framework in healthcare and social sectors. Evidence-based information updates on current VPH topics. Global animal disease surveillance.

Unit II

Recent diagnostic tools used for emerging public health problems including zoonoses. Molecular surveillance of recent pandemics of zoonoses. Modes of evolutionary emergence of disease agents pertinent to VPE.

Unit III

Application of bioinformatics, biotechnological and computational tools in food hygiene, safety, quality assurance and environmental health protection. Global pandemic threat preparedness. Emerging Disease Surveillance and Control. Biomedical models in veterinary public health.

VI. Practical

Estimation of burden of food-borne zoonotic diseases. Special problems related to field investigations of outbreaks of food poisoning and zoonotic diseases in a community. Application of recent analytical methods and *in-silico* techniques for public health research. Visits to hospitals to acquaint the students with public health related problems.

VII. Assignments

Each student will select at least two recent articles from journals related to the course and discuss the same in the class through presentation.

VIII. Suggested reading

- Eldridge BF and Edman JD. eds., 2012. *Medical entomology: A textbook on public health and veterinary problems caused by arthropods*. Springer Science and Business Media

- Noordhuizen, Josephus Pieter Thérèse Maria K Frankena, Michael V Thrusfield and EA M Graat. *Application of quantitative methods in veterinary epidemiology*. Wageningen Pers, 2001.
- Schwabe CW, Riemann HP and Franti CE. 1977. *Epidemiology in veterinary practice*. Lea and Febiger.
- Thrusfield M. 2018. *Veterinary epidemiology*. John Wiley and Sons.

I. Course Title : Emerging, Re-emerging Zoonoses and One Health

II. Course Code : VPE 602

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with emerging and re-emerging zoonotic diseases.

V. Theory

Unit I

Status of emerging and re-emerging zoonotic infections, National and international interests in zoonoses, Measurement and economics of zoonoses, Latest diagnostic and Management planning for zoonoses. Factors responsible for emergence and re-emergence of zoonotic diseases. Health threats at the human- animal-ecosystems/ environment interface (HAEI), a tripartite concept of OIE, WHO and FAO.

Unit II

Current challenges and strategies, euzoonoses, xenozoonoses, nosocomial zoonoses, newer zoonotic agents, viz., cat-scratch disease, rat bite fever, Creutzfeld-Jacob disease, Ebola, Marburg, Lassa, Nipah, Menangle, Herpes B, SARS, AI, ZIKA, MERS, etc.

Unit III

Simian and human immunodeficiency, bovine spongiform encephalopathy, hepatitis A and E, Toro, influenza viruses; re-emerging zoonoses with new pathology, viz., neuro-cysticercosis, campylobacteriosis, rabies, Guillain-Barre Syndrome, tuberculosis.

Unit IV

Safety regulations in laboratories, hospitals and biological plants. Use of bio safety cabinets. Bio security.

VI. Practical

Special problems related to emerging/ re-emerging/ prevalent zoonotic diseases in India. Status of Brucellosis and Tuberculosis in the India, OIE recommended diagnostic tests, vaccines/ strategies for prevention and control. Visits to rural health centres to acquire status of zoonotic diseases.

VII. Assignments

Each student will select at least two recent articles from journals related to course and discuss the same in the class through presentation.

VIII. Suggested reading

- Calvin W Schwabe. 1984. *Veterinary Medicine and Human health*. Williams and Wilkins
- Rezza G and Ippolito G. eds. 2017. *Emerging and Re-emerging Viral Infections*. Springer.
- Singh SK. ed. 2015. *Human Emerging and Re-emerging Infections*. John Wiley and Sons.

I. Course Title : Advances in Food Safety and Quality Control of Foods of Animal/ Aquatic

II. Course Code : VPE 603

III. Credit Hours : 2+1

IV. Aim of the course

To provide expertise to students the advances in the food safety, quality control and quality assurance of animal origin foods.

V. Theory

Unit I

Food supply chain. Food handling practices. New age voluntary and mandatory food standards. Types and evolution of food standards. Characteristics of food safety hazards. Quality control, assurance and food safety specifications for animal origin foods such as meat, milk, egg and fish. Trends in green technologies in food production and processing.Impacts and performance of organic farming *vis-a-vis* conventional farming.

Unit II

Recent innovations in shelf-life extension, preservation and packaging. Requirements for food testing and calibration Laboratory Mechanism of food spoilage (microbial and non-microbial). Nature of major food-borne infections and intoxications. Traceability system. Waste reduction along the food supply chain.

Unit III

Rapid detection of food safety hazards. Food safety risk assessment. Quality assurance schemes applicable to foods of animal origin. Elements of national food control system. National food control systems. Global considerations and role of committees and agencies associated with food safety, quality control and quality assurance.

Unit IV

Genesis of food quality/ safety standard. Food quarantine and export guidelines, specifications and standards. National and international food safety compliances. Traceability of foods of animal origin.

VI. Practical

Special problems on quality and safety of foods of animal origin foods. Detection, enumeration and identification of major food-borne pathogens. Visits to food processing establishments. Environmental impact assessment of production of foods of animal origin.

VII. Assignments

Each student will select at least two recent articles from journals related to course and discuss the same in the class through presentation.

VIII. Suggested reading

- Marriott NG, Schilling MW and Gravani RB. 2018. *Principles of food sanitation*. Springer.
- Nollet LM and Toldrá F. eds., 2016. *Safety analysis of foods of animal origin*. CRC Press
- Paustenbach DJ. ed., 2015. *Human and Ecological Risk Assessment: Theory and Practice* (Wiley Classics Library). John Wiley and Sons.
- Toldrá F and Nollet LM. eds., 2017. *Advances in food diagnostics*. John Wiley and Sons.

I. Course Title : Biosecurity and Occupational Health Safety

II. Course Code : VPE 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with biosafety and occupational health safety.

V. Theory

Unit I

Definitions. Physical, Chemical and Biological hazards. Bio-safety and bio-security. Elements of bio-security and bio-containment. Biosecurity requirements. Containment Barriers. Equipment safety. Risk assessment. Bio-safety levels. Laboratory safety. Bio-safety in microbiological and biomedical laboratories.

Unit II

Risk groups, Classification of organisms by risk groups. Classification of occupational groups. Laboratory designs. Transmission, spread, Maintenance and control of diseases affecting various occupational groups in contact with animals and their public health significance. Diseases associated with various occupations.

Unit III

Occupational safety and health. Occupational Health and Safety (OHS) management system standard ISO 45001. regulations pertaining to the Occupational safety and health. Occupational Safety and Health Administration. International Labour Organization.

VI. Practical

Diagnosis of occupational diseases of public health significance. Handling of Bio-safety cabinets. Relation of risk group to bio-safety levels, practices and equipment. Visit to BSL-3 and BSL-4 laboratories.

VII. Suggested reading

- Fleming DO and Hunt DL. 2006. *Biological safety: principles and practices* (No. Ed. 4). ASM Press.
- Guillén J. ed. 2017. *Laboratory Animals: Regulations and Recommendations for the Care and Use of Animals in Research*. Academic Press.
- Rabinowitz PM, Lefkowitz RY, Conti LA, Redlich CA and Weigler BJ. 2015. *Occupational health of laboratory animal workers. In Laboratory Animal Medicine* (pp. 1381-1402). Academic Press.
- World Health Organization. 2016. *Assessment Tool for Key Processes associated with the Design, Construction, Operation, Maintenance and Regulation of BSL-3 Facilities in the WHO African Region*.

I. Course Title : Recent Concepts in Epidemiology and Disease Forecasting

II. Course Code : VPE 605

III. Credit Hours : 2+1

IV. Aim of the course

To learn about different epidemiological aspects of major diseases and to develop suitable disease forecasting system.

V. Theory

Unit I

Review of epidemiological concepts and applications, recent concepts.

Unit II

Epidemiology of economically important diseases in the region (haemorrhagic septicaemia, foot and mouth disease, surra, brucellosis, PPR, swine fever, IBD, NCD, avian Influenza, sheep pox, contagious ecthyma, etc).

Unit III

Geographical Information System and its applications in epidemiology, various expert systems and their role in epidemiology.

Unit IV

Modelling and application of various models in disease forecasting. Epidemiological software and its applications, global and national early warning system.

VI. Practical

Epidemiological exercises of economically important diseases in the region, use of Geographical Information System in epidemiology, various expert systems, modelling and various models used in disease forecasting, development of suitable epidemiological software for the prevailing problems to attend disease outbreaks including laboratory investigations and reporting of routs.

VII. Suggested reading

1. Beaglehole R, Bonita R and Kjellstrom T. 1993. *Basic Epidemiology*, World Health Organization, Geneva.
2. Lilienfeld DE and Stolley P. 1994. *Fundamentals of Epidemiology*, 3rd ed., Oxford University Press, New York
3. Noordhuizen JPTM, Frankena K, van der Hoofd CM and Graat EAM: *Application of quantitative methods in Veterinary Epidemiology*. Wageningen Pers, Wageningen, The Netherlands. 1997.
4. Raj S Bhopal. 2016. *Concepts of Epidemiology: Integrating the ideas, theories, principles and methods of epidemiology*. 3rd Ed., Oxford University Press. Oxford.

I. Course Title : Risk Analysis and Predictive Modelling

II. Course Code : VPE 606

III. Credit Hours : 2+1

IV. Aim of the courses

To Acquaint the students with the latest knowledge on prediction od infections and the extent of risk in the population

Unit 1

Definitions. History of risk analysis. Relevance of risk analysis (RA) to food sector. Principles of risk analysis. Risk analysis components (risk assessment, management and communication). Microbial Risk Assessment (MRA) involving hazard identification, exposure assessment, hazard characterization, and risk characterization. Methodologies used in RA/ MRA. Qualitative and quantitative risk analysis. Quantitative Microbial Risk Assessment (QMRA) for foods of animal origin including water. Application of mathematical models to study propagation of microbial hazards from farm-to-fork. Risk-based decision-making.

Unit II

Variability and uncertainty inherent to biological data. Measurement and modelling of uncertainty and variability during risk assessment. Risk assessment, risk analysis and HACCP. Linking microbial food safety with risk assessment. Relevance of assumptions and observed data for predictive models. Study of software packages used for risk analysis.

Unit III

Mathematical modelling of microbial growth rate. Predictive modelling tools for food safety management. Microbial modelling for the prediction of product shelf life and safety. Applications of predictive modelling of microbial behaviour in foods.

V. Practical

Modelling of infectious diseases using computational and mathematical methods. Building and analysing models of infectious diseases. Study of population-level processes for infectious diseases of animals and humans. Performing risk analysis for selected food safety hazards using microbial risk analysis tools. Risk assessment using through simulation modelling.

VI. Suggested reading

1. Haas CN, Rose JB and Gerba CP. 1999. *Quantitative microbial risk assessment*. John Wiley and Sons.
2. Lelieveld HL, Holah J and Gabric D. eds., 2016. *Handbook of hygiene control in the food industry*. Woodhead Publishing.
3. Pastorok RA, Bartell SM, Ferson S and Ginzburg LR. eds., 2016. *Ecological modeling in risk assessment: chemical effects on populations, ecosystems, and landscapes*. CRC Press.
4. Subramaniam P and Wareing P. eds., 2016. *The stability and shelf life of food*. Woodhead Publishing.

I. Course Title : Advances in Environmental Hygiene

II. Course Code : VPE 607

III. Credit Hours : 2+1

IV. Aim of the course

To update knowledge on modern environmental pollution problem and control.

V. Theory

Unit I

Current status of problems pertaining to environmental hygiene, air, soil and water pollution, Disinfection procedures, Impact of global warming and other environmental problems leading to change in ecology of diseases and impact on human/ animal health; Carbon footprint, Eco-philosophy, Environmental ethics and Environmental economics, Environmental conflicts and cooperation.

Unit II

Environmental risks their assessment and management and reporting, modern global information, surveillance and monitoring systems, decision making and public awareness. Role of VPH in National Sanitation Programmes such as Swachh Bharat Abhiyan.

Unit III

International environmental management efforts, participatory international organizations and their selected programmes and selected legislations.

VI. Practical

Detection and monitoring/ estimation of air, soil and water pollution; detection of pathogens from environmental sources. Visits to water/ sewage treatment plants.

Assignments

Each student will select at least two recent articles from journals related to course and discuss the same in the class through presentation.

VII. Suggested reading

1. Curtis SE. 1983. *Environmental management in animal agriculture*. Iowa State University Press.
2. Frumkin H. ed., 2016. *Environmental health: from global to local*. John Wiley and Sons.
3. Paustenbach DJ. ed., 2015. *Human and Ecological Risk Assessment: Theory and Practice* (Wiley Classics Library). John Wiley and Sons.
4. Sparling DW. 2016. *Ecotoxicology essentials: environmental contaminants and their biological effects on animals and plants*. Academic Press.

I. Course Title : Herd Health Management and Disease Economics

II. Course Code : VPE 608

III. Credit Hours : 2+1

IV. Aim of the course

Adoption of holistic approach to address issues of herd health without affecting production.

V. Theory

Unit I

General principles, interactions between health and production and herd immunity.

Unit II

Dairy cattle: mastitis, brucellosis and haemo-protozoan control and health management of dairy cows and calves.

Unit III

Health and production in swine, sheep, goats and poultry, vaccination, biosecurity practices for prevention and control of diseases.

VI. Practical

Visit to various bovine, equine, sheep, goat and poultry farms, assessment of their problems, systematic programmes for prevention and control of specific diseases and its impact, calculation of disease economics. Animal-house hygienic practices.

Assignments

Each student shall select at least two recent articles from journals related to course and discuss the same in the class through presentation.

VII. Suggested Reading

- Dijkhuizen AA and Morris RS. 1997. *Animal health economics. Postgraduate Foundation in Veterinary Science*, University of Sydney, Sydney, Australia.
- FAO. 2016. *Economic analysis of animal diseases*. FAO Animal Production and Health Guidelines. No. 18. Rome.
- Schwabe CW. 1984. *Veterinary Medicine and Human Health, Baltimore*: Williams and Wilkins
- Rushton, Jonathan. 2009. *The economics of animal health and production*. CABI.

I. Course Title : Epidemiology of Trans-boundary, Non-infectious and Chronic Diseases

II. Course Code : VPE 609

III. Credit Hours : 2+1

IV. Aim of the course

To provide students the expertise in elucidating epidemiology of non-infectious and chronic diseases.

V. Theory

Unit I

Establishment of causality and associations in non-infectious and chronic diseases. Characteristics of Koch's/ Henle-Koch postulates and Evans' rules of disease causation. Unified principles of establishing causality for both infectious and non-infectious diseases. Infectious disease and chronic disease connections. Causal role of infectious agents in cancer (relating criteria). Establishment of trends in disease occurrence. Epidemiology of non-infectious and chronic diseases affecting different systems in various animal species.

Unit II

Emerging infectious determinants of chronic diseases- reasons for emergence, range of pathways and epidemiology of chronic non-infectious disease. Study of characteristics of risk factors (genetic, physiological, environmental, behavioral, etc) associated with non-infectious and chronic diseases. Demographic, epidemiological and nutrition transition. Social determinants of non-communicable diseases. Spatial and temporal epidemiology of non-infectious diseases, viz., nutritional, reproductive, chemical poisoning, toxicity (pesticides, poisonous plants), metabolic diseases, toxicities, neoplastic and other miscellaneous diseases.

Unit III

Global status of non-communicable diseases. Modelling of non-infectious non - communicable diseases or chronic diseases. Economic Impact of chronic diseases. Prevention and control: current status and future perspectives.

VI. Practical

Measurement of burden of non-infectious and chronic diseases (mortality, morbidity, survival, risk factors, etc.). Controlled trials and short research problem(s) involving contemporary issues and research techniques. Animal models for the study of non-infectious and chronic diseases. Survey of non-infectious and chronic diseases using animal disease model systems.

VII. Suggested Reading

- Baldock C, Forman T, Geering B and Taylor B. 1999. *New Technologies in the fight against transboundary animal diseases*. In: FAO-Japan Cooperative Project: Collection of Information on Animal Production and Health. Rome, Italy: The Food and Agricultural Organization of the United Nations.
- Fernández PJ and White WR. 2016. *Atlas of transboundary animal diseases*. OIE (World Organisation for Animal Health).
- Martin SW, Meek AH and Willeberg P: *Veterinary epidemiology. Principles and methods*. 1986, IOWA State University Press/ Ames, Iowa, USA
- Noordhuizen JPTM, Frankena K, van der Hoofd CM and Graat EAM: *Application of*

quantitative methods in veterinary epidemiology. Wageningen Pers, Wageningen, The Netherlands. 1997.

- Thrusfield M: *Veterinary epidemiology*. 1995.Blackwell Science Ltd. Oxford, UK.

I. Course Title : Ecology and Animal/ Human Health

II. Course Code : VPE 610

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about ecological basis of disease.

V. Theory

Unit I

Establishment of links between animal/ human health with the ecosystems. Assessment of changing trends in the environments and its on the animal/ human health. Study of emerging public health threats linked to the changes in the environment. Study of landscape epidemiology of diseases. Study of contemporary issues centered on ecological and evolutionary perspectives of infectious diseases.

Unit II

Animal–human-ecosystem interface. Study of ecological/ environmental factors influencing spatio-temporal occurrence of disease such as temperature, rainfall and other environmental factors. Ecological conditions and evolutionary dynamics. Disease ecology based explanatory and predictive models. Elucidation of natural history and host-parasite interactions linked to the ecological factors.

Unit III

Ecology of vector borne diseases. Vector dynamics and ecology. Study extrinsic incubation period. Understanding of critical risk factors of spread such as timing, distribution, abundance of competent vectors.

Unit IV

Study of cyclical patterns of disease. Mapping environmental conditions with disease. Establishing functional links between environmental modifications and disease. Linking climate change with disease occurrence. Study of dynamics of ENSO with climate change and disease. Evolution of disease alert and forecasting systems. Use of global positioning and remote sensing tools for disease management. Early warning and GIS based disease predictions.

VI. Suggested reading

- Norrgren L and Levengood JM. eds., 2012. *Ecology and Animal Health* (No. 2). Baltic University Press.
- Waltner-Toews, David. 2007. *The Chickens Fight Back: Pandemic Panics and Deadly Diseases that Jump from Animals to Humans*. Vancouver: Greystone Books
- World Health Organization. 2013. "*Zoonoses and Veterinary Public Health*." WHO

I. Course Title : Diagnostic Approaches in Epidemiology

II. Course Code : VPE 611

III. Credit Hours : 2+1

IV. Aim of the course

Learning of recent advanced molecular techniques for establishing disease diagnosis.

V. Theory

Unit I

The concept of molecular basis of a disease, molecular determinants of pathogenicity of infectious agents and their transmissibility to susceptible populations of livestock and poultry.

Unit II

Laboratory biosafety, Antigenic, Genetic and Biological characterization of field isolates of pathogens incriminated in field outbreaks, Differentiation of field and Vaccine strains, the concept of Marker vaccines, and Correlation of pathotypes and genotypes of a pathogen.

Unit III

Immunological tests, immunoblotting techniques and use of monoclonal antibodies in different ELISAs for antigenic analysis. Application of nucleic acid-based assays, viz., polymerase chain reaction (PCR) assays, nucleotide sequencing, restriction endonucleaseanalysis and RFLP analysis for genomic characterization using the field material directly or after extraction of nucleic acid from small scale cultures, use of radio-actively labelled or non-radioactive oligo-nucleotide probes in dot-blot and Southern hybridizations.

VI. Practical

Finger printing of the nucleic acid obtained from field isolates and their comparative analysis. PCR and ELISA for screening of field samples.

VII. Assignment

Each student shall select at least two recent articles from journals related to the course and discuss the same in the class through presentation.

VIII. Suggested reading

- Boniolo G and Nathan MJ. eds., 2016. *Philosophy of molecular medicine: Foundational issues in research and practice*. Taylor and Francis.
- Pfeiffer D. 1998. *Veterinary Epidemiology. An Introduction. Institute of Veterinary*, *Animal and Biomedical Sciences*. Massey University, Palmerston, New Zealand.
- Stites DP, Stobo JD, Fundenberg HH and Wells JV. 1982. *Basic and Clinical Immunology*, 4th Edition. Lange Medical Publications, Los Altos, USA.
- Thrusfield M. 2018. *Veterinary Epidemiology,* John Wiley and Sons.

I. Course Title : Surveys, Surveillance and Data Management

II. Course Code : VPE-612

III. Credit Hours : 2+1

IV. Aim of the course

To demonstrate different methodologies and procedures involved in conducting survey and surveillance and collection of data, analysis and interpretation of data. Systematic data collection, analysis and management

V. Theory

Unit I

Robust survey: Planning, Statistical models for the same and Surveillance, Purpose and method of sampling, Size of sample, Questionnaires. State, National and

International agencies (OIE, CDC, etc.), their data bases and their management systems.

Unit II

Goals and types of surveillance, monitoring, mechanism of surveillance and surveillance network.

Unit III

Disease/ data recording and reporting, vet. recording schemes, vet. information system and data bases.

Unit IV

Emergence of new diseases and re-emergence of old diseases. Epidemiology of globally and nationally important emerging/ re-emerging diseases and designing of strategies for their prevention and control.

VI. Practical

Prepare questionnaires on selective topics, survey for livestock and poultry farmers to find out usefulness/ effectiveness of vaccination/ artificial insemination/ other practices, surveillance of important diseases in different parts of state, data analysis and presentation of data, development of suitable software.

VII. Assignment

Each student will select at least two recent articles from journals related to course and discuss the same in the class through presentation.

VIII. Suggested reading

- Hawker J, Begg N, Reintjes R, Ekdahl K, Edeghere O and Van Steenbergen JE. 2018. *Communicable disease control and health protection handbook*. John Wiley and Sons.
- Salman M. ed., 2008. *Animal disease surveillance and survey systems: methods and applications*. John Wiley and Sons.
- Thrusfield M. *Veterinary epidemiology*. John Wiley and Sons; 2018 Apr 30.

I. Course Title : Special Problem

II. Course Code : VPE 690

III. Credit Hours : 0+1

IV. Aim of the course

To provide expertise in handling practical research problem(s).

V. Practical

Short research problem(s) involving contemporary issues and research techniques. Presentation and discussion of novel research papers on the disease or intervention strategies such disease pathogenesis, pathobiology, epidemiology, host-agent-environmental relationships, molecular mechanisms/ diagnostics, spatio-temporal trends, etc. Planning a short research problem or working on a published research paper or new developments.

Course Outline-cum-Lecture Schedule for Doctoral Degree Programme

I. Course Title : Advances in Veterinary Public Health and Epidemiology
II. Course Code : VPE 601
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1-3	Contemporary status of Veterinary Public Health in India and abroad. Public Health in the Twenty first Century
4	Veterinary public health and its role in the society
5-6	Role of veterinary public health professionals in prevention and control of zoonoses.
7	Opportunities for veterinary public health professionals
8-9	Organization and administration of veterinary public health agencies structure and functions
10-11	Data analysis framework in healthcare and social sectors
12-15	Evidence-based information updates on current VPH topics
16-17	Global animal disease surveillance
18-19	Recent diagnostic tools used for emerging public health problems including zoonoses
20-21	Molecular surveillance of recent pandemics of zoonoses
22-23	Modes of evolutionary emergence of disease agents pertinent to VPH
24-27	Application of bioinformatics, biotechnological and computational tools for food hygiene. food safety quality assurance environmental health protection
28-29	Global pandemic threat preparedness
30-31	Emerging Disease Surveillance and Control
32	Biomedical models in veterinary public health
Practical	
1	Assessment of health status of an individual
2-3	Estimation of disease burdens in a population
4-5	Estimation of burden of food-borne and zoonotic diseases
6	Molecular epidemiology and genetic analysis of agents of VPH significance
7	Case study related to field investigations of outbreaks of food poisoning
8	Case study related to zoonotic diseases in a community
9	Application of recent analytical methods (*in-vitro, invivo* and *in silico* techniques) used for public health research
10	Visits to hospitals to acquaint the students about public health related problems.
11	Health hazards across food supply chain
12	Hygiene of production/ processing of foods of animal origin
13	Safety management at the large-scale production or processing units of foods of animal origin
14	Longitudinal and integrated food safety assurance
15-16	Assignment: Each student will select at least two recent articles from journals related to the course and discuss in the class through presentation

I. Course Title : Emerging, Re-emerging Zoonoses and One Health
II. Course Code : VPE 602
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Definitions – emerging and re-emerging zoonoses. Public health risks of emerging and re-emerging zoonoses
2	Status of emerging and re-emerging zoonotic infections
3	National and international interests in emerging and re-emerging zoonoses
4	Measurement of emerging and re-emerging zoonoses
5	Economics of emerging and re-emerging zoonoses
6	Factors responsible for emergence and re-emergence of zoonotic diseases
7	Role of wildlife in emerging and re-emerging zoonoses
8	Current concepts in the diagnosis of emerging and re-emerging diseases
9	Epidemiology and combating of emerging and re-emerging zoonotic diseases
10	Latest diagnostics and management planning for emerging and re-emerging zoonoses
11-12	Health threats at the human- animal-ecosystems/ environment interface (HAEI) - tripartite (OIE, WHO and FAO) initiatives
13	Comparative medicine and VPH - horizons and perspectives in emerging and re-emerging zoonotic infections
14	Current challenges and strategies in the area of euzoonoses, xenozoonoses, nosocomial zoonoses and newer zoonotic agents
15-16	Characteristics, host range, epidemiology and management of Cat-scratch disease, Rat bite fever, Ebola and Marburg
17-18	Characteristics, host range, epidemiology and management of Lassa, Nipah, and Menangle viruses
19-20	Characteristics, host range, epidemiology and management of SARS, Toro, ZIKA and MERS virus infections
21	Characteristics, host range, epidemiology and management of zoonotic influenza viruses
22	Characteristics, host range, epidemiology and management of herpes and hepatitis (A and E) viruses
23	Characteristics, host range, epidemiology and management of co-infections, super-infections and syndemics - Simian and human immunodeficiency viruses
24	Characteristics, host range, epidemiology and management of taeniasis/ cysticercosis
25	Characteristics, host range, epidemiology and management of Bovine spongiform encephalopathy
26	Characteristics, host range, epidemiology and management of Creutzfeldt-Jacob disease
27	Characteristics, host range, epidemiology and management of brucellosis, tuberculosis and other emerging bacterial zoonoses
28	Guillain-Barre Syndrome and related sequel due to emerging/ re-emerging zoonoses
29-30	Close collaborations with regional, national and international organizations in the control of emerging/ re-emerging pathogens
31-32	Case study on emerging/ re-emerging zoonotic disease
Practical	
1	Application of safety regulations in laboratories, hospitals and biological units for handling emerging/ re-emerging agents
2	Methods to elucidate epidemiology of emerging/ re-emerging zoonoses

Lecture(s)	Topic
3	Approach to establish role of wildlife in emerging/ re-emerging zoonoses
4	Epidemiology of drug resistant emerging/ re-emerging zoonotic agents
5	Establishing genetic basis of bacterial emerging/ re-emerging zoonoses
6	Establishing genetic basis of viral and prion emerging/ re-emerging zoonoses
7	Establishing genetic basis of fungal, rickettsial and chlamydial emerging/ re-emerging zoonoses
8	Recommended diagnostic testing (OIE) for emerging/ re-emerging zoonoses
9	Vaccination and other strategies for the prevention of emerging/ re-emerging zoonoses
10	Application of Novel molecular methods for the understanding of emerging/ re-emerging zoonoses
11	Study abundance, behaviour, profiling and dynamics of vectors associated with emerging/ re-emerging zoonoses
12	Institutional surveillance of emerging/ re-emerging zoonoses
13	Visits to health centre to study of zoonotic diseases and categorization of agents as emerging/ re-emerging zoonosis
14	Special problem related to emerging/ re-emerging or prevalent zoonotic diseases
15-16	**Assignment:** Each student will select at least two recent articles from journals related to course and discuss in the class through presentation

I. Course Title : Advances in Food Safety and Quality Control of Foods of Animal/ Aquatic Origin

II. Course Code : VPE 603

III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Food supply chain dynamics
2	Food production, processing and handling practices
3	Food safety and quality assurance of foods of animal origin
4	New age voluntary and mandatory food standards
5	Types and evolution of food standards
6	Characteristics of food safety hazards
7-8	Quality control, assurance and food safety specifications for animal origin foods such as meat, milk, egg and fish
9-10	Recent innovations in shelf-life extension, preservation and packaging
11	Requirements for food testing and calibration Laboratory Mechanism of food spoilage (microbial and non-microbial)
12	Nature of major food-borne infections and intoxications
13	Elimination of food safety hazards from primary production systems
14	Rapid detection of food safety hazards
15	Impact of animal feed on food safety. Prevention and control of risks arising due to animal feeds
16	Coordination of surveillance policies in animal health and food safety
17	Food safety challenges in animal production systems affecting global markets
18	Quality assurance schemes applicable to foods of animal origin
19	Veterinary services for public health and consumer safety
20	Food safety risk assessment
21	National food control systems and its elements

Lecture(s)	Topic
22	Genesis of food quality/ safety standard
23-24	Food quarantine and export guidelines, specifications and standards
25	National and international food safety compliances
26	Traceability system - Traceability of foods of animal origin
27	Global considerations and role of committees and agencies associated with food safety, quality control and quality assurance
28	Trends in green technologies in food production and processing
29	Waste reduction along the food supply chain
30	Impacts and performance of organic farming *vis-a-vis* conventional farming
31	Consumer perspectives of food quality and safety
32	Environmental impact assessment of production of foods of animal origin
Practical	
1-2	Detection, enumeration and identification of food safety hazards
3	Pre-requisite programs for ensuring food safety
4	Environmental impact assessment
5	Application of generic traceability system for foods of animal origin
6	Detection of allergens associated with foods of animal origin
7	Emerging technologies for microbial control in food processing
8-9	Methods of management of waste arising from production and processing units (foods of animal origin including aquaculture)
10	Rapid alert system for food and feed
11-12	Visit to food processing establishments
13-14	Special problems on quality and safety of foods of animal origin foods
15-16	Assignment: Each student will select at least two recent articles from journals related to course and discuss in the class through presentation

I. Course Title : Biosecurity and Occupational Health Safety

II. Course Code : VPE 604

III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Definitions: Bio-safety, bio-security and bio-containment; physical, chemical and biological hazards
2	Elements of bio-security and bio-containment
3	Nature of physical, chemical and biological hazards at work places
4-5	Bio-security requirements, Containment Barriers
6-7	Laboratory and equipment safety
8	Risk assessment
9	Bio-safety levels
10-11	Bio-safety in microbiological and bio-medical laboratories
12-13	Risk groups, classification of organisms by risk groups
14	Classification of occupational groups
15	Laboratory designs - Biosafety Level 1/ Animal Biosafety Level 1
16	Laboratory designs - Biosafety Level 2/ Animal Biosafety Level 2
17	Laboratory designs - Biosafety Level 3/ Animal Biosafety Level 3
18	Laboratory designs - Biosafety Level 4/ Animal Biosafety Level 4
19-21	Transmission, spread, maintenance and control of diseases affecting various occupational groups in contact with animals and their public health significance

Lecture(s)	Topic
22-23	Diseases associated with various occupations
24	Occupational safety and health
25	Occupational Health and Safety (OHS) management system standard ISO 45001
26	Regulations pertaining to the Occupational safety and health
27	Occupational Safety and Health Administration
28	Risk group classification, Bio-risk Management
29	Classification of infective microorganisms by risk groups
30	Institutional Biosafety Committees (IBCs)
31	The Bio-medical Waste Management (Amendment) Rules, 2018
32	International Labour Organization and its occupational safety provisions, Research Ethics and Compliance
Practical	
1	Standard laboratory practices
2	Handling of Bio-safety cabinets
3-4	Detection of occupational diseases of public health significance
5	Relation of risk group to biosafety levels, practices and equipment
6-7	Design of BSL-1 to BSL-4 laboratories
8	Survey of biosafety and biosecurity in biomedical laboratories
9-11	Transportation of dangerous pathogens/ samples – modes, guidelines and regulations
13	Activity spectrum of detergents and disinfectants
14	Personal protection, Bio-risk Assessment Sheet and Material Safety Data Sheet (MSDS)
15	Case study on occupational safety in specialized laboratories
16	Case study on biosafety level 3 or 4 laboratory

I. Course Title : Recent Concepts in Epidemiology and Disease Forecasting

II. Course Code : VPE 605

III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Epidemiological concepts of disease occurrence in population
2	Variations in disease by time, place, and animal/ person
3	Recent epidemiological approaches for elucidating cause and effect
4	Variations: Role of error, bias, and confounding
5	The concept of risk/ risk factor in relation to the disease
6	Characterization and quantification of risk in epidemiology
7	Concepts in the measures of disease frequency
8	Analysis and integration of data for epidemiological methods/ techniques
9	Concepts in epidemiological study designs
10	Recent concepts in the epidemiology of economically important bacterial animal diseases of the region (haemorrhagic septicaemia, brucellosis, etc)
11-12	Recent concepts in the epidemiology of economically important viral animal diseases, viz., FMD, Swine fever, Avian Influenza, Sheep Pox, IBD, NCD and others of the region
13-14	Recent concepts in the epidemiology of economically important fungal, parasitic

Lecture(s)	Topic
	and other animal diseases of the region
15	Geographical Information System (GIS)
16	Advancements in GIS technology for epidemiological application in Veterinary and Animal Sciences
17	Various expert systems and their role in epidemiology
18	Concepts in animal disease modelling, Animal disease modelling, Disease prediction models
19	Modelling of economically important animal diseases
20	Modelling of emerging zoonotic infections
21	Advances in disease forecasting
22	Application of advanced disease forecasting concepts for animal/ zoonotic diseases
23	Disease early warning systems
24	Global and national disease early warning systems
25	Epidemiological softwares and their applications related to animal/ zoonotic infections
26	Common software packages and databases used in veterinary practice
27	Epidemiological Concepts Regarding Disease Monitoring and Surveillance
28	Advances in the practice of Public Health Surveillance
29	Real-time animal tracking using global positioning systems (GPS)
30	Use of advanced computing and remote sensing/ satellite technology for the study of animal/ zoonotic diseases
31	Case study related to application of recent epidemiological tool
32	Case study related to disease forecasting
Practical	
1	Use of Geographical Information System to study epidemiology of disease
2	Disease expert systems for animal/ zoonotic diseases
3	Disease modelling for animal/ zoonotic diseases
4	Model designing for disease forecasting
5	Study of epidemiology of disease outbreaks using advanced epidemiological techniques
6	Investigation of animal/ zoonotic diseases using recent epidemiological tools
7	Advanced disease reporting system
8	Study of animal/ zoonotic diseases using advanced computing tools
9	Study of animal/ zoonotic diseases using remote sensing/ satellite technology
10	Risk mapping for animal/ zoonotic diseases
11-12	Epidemiological exercises of economically important diseases of the region
13	Use of artificial intelligence and neural networks in veterinary epidemiology
14	Integrated disease surveillance system – prototype development
15	Case study related to advanced epidemiological tool
16	Case study related to advanced disease forecasting/ modelling

I. Course Title : Risk Analysis and Predictive Modelling
II. Course Code : VPE 606
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Definitions, History of risk analysis
2	Relevance of risk analysis (RA) to food sector

Lecture(s)	Topic
3	Principles of risk analysis
4	Risk analysis components (risk assessment, management and communication)
5	Risk assessment
6	Risk management
7	Risk communication
8	Microbial Risk Assessment (MRA) involving hazard identification, exposure assessment, hazard characterization, and risk characterization
9	Hazard identification
10	Exposure assessment
11	Hazard characterization
12	Risk characterization
13	Methodologies used in risk analysis (RA)/ Microbial Risk Assessment MRA
14	Qualitative and quantitative risk analysis
15	Qualitative risk analysis
16	Quantitative Microbial Risk Assessment (QMRA) for foods of animal origin including water
17	Application of mathematical models to study propagation of microbial hazards from farm-to-fork
18	Risk-based decision-making
19	Variability and uncertainty inherent to biological data
20	Measurement and modelling of uncertainty and variability during risk assessment.
21	Integration of risk assessment/ risk analysis with HACCP and other quality management or assurance systems
22	Linking microbial food safety with risk assessment
23	Relevance of assumptions and observed data for predictive models
24	Study of software packages used for risk analysis
25	Mathematical modelling of microbial growth rate in food/ feeds
26	Predictive modelling tools for food safety management
27	Microbial modelling for the prediction of product shelf-life and safety
28	Applications of predictive modelling of microbial behaviour in foods
29	Meta-analysis in risk analysis of animal/ zoonotic diseases
30	Risk prediction models
31	Multivariate prediction models
32	Case study related to MRA of foods of animal origin

Practical

1. Microbial Risk Assessment (MRA)
2. Risk assessment
3. Risk management
4. Risk communication
5. Qualitative MRA
6. Quantitative MRA
7. Modelling of infectious diseases using computational and mathematical methods.
8. Building and analyzing models of infectious diseases
9. Study of population-level processes for infectious diseases of animals and humans
10. Performing risk analysis for food safety hazards using microbial risk analysis tools
11. Risk assessment using high throughput simulation modelling
12. Investigation of uncertainty, variability and sensitivity analysis techniques using computer models
13. Risk prediction models – study of prototype
14. Meta-analysis – study of prototype

Lecture(s)	Topic
15.	Multivariate prediction models – study of prototype
16.	Case study on MRA

I. Course Title : Advances in Environmental Hygiene
II. Course Code : VPE 607
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Current status of problems pertaining to environmental hygiene
2	Status, impact and management of air pollution
3	Status, impact and management of global warming
4	Status, impact and management of soil pollution
5	Status, impact and management of water pollution
6	Status, impact and management of environmental problems
7	Impact of pollution on the ecology of diseases
8	Environmental impact of intensive animal husbandry
9	Impact of intensive animal husbandry on the public health
10	Animal sector consequences of carbon footprints
11	Eco-philosophy, policy and advocacy of environmental hygiene with veterinary/ animal husbandry perspectives
12	Environmental economics
13	Environmental conflicts and cooperation
14	Ethics and compliance - sustainable animal husbandry and environmental safety
15	Disinfects and disinfection procedures
16	Environmental risk analysis (assessment and management)
17	Occupational health impact of animal farming
18	Occupational environmental hygiene and safety linked to animals
19	Health risk profiling and risk analysis of animal farming and trade
20	Epidemiology of chronic occupational disease induced by environmental pollution
21	Ecotoxicology of toxicants used in the farming
22	Bio-accumulation, concentration and bio-magnification of pollutants, toxicants and hazardous substances in the environment
23	Reporting of environmental issues and global informatics
24	Environmental hazard surveillance and monitoring systems
25	Decision making and public awareness
26	Role of VPH in National Sanitation Programmes (Swachh Bharat Abhiyan and other governmental programmes)
27	International environmental management efforts
28	International organizations and programmes
29	Legislations on environmental hygiene, safety and policy
30	Case study on ammonia as pollutant from animal sector
31	Case study on hydrogen sulphide as pollutant from animal sector
32	Case study on methane as pollutant from animal sector
Practical	
1	Hygiene and sanitization of animals and animal premises
2	Detection and monitoring of pollutants emanating from animals to the air
3	Detection and monitoring of pollutants emanating from animals to the soil

Lecture(s)	Topic
4	Detection and monitoring of pollutants emanating from animals to the water
5	Detection and monitoring of pollutants emanating from animals to other environmental sources
6	Advanced environmental hazard measurement methods
7	Measurement of health effects of environmental toxicants
8	Environmental risk assessment methods
9	Risk analysis of animal contributed ammonia
10	Risk analysis of animal contributed hydrogen sulphide
11	Risk analysis of animal contributed methane
12	Risk analysis of animal contributed other environmental hazards
13-14	Visits to remediation unit, waste water treatment plant, sewage treatment plants, tannery, etc. to study characteristics, impact and mitigation of hazards and associated risks
15-16	Assignments: Each student will select at least two recent articles from journals related to course and discuss in the class through presentation

I. Course Title : Herd Health Management and Disease Economics

II. Course Code : VPE 608

III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	General principles of herd health
2	Interaction between health and production
3	Health effects of animal and zoonotic infections at the farm level
4	Direct and indirect losses due to zoonotic diseases
5	Components of the economic impact of animal diseases
6	Herd health management and disease economics
7	Linking heard health with economics – margin of returns
8	Health effects of animal and zoonotic infections at the regional/ state/ national/ international level
9	Interactions between health, production and disease
10	General principles of enhancing herd immunity
11	Economic methods of disease control for decision support
12	Herd health management – intervention options and their economic assessment
13	Quantification of financial effects of animal disease
14	Methods for optimizing decisions at individual animal, herd and population levels
15	Determination of costs and benefits of disease control measures
16	Estimation of extent of the disease and potential spread
17	Economic aspects and impact of zoonotic diseases
18	Estimation of cost of animal/ zoonotic disease on livelihoods outcomes (income, health, and trade), including environmental impacts
19	Assessment of the cost-effectiveness of control strategies used to reduce the risk of animal/ zoonotic diseases
20	Identification of factors affecting adoption of zoonotic risk reduction strategies
21	Estimation of disability adjusted life years (DALYs) parameters
22	Herd health management and disease economics of diseases in cattle/ buffalo
23	Herd health management and disease economics of diseases in sheep/ goat
24	Herd health management and disease economics of diseases in swine

Lecture(s)	Topic
25	Herd health management and disease economics of diseases in poultry
26	Herd health management and disease economics of diseases in other livestock
27	Preventive healthcare through vaccination
28	Preventive healthcare through bio-security practices
29	Economic benefits of prevention and control of diseases
30	Zoning and creation of disease-free area
31	Disease eradication and surveillance
32	Case study on eradiation of disease–Economic perspectives
Practical	
1	Study of framework of animal health management
2	Steps and methods for assessment of the economic impact of a disease
3	Assessing economic merit of interventions to control disease
4	Decision analysis and decision support systems for promoting animal health
5	Modelling animal health economics
6	Modelling the economics of Veterinary Services at the Farm Level
7	Modelling the economics of National Disease Control Programs
8	Economic modelling techniques (i.e. partial budgeting, cost-benefit analysis, decision analysis, and systems simulation) for veterinary decision making
9	Economic assessment of problems, programmes, prevention/ control measures, impact, etc.
10	Economic evaluation of hygienic practices in the animal house
11	Estimation of burden of animal/ zoonotic diseases
12	Estimation of DALY and other disease parameters
13	Case study on economic impact of zoonotic diseases
14	Visit to various livestock farms, assessment of their problems
15-16	Assignments: Each student shall select at least two recent articles from journals related to course and discuss in the class through presentation

I. Course Title : Epidemiology of Trans-boundary, Non-infectious and Chronic Diseases

II. Course Code : VPE 609

III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Definition and characteristics of trans-boundary diseases
2	Global trends in the occurrence of trans-boundary diseases
3	Role of wildlife in emergence of trans-boundary diseases
4	Prevention/ control of trans-boundary diseases
5	Important trans-boundary diseases categorized according to the aetiology
6	Important trans-boundary diseases categorized according to the animal species
7	New Technologies to fight transboundary animal diseases
8	Role of veterinary public health and veterinary services in the management of non-infectious and chronic diseases
9	Establishment of causality and associations in non-infectious and chronic diseases
10	Characteristics of Koch's/ Henle-Koch postulates and Evans' rules of disease causation
11	Unified principles of establishing causality for both infectious and non-infectious diseases

Lecture(s)	Topic
12	Infectious and chronic disease connections
13	Causal role of infectious agents in cancer (relating criteria)
14	Global status of non-communicable diseases
15	Establishment of trends of non-infectious and chronic disease occurrence
16	Epidemiology of non-infectious and chronic diseases affecting different species (livestock/ poultry) and production systems
17	Determinants of chronic and non-infectious diseases- reasons for emergence range of pathways and epidemiology
18	Study of characteristics of risk factors (genetic, physiological, environmental, behavioural, etc) associated with non-infectious and chronic diseases
19	Demographic, epidemiological and nutritional factors
20	Economic impact of chronic and non-communicable diseases
21	Social determinants of non-communicable diseases
22	Spatial and temporal epidemiology of nutritional and metabolic diseases
23	Spatial and temporal epidemiology of reproductive diseases
24	Spatial and temporal epidemiology of chemical poisonings and toxicities (pesticides, poisonous plants, etc)
25	Spatial and temporal epidemiology of neoplastic and other miscellaneous diseases
26	Modelling of non-infectious non –communicable diseases or chronic diseases
27	Trends in the prevention and control of non-infectious and chronic disease – current status and future perspectives
28	Early detection, notification and surveillance
29	Participatory surveillance
30	Case study on vector-borne trans-boundary diseases
31	Case study on non-infectious chronic livestock disease
32	Case study on emerging/ re-emerging zoonotic trans-boundary diseases
Practical	
1	Detection and characterization of trans-boundary diseases
2	Capacity building and training
3	Study of the role of wildlife in trans-boundary animal diseases
4	Wildlife disease surveillance
5	Study of wildlife–livestock interface and disease ecology
6	Disease investigation - data and information collection, collation and sharing
7	Surveillance for trans-boundary diseases
8	Measurement of burden of non-infectious and chronic diseases (mortality, morbidity, survival, risk factors, etc.)
9	Survey of non-infectious and chronic diseases
10	Animal models for the study of non-infectious and chronic diseases
11	Establishment of evidence/ proof of causation of non-infectious and chronic diseases
12	Study of risk factors associated with non-infectious and chronic diseases
13	Measurement of socioeconomic impacts associated with non-infectious and chronic diseases
14	Controlled trials involving contemporary non-infectious and chronic diseases
15	Undertaking short research problem(s)
16	Case study on trans-boundary/ chronic livestock disease

I. Course Title : Ecology and Animal/ Human Health
II. Course Code : VPE 610
III. Credit Hours : 2+0

Lecture(s)	Topic
Theory	
1	Definitions related to ecology and animal or human health
2	Linkage between human/ animal health and the ecosystem
3	Spill-over of diseases – elucidation of social and ecological basis of disease
4	Assessment of changing trends in the environments and its impact on the animal/ human health
5	Study of emerging public health threats linked to the changes in the environment
6	Study of landscape epidemiology of diseases
7	Study of contemporary issues centred on ecological and evolutionary perspectives of infectious diseases
8	Animal–human-ecosystem interface
9	Study of ecological/ environmental factors influencing spatio-temporal occurrence of disease such as temperature, rainfall and other environmental factors
10	Ecological conditions and evolutionary dynamics
11	Disease ecology based explanatory and predictive models
12	Elucidation of natural history and host-parasite interactions linked to the ecological factors
13	Ecology of vector borne diseases
14	Vector dynamics and ecology
15	Study extrinsic incubation period
16	Understanding of critical risk factors of disease spread – timing, distribution, and abundance of competent vectors
17	Study of cyclical patterns of disease
18	Mapping environmental conditions with disease
19	Establishing functional links between environmental modifications and disease
20	Linking climate change with disease occurrence
21	Impact of climate change on disease occurrence
22	Study of dynamics of ENSO with climate change and disease
23	El Niño/ Southern Oscillation (ENSO), influence on global climate variability and disease occurrence
24	Evolution of disease alert and forecasting systems
25	Use of global positioning and remote sensing tools for disease management
26	Early warning and GIS based disease predictions
27	Role of bio-security measures in curtailing transmissible diseases at the animal-animal, animal-human and human-human interface
28	Biology and ecology of vector-borne diseases – ecology of disease – the intersection of human and animal health
29	Impact of ecological/ environmental factors on the emergence of human/ animal diseases
30	Clusters of disease outbreaks
31	Environmental impact of antimicrobial resistance
32	Preparedness for combating the impacts of climate change

I. Course Title : Diagnostic Approaches in Epidemiology
II. Course Code : VPE 611
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Concepts of molecular basis of a disease
2	Molecular epidemiology of diseases/ infections
3	Molecular determinants of pathogenicity and virulence amongst agents
4	Dynamics of disease transmissibility in populations of livestock and poultry
5-6	Epidemiology of antigenic, genetic and biological diversity amongst pathogens associated with disease/ outbreaks
7	Differentiation of field isolates (wild) from vaccine strains (markers, DIVA, etc).
8	Marker vaccine development
9	Detection and characterization of pathotypes, serotypes, biotypes and genotypes of pathogens
10	Understanding epidemiology of disease using immunological, immunoblotting and monoclonal antibody-based tests
11	Understanding epidemiology of disease using conventional and rapid enzyme immune assays. Use of monoclonal antibodies in different ELISAs for antigenic analysis
12	Understanding epidemiology of disease using pathogen typing methods, viz., polymerase chain reaction, sequencing, RFLP, etc.
13	Understanding epidemiology of disease using radio-actively labelled or non-radioactive oligo-nucleotide probes - dot-blot and Southern hybridizations
14	Evaluation of diagnostic tests/ assays using epidemiological approaches
15	Vaccine efficacy/ effectiveness trails
16	Epidemiology of screening and confirmatory diagnostic assays
17	Estimation of disease burden in populations
18	Estimation of frequency and pattern of health events in a population
19	Designing of epidemiological studies
20	Representation disease data/ information
21	Study of disease databases and online resources
22	Quantification of zoonotic agents using conventional and molecular tools
23	Rapid detection of foodborne and zoonotic agents
24	On-site, on-farm and animal-side detection systems- approaches and applications
25	Phylogenetic analysis of disease agents
26	Use of modern bio-informatics and disease informatics tools for the study of zoonotic and other determinants of public health significance
27	Source tracing of origin of infectious agents
28	Outbreak investigation and disease reporting including notifiable diseases
29	Traceability of livestock and its implications
30	Multi-centric molecular typing and validation of foodborne and zoonotic agents
31	Epidemiology of chronic disease makers
32	Case study on quantitative epidemiological analysis
Practical	
1	Molecular fingerprinting of pathogens
2	Molecular epidemiology of foodborne and zoonotic agents
3-4	Detection and characterization of pathogens using nucleic acid based techniques
5	Sero-epidemiology – methods and applications
6-7	Multi-locus sequence typing (MLST), pulsed-field gel electrophoresis (PFGE), and amplified fragment length polymorphism (AFLP) typing of pathogens

Lecture(s)	Topic
8	Source tracing of outbreaks
9	Construction and characterization of epidemic curve
10	Spatio-temporal clustering of diseases
11	Mapping disease and risk factors
12	Calculation of variables and confounders using logistic regression analysis
13	Epidemiological analysis for the disease prediction, early warning and forecasting
14	Epidemiological analysis involving remote sensing, GIS and satellite technologies
15-16	Assignment: Each student shall select at least two recent articles from journals related to the course and discuss in the class through presentation

I. Course Title : Surveys, Surveillance and Data Management
II. Course Code : VPE 612
III. Credit Hours : 2+1

Lecture(s)	Topic
Theory	
1	Robust survey: planning, statistical models. Survey iceberg (tools and technologies).
2	Structured population-based surveys, types of surveys.
3	Survey design - Sampling, Sampling methods, Sample size, etc.
4	National surveys.
5	Surveillance – definition, goals and types of surveillance system.
6	Principles of surveillance.
7	Critical elements of surveillance.
8	Surveillance methods and approaches.
9	Surveillance for distribution and occurrence of infection.
10	Information architecture for surveillance.
11	Structured non-random surveillance.
12	Surveillance programmes. Designing an active surveillance program.
13	Surveillance to demonstrate freedom from disease or infection.
14	Epidemiological surveillance network.
15	Components of regional or national surveillance system.
16	Statistical models for surveillance.
17	Softwares used for surveillance.
18	State, National and International agencies (OIE, CDC, etc.), databases and management systems.
19-20	Surveillance of emerging and re-emerging diseases
21	Animal health surveillance
22	Data and database
23-24	Data acquisition - Sampling and questionnaires
25	Disease/ data recording and reporting
26	Veterinary data recording schemes and information system (databases)
27	National veterinary epidemiology and disease informatics
28-29	Epidemiology informatics on globally and nationally important emerging/ re-emerging diseases and designing of strategies for their prevention and control.
30	Analysis of disease data using software analysis
31	Study of veterinary epidemiology and disease informatics software (e.g. EpiInfo)
32	Case study on disease surveillance

Lecture(s)	Topic
Practical	
1	Data collection, storage and quality control
2	Sampling methods - confidence level, sample unit, sample size, etc.
3	Statistical methods for analysis of disease data
4	Preparation and analysis of questionnaires
5	Questionnaire survey for disease prevalence
6	Data analysis using computer software
7	Data analysis and representation of data pertaining to animal disease/ productivity
8	Survey for livestock and poultry diseases
9	Study/ development of computer software for animal disease/ productivity
10	Evaluation of veterinary/ animal husbandry interventions
11	Evaluation of animal disease surveillance systems
12	Study of national health surveys related to animal/ human disease
13	Surveillance of economically important disease of the region/ state
14	Usefulness/ efficacy/ effectiveness of vaccines/ vaccination
15-16	Assignment: Each student will select at least two recent articles from journals related to course and discuss in the class through presentation

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Veterinary Para-Clinical Subjects
– Veterinary Pharmacology and Toxicology

Course Title with Credit Load M.V.Sc. in Veterinary Pharmacology and Toxicology

Course Code	Course Title	Credit Hours
VPT 501	Concepts of Pharmacology, Drug Design and Development*	2+0
VPT 502	Autonomic and Autacoid Pharmacology*	2+1
VPT 503	CNS Pharmacology	2+1
VPT 504	Digestive and Respiratory Pharmacology	2+1
VPT 505	Cardiovascular and Urinary System Pharmacology	2+0
VPT 506	Endocrine and Reproductive Pharmacology	2+1
VPT 507	Chemotherapy*	2+1
VPT 508	Toxicology of Xenobiotics*	2+1
VPT 509	Toxinology	2+1
VPT 510	Pharmacological Techniques*	0+2
VPT 511	Techniques in Toxicology*	0+2
VPT 512	Ethnopharmacology	1+1
VPT 513	Fundamentals of Pharmacokinetics	1+1
VPT 591	Master's Seminar*	1+0
VPT 599	Master's Research	30

*Core courses

Course Contents
M.V.Sc. in Veterinary Pharmacology and Toxicology

I. Course Title : Concepts of Pharmacology, Drug Design and Development
II. Course Code : VPT 501
III. Credit Hours : 2+0
IV. Aim of the course

To study the basic concepts of drug actions, and drug design and development.

V. Theory

Unit I

Scope of pharmacology, Drugs and other therapeutic agents, Principles of biopharmaceutics and veterinary dosage forms, Dynamics of ADME; Principles of therapeutics; Rationale and Empirical, Various other types of therapeutics.

Unit II

Pharmacodynamics targets for drug actions (enzymes, ion channels, structural and transporter proteins) evidence of drug action through receptor, Signal transduction mechanisms (GPCR, enzyme linked receptor), Regulation and malfunctioning of diseases.

Unit III

Quantitation of drug-receptor interactions and elicited effects, Drug-drug interactions and adverse drug reactions.

Unit IV

Drug invention: Screening, Assaying, Designing and Development of drugs, Clinical trials, Drug safety, Regulations and standards; Gene based therapy and drug delivery system.

I. Course Title : Autonomic and Autacoid Pharmacology
II. Course Code : VPT 502
III. Credit Hours : 2+1
IV. Aim of the course

To study the pharmacological basis of the rapeutic uses of autonomic and autacoid drugs.

V. Theory

Unit I

Anatomical and physiological considerations of autonomic and somatic motor nervous system and Neurohumoral transmission.

Unit II

Agents modulating peripheral nervous system, Non-adrenergic-non cholinergic (NANC) transmission.

Unit III

Pharmacology of adrenergic agonists, Antagonists and Adrenergic neuron blockers.

Unit IV

Pharmacology of cholinergic agonists, Antagonists and cholinergic neuron blockers.

Unit V

Drugs acting at the Neuromuscular Junction and Autonomic Ganglia.

Unit VI

Autacoids: Introduction to immunity and inflammation, Immunostimulants, Immunosuppressants and Tolerogens, Pharmacological aspects of histamine, serotonin, kinins, eicosanoids and platelet activating factor, Angiotensins and other putative autacoids.

VI. Practicals

Pharmacological experiments on intact and isolated preparations for studying the effects of various prototype autonomic and autacoids drugs on vascular, intestinal, respiratory, urinary and reproductive smooth muscles, autonomic ganglia, skeletal muscles; blood pressure, ECG, heart, etc.

I. Course Title : CNS Pharmacology

II. Course Code : VPT 503

III. Credit Hours : 2+1

IV. Aim of the course

To study the pharmacology of drugs acting on central nervous system (CNS).

V. Theory

Unit I

Anatomical and physiological considerations and neurohumoral transmission in CNS.

Unit II

Historical development, theories, principles and stages of general anaesthesia.

Unit III

Recent advances in pharmacology of general anaesthetics and therapeutic gases, local anaesthetics, sedatives, hypnotics, neuroleptics, antiepileptics.

Unit IV

Pharmacology of CNS stimulants, analeptics, opioid agonists and antagonists; non-steroidal anti-inflammatory agents, central muscle relaxants, Pharmacology and regulations of euthanizing agents.

VI. Practicals

Study of pharmacodynamics of prototype drugs of each class of drugs in experimental animals.

I. Course Title : Digestive and Respiratory Pharmacology
II. Course Code : VPT 504
III. Credit Hours : 2+1

IV. Aim of the course

To study the pharmacological aspects of drugs acting on digestive and respiratory systems.

V. Theory

Unit I

Physiological considerations of GIT functions in ruminants and non-ruminants. Pharmacology of drugs acting on gastrointestinal tract. Appetite stimulants, emetics and anti-emetics.

Unit II

Pharmacology of anti-ulcer drugs, modulators of gastric and intestinal motility and secretions.

Unit III

Agents promoting digestive functions; bile acids and pancreatic enzymes, drugs affecting liver; rumen pharmacology.

Unit IV

Gastrointestinal protectant and adsorbents, laxatives and cathartics.

Unit V

Physiological considerations of respiratory functions in animals. Pharmacology of drugs acting on respiratory system: Bronchodilators, Antitussives, Mucolytics, Expectorants, Decongestants. Drugs used in treatment of asthma.

VI. Practicals

Study of effects of drugs on digestive and respiratory functions using different *in-vitro* and *in vivo* animal models.

I. Course Title : Cardiovascular and Urinary System Pharmacology
II. Course Code : VPT 505
III. Credit Hours : 2+0

IV. Aim of the course

To study the pharmacological aspects of drugs acting on CVS and kidneys.

V. Theory

Unit I

Cardiac electrophysiology consideration, Pharmacology of antiarrhythmic drugs, Cardiac glycosides, Myocardial stimulants.

Unit II

Antihypertensive, Antihypotensive and Antihyperlipidaemic drugs.

Unit III

Coagulants and anticoagulants, Thrombolytic agents, Plasma expanders, Drugs affecting haemopoietic system and antiplatelet drugs.

Unit IV

Pharmacology of drugs affecting renal functions and fluid-electrolyte balance: Diuretics, Antidiuretics, Urinary acidifiers, Urinary alkalizers, Urinary antiseptics and Uricosuric and other anti-gout drugs. Principles of acid-base balance, fluid and electrolyte therapy and blood substitutes.

I. Course Title : Endocrine and Reproductive Pharmacology

II. Course Code : VPT 506

III. Credit Hours : 2+1

IV. Aim of the course

To study the pharmacology of drugs affecting endocrine functions.

V. Theory

Unit I

Drugs affecting endocrine functions of hypothalamus, pituitary, thyroid, adrenals and pancreas.

Unit II

Drugs affecting calcium and phosphorus homeostasis.

Unit III

Drugs affecting male reproductive organs, spermatogenesis and erectile dysfunctions.

Unit IV

Drugs affecting female reproductive organs: ovulation, oestrus, conception, gestation and lactation.

Unit V

Oxytocic and other drugs affecting uterus.

VI. Practicals

To study the effects of various endocrine agonists and antagonists in animal models and isolated tissues.

I. Course Code : VPT 507

II. Course Title : Chemotherapy

III. Credit Hours : 2+1

IV. Aim of the course

To study the recent advances in chemotherapeutic agents with relevance to their molecular mechanisms and therapeutic aspects.

V. Theory

Unit I

General consideration and principles of Chemotherapy, Classification of chemotherapeutic agents; Molecular mechanism of Antimicrobial resistance-development and Prevention strategies; Combination therapy, Therapeutic failure.

Unit II

Systemic and gut acting sulphonamides, diaminopyrimidines, sulfones, quinolones, nitrofurans, nitroimidazoles.

Unit III

Penicillins, Cephalosporins, Carbapenems, Carbacephems, monobactam, beta lactamase inhibitors.

Unit IV

Aminoglycosides, Tetracyclines, Chloramphenicol and its congeners, macrolides, lincosamides.

Unit V

Antitubercular drugs, Glycopeptides, and Polypeptide antibiotics, Methenamine, Carbadox, Novobiocin, Virginiamycin, Spectinomycin, Oxazolidinones and newer agents.

Unit VI

Antiprotozoans, Anthelmintics, Ectoparasiticides

Unit VII

Antifungal agents, Antiviral and Anti-neoplastic drugs.

VI. Practicals

Assay of chemotherapeutic agents, Antibiotic sensitivity tests. Determination of minimum inhibitory concentration (MIC), Mutant Prevention Concentration (MPC), Minimum Bactericidal Concentration (MBC) and time kill kinetics. Molecular techniques for intervention of antimicrobial resistance. Determination of anthelmintic properties of drugs using *in-vitro* models.

I. Course Title : Toxicology of Xenobiotics

II. Course Code : VPT 508

III. Credit Hours : 2+1

IV. Aim of the course

To study the molecular basis of poisoning and antidotal therapy in animals.

V. Theory

Unit I

Principles and scope of toxicology.

Unit II

Molecular mechanism of action of poisons and their detoxification, rational approach for diagnosis and treatment of poisonings.

Unit III

Toxicology of metals, non-metals, agrochemicals, solvents and vapors, common salt, urea and other feed additives. Toxicity of drugs.

Unit IV

Genotoxic and other effects of radiations and radioactive chemicals; toxicogenomics and developmental toxicology; forensic and regulatory aspects of toxicology.

VI. Practicals

Extraction, separation and detection of common poisons in toxicological specimens, study of toxicity and antidotal treatment in animals, designing of animal toxicity experiments and general toxicity spot tests.

I. Course Title : Toxinology
II. Course Code : VPT 509
III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge of molecular basis of toxicity induced by toxins of plants, microbes and animals origin.

V. Theory

Unit I

Classification and identification of different types of toxins.

Unit II

Toxicity induced by abrin, strychnine, dhurin, amygdaline, sanguine, solamine, gossypol, beta-amino propionitryl, beta-oxolyl amino L-alanine, other Phytotoxins

Unit III

Toxin induced Teratogenicity, Thiamine deficiency and Phototoxicity.

Unit IV

Toxicology of mycotoxins: aflatoxins, rubratoxins, ochratoxins, sporidesmin, citrinin, F-2 toxin, trichothecenes, tremorgens and ergot alkaloids.

Unit V

Zootoxins: snake venom, scorpion, spider and insect stings and bufotoxins, Puffer fish and Shell fish toxins. Bacterial toxins (botulinum and tetanus toxins)

VI. Practicals

Detection of alkaloids, glycosides, cyanides, nitrate/ nitrite, tannins, saponins, resins and oxalates. Detection of mycotoxins in the samples of feed/ fodder and animal tissue. Identification of toxic weeds and plants of the state/ local area.

I. Course Title : Pharmacological Techniques
II. Course Code : VPT 510
III. Credit Hours : 0+2

IV. Aim of the course

To impart the knowledge of various pharmacological techniques and screening methods of drugs.

V. Practicals

Unit I

Principles of drug action and bioassay. Construction of dose-response plots and their significance. Determination of EC_{50}, median effective (ED_{50}), toxic (TD_{50}) or lethal doses (LD_{50}) from dose-response plots. Calculation of dissociation rate constants, therapeutic ratio, margin of safety, potency ratio, pAx, pDx and pD'x values.

Unit II

Techniques for setting up isolated and intact preparations, recording of BP in hen/ rat, recording of ECG in rat/ other small animals.

Unit III

Organization of screening programme of drugs; multidimensional screening procedures and gross observational methods. Specific tests for evaluation of tranquillizing, hypnotic, analgesic, anticonvulsant, general and local anaesthetic, muscle relaxant, anti-inflammatory, antipyretic, antiarrhythmic, antihypertensive and antihyperglycemic activities.

Unit IV

Guidelines for safety studies on drugs.

I. Course Title : Techniques in Toxicology

II. Course Code : VPT 511

III. Credit Hours : 0+2

IV. Aim of the course

To understand the animal toxicity tests and assessment of various toxicants using specific tests.

V. Practicals

Unit I

Designing of animal models in toxicological studies. Introduction to different toxicological guidelines for *in-vitro* and *in vivo* studies (OECD, WHO, EPA, etc.). In silico toxicity prediction.

Unit II

Animal toxicity tests for acute, sub-acute and chronic toxicity.

Unit III

Specific toxicity tests for Neurotoxicity, Immunotoxicity, Behavioural, Reproductive and Developmental, Inhalation Toxicity, Mutagenicity, Carcinogenicity.

Unit IV

Toxicological tests for the study of metabolism, synergism and antagonism. Assay for marker enzymes, analysis of toxicant residues in biological materials.

I. Course Title : Ethnopharmacology

II. Course Code : VPT 512

III. Credit Hours : 1+1

IV. Aim of the course

To impart the knowledge and importance of traditional Indian medicine.

V. Theory

Unit I

Historical aspects of traditional Indian remedies. Alternate systems of medicine in animals. Scope of Ethnopharmacology.

Unit II

Classification and identification of medicinal plants. Classification, Metabolism and interactions of Phytoconstituents.

Unit III

Standardization and clinical validation of bioactive molecules from plant sources. Therapeutic and adverse effects of potential herbal drugs. Indigenous drugs used as glactagogues, carminatives, antiseptics, antidiarrhoeals, anthelmintics, Immuno-stimulants, antimicrobials, bioenhancers, analgesics, anti-inflammatory agents, etc.

VI. Practicals

Identification of medicinal plants. Preparation of plant extracts in various solvents using different techniques. Phytochemical screening of plant extracts. Evaluation of pharmacological activities of extracts using *in-vitro* and *in-vivo* methods.

I. Course Title : Fundamentals of Pharmacokinetics

II. Course Code : VPT 513

III. Credit Hours : 1+1

IV. Aim of the course

To study the disposition of drugs and dosage regimen.

V. Theory

Unit I

Routes of drug administration, ADME, plasma protein binding, factors modifying ADME

Unit II

Basic concept of pharmacokinetics, Order of pharmacokinetics processes (zero order, first order and mixed order), Models of pharmacokinetics analysis of drugs (compartmental, non-compartmental model)

Unit III

Compartmental models of drug distribution, determinants of absorption, distribution and elimination, rate constants (Cmax, Tmax)

Unit IV

Calculation of pharmacokinetic parameters, dosage regimen and bioavailability based on compartmental analysis, Non-compartmental pharmacokinetic modelling.

VI. Practicals

Analysis of pharmacokinetic data and determination of different pharmacokinetic parameters and bioavailability of drugs in normal and diseased animal models.

Course Outline-cum-Lecture Schedule for Master Degree Programme

I. Course Title : Concepts of Pharmacology, Drug Design and Development

II. Course Code : VPT 501

III. Credit Hours : 2+0

IV. Aim of the course

To study the basic concepts of drug actions, and drug design and development.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Scope of pharmacology, nature and sources of drugs and other therapeutic agents	2
2.	Principles of biopharmaceutics and dosage forms of drugs	2
3.	Principles of Pharmacokinetics-Absorption, distribution, metabolism and excretion of drugs.	4
4.	Principles of drug action, rational, empirical and various other therapeutics	2
5.	Pharmacodynamics-targets for drug actions (enzymes, ion channels, structural and transporter proteins)	4
6.	Receptor mediated drug action, types of drug receptors, second messengers of drug action and signal transduction	4
7.	Regulation and malfunctioning of diseases.	1
8.	Quantitation of drug-receptor interactions and elicited effects	2
9.	Drug interactions and adverse drug reactions	2
10.	Drugs design and development, Screening and drug assay	3
11.	Clinical drug trials	2
12.	Drug safety, drug standards and regulations	2
13.	Gene therapy and novel drug delivery systems.	2

I. Course Title : Autonomic and Autacoid Pharmacology

II. Course Code : VPT 502

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the pharmacological basis of therapeutic uses of autonomic and autacoid drugs.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction to autonomic nervous system (ANS), Anatomical and physiological considerations of autonomic and somatic motor nervous system	2
2.	Neurohumoral transmission	2
3.	Exceptions to generalization of ANS, Agents modulating peripheral nervous system, non adrenergic-non cholinergic (NANC) transmission	3
4.	Sympathetic nervous system, adrenergic agonists, antagonists and adrenergic neuron blockers	4
5.	Therapeutic uses of sympathetic drugs and blockers	1
6.	Parasympathetic nervous system, cholinergic agonists, antagonists and cholinergic neuron blockers	4
7.	Therapeutic uses of parasympathetic drugs and blockers	1
8.	Ganglion stimulating and blocking drugs	2
9.	Neuromuscular blocking drugs	1
10.	Introduction to immunity and inflammation	2
11.	Immunostimulants, immunosuppressants and tolerogens	1
12.	Histaminergic and antihistaminics	2
13.	Serotonin and antiserotonin agents	1
14.	Kinins as mediators of inflammation	2
15.	Eicosanoids and platelet activating factor	3
16.	Angiotensins and other putative autacoids	2
17.	Angiotensins and inhibitors of renin-angiotensin system	1
Practical		
1.	Effect of sympathetic agonists and antagonists on intact and isolated preparations through experiments/ simulation programmes.	5
2.	Effect of sympathetic agonists and antagonists on intact and isolated preparations through experiments/ simulation programmes.	5
3.	Effects of autonomic drugs on blood pressure, ECG, etc.	2
4.	Effect of autacoids on different systems	4

I. Course Title : CNS Pharmacology

II. Course Code : VPT 503

III. Credit Hours : 2 +1

IV. Aim of the course

To study the pharmacology of drugs acting on central nervous system (CNS)

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction to CNS – Physiological and anatomical considerations	1
2.	Drugs action on CNS	1
3.	Central neurotransmitters	2

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
4.	General anaesthesia – History, theories and stages of general anaesthesia	1
5.	Adjuvants to general anaesthetics	1
6.	Inhalant general anaesthetics	3
7.	Injectable general anaesthetics	3
8.	Local anaesthetics	2
9.	Hypnotics and sedatives	3
10.	Psychotropic drugs and drugs modifying abnormal behaviour of animals	3
11.	Anticonvulsants	2
12.	Opioid agonists (analgesics) and antagonists	3
13.	Non steroidal anti-inflammatory drugs (NSAIDs)	3
14.	CNS stimulants	1
15.	Central muscle relaxants	1
16.	Drugs of abuse	2
17.	Currents topics/ Discussion on library assignments	2
Practicals		
1.	Study on general anaesthetics	1
2.	Study on local anaesthetics	2
3.	Study on sedatives and hypnotics	2
4.	Study on anticonvulsants	1
5.	Study on antipyretics	1
6.	Study on analgesics	2
7.	Study on anti-inflammatory drugs	2
8.	Study on psychotropic drugs	2
9.	Study on CNS stimulants	1
10.	Study on central muscle relaxants.	1

I. Course Title : Digestive and Respiratory Pharmacology

II. Course Code : VPT 504

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the pharmacological aspects of drugs acting on digestive and respiratory systems.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Drugs affecting salivary secretions – Sialics and antisialics	1
2.	Drugs affecting gastric secretion – Stomachics, histamine and gastrin analogues	2
3.	Gastric antisecretory and antiulcer drugs – H_2-receptor antagonists and proton pump inhibitors	2
4.	Antacids	2
5.	Emetics	1
6.	Antiemetics	2
7.	Carminatives and antizymotics	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
8.	Appetizers and digestants	1
9.	Pro-kinetics	2
10.	Cathartics	2
11.	Antidiarrhoeic drugs	2
12.	Physiological basis of renal pharmacology	2
13.	Diuretics	3
14.	Drugs affecting fluid, electrolyte and acid-base balance	2
15.	Drugs affecting urinary pH and tubular transport	1
16.	Antitussives	1
17.	Expectorants	1
18.	Analeptics	1
19.	Bronchodilators and other drugs acting on respiratory system	1
20.	Drugs acting on skin and mucous membrane – Demulcents, emollients, protectants, counterirritants, caustics, keratolytics, and wound cleansing agents	2
21.	Current topics/ Disccusion on library assignments.	2
Practicals		
1.	Effects of drugs on digestive functions using different *in-vitro* models	4
2.	Effects of drugs on digestive functions using *in vivo* animal models	4
3.	Effects of drugs on respiratory functions using different *in-vitro* models	4
4.	Effects of drugs on respiratory functions using different animal models	

I. Course Title : Cardiovascular and Urinary System Pharmacology

II. Course Code : VPT 505

III. Credit Hours : 2 + 0

IV. Aim of the course

To study the pharmacological aspects of drugs acting on CVS and kidneys.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	General considerations to cardiovascular system	2
2.	Myocardial stimulants – Cardiac glycosides and other myocardial stimulants	3
3.	Anti-arrhythmic drugs	3
4.	Vasodilators and antianginal drugs	2
5.	Antihypertensive agents	1
6.	Haemostatics and coagulants	2
7.	Anti-coagulants	2
8.	Fibrinolytic and anti-platelet drugs	1
9.	Heamtaopoietic drugs	2
10.	Blood components and blood substitutes	1
11.	Drugs used in treatment of shock	2
12.	Antihyperlipoproteinemics	1
13.	Physiological basis of renal pharmacology	2
14.	Diuretics	3

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
15.	Drugs affecting fluid, electrolyte and acid-base balance	3
16.	Drugs affecting urinary pH and tubular transport	2
17.	Current topics/ Disccusion on library assignments	2

I. Course Title : Endocrine and Reproductive Pharmacology

II. Course Code : VPT 506

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the pharmacology of drugs affecting endocrine functions.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	General considerations to Endocrine and reproductive systems	2
2.	Pharmacology of drugs affecting endocrine functions of Pituitary gland	3
3.	Pharmacology of drugs affecting endocrine functions of thyroid gland	2
4.	Pharmacology of drugs affecting endocrine functions of adrenals	3
5.	Pharmacology of drugs affecting endocrine functions of the Pancreas	2
6.	Physiological basis of calcium and phosphorus homeostasis	2
7.	Hormonal regulation of calcium and phosphorus homeostasis.	2
8.	Pharmacology of drugs affecting male reproductive organs,	2
9.	Drugs affecting spermatogenesis	2
10.	Pharmacology of drugs affecting female reproductive organs	2
11.	Drugs affecting ovulation	2
12.	Drugs affecting oestrus	1
13.	Drugs affecting conception	2
14.	Drugs affecting gestation	2
15.	Drugs affecting lactation	2
16.	Current topics/ Disccusion on library assignments	3
Practicals		
1.	Effects of various hormones in animal models and isolated tissues.	4
2.	Effects of various hormones in and isolated tissues	4
3.	Effects of different hormone antagonists in animal models	4
4.	Effects of different hormone antagonists in isolated tissues	4

I. Course Title : To study the recent advances in chemotherapeutic agents with relevance to their molecular mechanisms and therapeutic aspects.

II. Course Code : VPT 507

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the recent advances in chemotherapeutic agents with relevance to their molecular mechanisms and therapeutic aspects.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	General principles of antibacterial therapy, classification of antibacterial drugs, clinical use of antibiotics, antibiotic combinations. Bacterial resistance	2
2.	Sulfonamides	2
3.	Penicillins and Beta-lactamase inhibitors	2
4.	Cephalosporins	2
5.	Aminoglycosides and Aminocyclitols	2
6.	Chloramphenicol and Thiamphenicol	2
7.	Tetracyclines	2
8.	Macrolide antibiotics and Membrane antibiotics	2
9.	Quinolones – Spectrum, mechanism, kinetics and uses	2
10.	Antifungal agents	2
11.	Antiviral agents	2
12.	Anticancer agents – General principles, classification, mechanism, toxicity, uses	2
13.	Anthelmintics – Antinematodal drugs, Anticestodal drugs, Antitrematodal drugs	2
14.	Ectoparasiticides	2
15.	Antiprotozoan Drugs	2
16.	Antitubercular drugs	2
17.	Curent discussions and assignments	2
Practical		
1.	General methods for assay of chemotherapeutic agents	2
2.	Estimation of sulfonamides in biological fluids	2
3.	Estimation of penicillins in biological fluids	3
4.	Estimation of oxytetracyclines in biological fluids	2
5.	Estimation of trimethoprim in biological fluids	2
6.	Estimation of nitrofurans in biological fluids	2
7.	Antibiotic sensitivity tests	2

I. Course Title : Toxicology of Xenobiotics

II. Course Code : VPT-508

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the molecular basis of poisoning and antidotal therapy in animals.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction, definitions and fields of toxicology	1
2.	History and scope of toxicology	1
3.	Sources and classification of toxicants	1
4.	General modes of action of poisons	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
5.	Detoxification of poisons	2
6.	Principles and fundamentals of toxicology	3
7.	Factors affecting toxicity	1
8.	Diagnosis of poisoning	2
9.	Treatment and management of poisonings	2
10.	Toxicology of metals – Arsenic, mercury, lead, copper, molybdenum, cadmium and iron	5
11.	Toxicology of agrochemicals – Insecticides, herbicides, fungicides and rodenticides	5
12.	Toxicology of solvents and vapours	2
13.	Feed additives – Growth and performance enhancers, non-protein nitrogen compounds, common salt	2
14.	Radiations and radioactive chemicals	2
15.	Genetic and developmental toxicology	2
16.	Regulatory and forensic toxicology	2
17.	Current topics/ Discussion of library assignments	2
Practical		
1.	Collection of material for toxicological investigations	2
2.	Dispatch and processing of samples for toxicological investigations	2
3.	Extraction and separation of poisons from toxicological specimens	2
4.	Identification and detection of common poisons	3
5.	Designing and experiments for acute, subacute and chronic toxicities	2
6.	Calculation of TD50 and LD50	2
7.	Antidotal treatment in animals	2

I. Course Title : Toxinology

II. Course Code : VPT 509

III. Credit Hours : 2 + 1

IV. Aim of the course

To impart knowledge of molecular basis of toxicity induced by toxins of plants, microbes and animals origin.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Classification, identification and chemical constituents of poisonous plants	2
2.	Nitrate/ nitrite poisoning: sources, mechanism of toxicity, clinical findings, diagnosis, treatment and control	2
3.	Cyanide poisoning – Causes, cyanogenetic plants: jowar, etc., mechanism of toxicity diagnosis and treatment	2
4.	Photosensitization – *Lantana camara*: mechanism of toxicity, clinical signs and treatment	2
5.	Bracken fern poisoning – Clinical signs, diagnosis and treatment	2
6.	Poisoning due to strychnos nux-vomica, Ricinus communis and	

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
	kaner – Mechanism of toxicity, clinical signs, diagnosis and treatment	2
7.	Toxicity due to dhatura, Abrus precatorius, Ipomoea carnea – Mechanism of toxicity, clinical signs and treatment	2
8.	Toxicity due to plants containing oxalate – Mechanism of toxicity, clinical signs and treatment	2
9.	Mycotoxins – Hepatotoxins (sporidesmin, aflatoxins and rubratoxins): mechanism of toxicity, symptoms and treatment	2
10.	Nephrotoxins (ochratoxin, citrinin) neurotoxins (penitren A and Patulin). Ergot alkaloids, estrogenism and Trichothecene toxins: clinical signs and treatment	3
11.	Bacterial toxins – Diphtheria toxins, Botulinum toxin, Cholera toxin, tetanus toxin, E.coli., Enterotoxin, Endotoxin	3
12.	Toxicity due to snake venom – Mechanism of toxicity, clinical signs and treatment	3
13.	Toxicity due to scorpion – Mechanism of toxicity, clinical signs and treatment	2
14.	Toxicity due to spider and insect stings and toad poisoning – Mechanism of toxicity, clinical signs and treatment	2
15.	Current topics/ Discussion of library assignments	3
Practicals		
1.	Detection of alkaloids, glycosides, cyanides, nitrate/ nitrite, tannins, saponins, resins and oxalates in toxic plants	8
2.	Phytochemical analysis of toxic plant extracts	2
3.	Detection of mycotoxins in the samples of feed/ fodder and animal tissue	2
4.	Identification of toxic weeds and plants of the state/ local area	2

I. Course Title : Pharmacological Techniques

II. Course Code : VPT 510

III. Credit Hours : 0 + 2

IV. Aim of the course

To impart the knowledge of various pharmacological techniques and screening methods of drugs.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Practicals		
1.	Principles of drug action	1
2.	Bioassay.Typs of bioassay, bioassay techniques	3
3.	Setting up of an isolated tissue preparation and an intact preparation	2
4.	Study of dose response relationship	2
5.	Suprmaximal effect by cumulative dose response study	1
6.	Study on isolated organ assembly	3
7.	Intact frog heart perfusion	1
8.	Recording of blood pressure in animals	2
9.	Recording of ECG in animals	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
10.	Screening Programme of drugs: General and multidimensional	2
11.	Gross observational methods in Screening procedures	2
12.	Calculation of EC50, potency ratio, PDv, PDx PD values	1
13.	Screening of hypnotic activity	1
14.	Study of analgesic, antipyretic and anti-inflammatory activity in laboratory animals	2
15.	Study of general and local anaesthesia in experimental animals	1
16.	Study of anticonvulsant and muscle relaxant effect of drugs	2
17.	Study of antiarrythmic and antihypertensive action of test compound	2
18.	Study of antihyperglycemic and anticholinesteric acivity	1

I. Course Title : Techniques in Toxicology

II. Course Code : VPT 511

III. Credit Hours : 0 + 2

IV. Aim of the course

To understand the animal toxicity tests and assessment of various toxicants using specific tests.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Practicals		
1.	Animal models for toxicological studies	2
2.	Animal toxicity tests for acute, subacute, and chronic toxicity	2
3.	Specific toxicity test for neurotoxicity	1
4.	Specific toxicity test for immunotoxicity	1
5.	Specific toxicity test for developmental toxicity	1
6.	Specific toxicity test for behavioral toxicity	1
7.	Specific toxicity test for mutagenecity	1
8.	Specific toxicity test for reproductive toxicity	1
9.	Specific toxicity test for inhalation toxicity	1
10.	Study specific toxicity test for carcinogenecity	1
11.	Animal toxicological tests to study metabolism	1
12.	Animal toxicological tests for synergism	1
13.	Animal toxicological tests for study of antagonisms	1
14.	Good laboratory practices in toxicology	2
15.	Assays for marker enzymes: AchE, GPx, SOD, Catalase	3
16.	Biochemical analysis of suspected toxicity specimens	2
17.	Haematological evaluation of toxicological samples	2
18.	Determination of pesticide residues using Gas Chromatography	2
19.	Analysis of toxicant residues in biological materials	2
20.	Recent advances	1

I. Course Title : Ethnopharmacology

II. Course Code : VPT 512

III. Credit Hours : 1 + 1

IV. Aim of the course

To impart the knowledge and importance of traditional Indian medicine.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	History, traditional remedies and regional folklore in disease cure.	1
2.	Plant drugs with proven pharmacological and therapeutic efficacy	1
3.	Indigenous drugs used in treatment of various gastrointestinal ailments	1
4.	Indigenous drugs used as antimicrobials	1
5.	Indigenous drugs used as analgesics	1
6.	Indigenous drugs used in cardiovascular disorders	1
7.	Indigenous drugs used in CNS disorders	1
8.	Indigenous drugs used in behavioural disorders	1
9.	Indigenous drugs used in Renal and Urinary tract disorders	1
10.	Indigenous drugs used in eye, ear and skin disorders	1
11.	Therapeutic and adverse effects of potential herbal drugs	2
12.	Alternate systems of medicine in animals – Homeopathy	2
13.	Alternate systems of medicine in animals – Folklore medicine	2
14.	Current topics/ Discussion of library assignments	2
Practicals		
1.	Identification of medicinal plants	1
2.	Various processes used in purification and preparation of active constituents from medicinal plants	4
3.	Classification, identification and chemical constituents of medicinal plants	2
4.	Preparation of plant extracts in various solvents using different techniques	2
5.	Phytochemical screening of plant extracts	2
6.	Pharmacological screening of extracts using *in-vitro* methods	2
7.	Evaluation of pharmacological activities of extracts using in animals	2

I. Course Title : Fundamentals of Pharmacokinetics

II. Course Code : VPT 513

III. Credit Hours : 1 + 1

IV. Aim of the course

To study the disposition of drugs and dosage regimen.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Dosage forms of drugs	1
2.	Routes of drug administration	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
3.	Transfer of drugs across biological membranes	2
4.	Absorption of drugs	1
5.	Distribution of drugs	1
6.	Biotransformation of drugs	2
7.	Excretion of drugs	1
8.	Principles of pharmacokinetics	2
9.	Various Pharmacokinetics models	1
10.	Important pharmacokinetic parameters	2
11.	Dosage regiment	1
12.	*In-vitro* plasma protein binding of drugs	1
Practicals		
1.	Various methods of drug assay	2
2.	Microbiological assay for antimicrobial drugs	2
3.	HPLC techniques	4
4.	Bioavailability of drugs	1
5.	Pharmacokinetics in animal disease models	2
6.	*In-vitro* plasma protein binding of drugs	1
7.	Determination of different pharmacokinetic parameters	2
8.	Analysis of pharmacokinetic data	2
9.	PK-PD modelling and Time kill kinetics	1

Course Title with Credit Load
Ph.D. in Veterinary Pharmacology and Toxicology

Course Code	Course Title	Credit Hours
VPT 601	Molecular Pharmacology*	3+0
VPT 602	Advances in Autacoid Pharmacology	1+0
VPT 603	Pharmacology of Herbal Drugs	2+1
VPT 604	Biotransformation of Xenobiotics	2+0
VPT 605	Clinical Pharmacology and Pharmacokinetics*	2+1
VPT 606	Pharmacogenomics	2+0
VPT 607	Immunopharmacology and Immunotoxicology	2+0
VPT 608	Molecular Toxicology	3+0
VPT 609	Clinical Toxicology*	2+1
VPT 610	Ecotoxicology	3+0
VPT 611	Regulatory Toxicology	2+1
VPT 690	Special Problem	0+1
VPT 691	Doctoral Seminar I*	1+0
VPT 692	Doctoral Seminar II*	1+0
VPT 699	Doctoral Research	**75**

*Core courses

Course Contents
Ph.D. in Veterinary Pharmacology and Toxicology

I. Course Title : Molecular Pharmacology
II. Course Code : VPT 601
III. Credit Hours : 3+0

IV. Aim of the course

To understand the identification and characterization of receptors and drug receptors interactions and underlying mechanisms of drug receptor interactions and its effects.

V. Theory

Unit I

Physicochemical properties of drugs, Forces involved in binding of drugs to receptors, Classification of receptors, Molecular structure of receptors, Properties and regulation of receptors, Receptors for physiological regulatory molecules.

Unit II

Receptor conformation and configuration. Structure activity relationship. Ligand binding study of receptors. Cellular mechanism of signal transduction and second messenger systems; Structures, Types and Functions of membrane ion channels.

Unit III

Theories of drug receptor interactions; Analysis of dose response Relationship and molecular mechanisms of drug actions, Quantitation of drug-receptor interactions and effects, receptors as pharmaceutical targets.

Unit IV

Calcium homeostasis within the cells, pharmacology of mitogen-activated protein (MAP) kinases/ extracellular signal-regulated kinases (ERK) and small G proteins. Methods of identification, isolation and characterization of receptors.

I. Course Title : Advances in Autacoid Pharmacology
II. Course Code : VPT 602
III. Credit Hours : 1+0

IV. Aim of the course

To study the pharmacodynamics and clinical implications of autacoids.

V. Theory

Unit I

Histamine and antihistamines, serotonin and its antagonists.

Unit II

Kinins (Bradykinin, kallikrein, Neurokinin, Substance P, Atrial natriuretic peptides and others).

Unit III

Angiotensins, agonists and antagonists.

Unit IV

Eicosanoids, platelet-activating factors, slow reacting substances of anaphylaxis, Putative neurotransmitters (purine nucleotides, peptides, amino acids and nitric oxide).

Unit V

Pharmacotherapy of inflammation, fever, pain and gout; clinical manifestation of autacoid imbalance.

I. Course Title : Pharmacology of Herbal Drugs
II. Course Code : VPT 603
III. Credit Hours : 2+1

IV. Aim of the course

To study the Pharmacological, Therapeutic and Toxicological aspects of potential medicinal plants.

V. Theory

Unit I

Historical aspect, Chemical constituents of medicinal plants and their classification.

Unit II

Identification, Collection, Preservation, Purification, Isolation, Standardization and Clinical validation of bioactive molecules from vegetable sources.

Unit III

Characterization of pharmacological, therapeutic and toxic effects of potential herbal drugs.

Unit IV

Strategies for development of herbal drugs.

VI. Practical

Extraction, detection, phytochemical analysis and fractionation of medicinal plant extracts. Screening of plant extracts for potential pharmacological activity; Pharmacological effects of herbal drugs on intact and isolated preparations.

I. Course Title : Biotransformation of Xenobiotics
II. Course Code : VPT 604
III. Credit Hours : 2+0

IV. Aim of the course

To study the molecular mechanisms of biotransformation of xenobiotics.

V. Theory

Unit I

Process of drug biotransformation phase I, phase II, and III, Microsomal and non-microsomal metabolizing enzyme systems.

Unit II

Mechanisms and processes of synthetic biotransformation

Unit III

Chemical, biological, genetic and environmental factors affecting drug biotransformation mechanisms.

Unit IV

Metabolic interactions, Enzyme induction and inhibition. Scope of biotransformation in drug development.

I. Course Title : Clinical Pharmacology and Pharmacokinetics
II. Course Code : VPT 605
III. Credit Hours : 2+1
IV. Aim of the course

To study the efficacy and disposition of drugs in clinical conditions.

V. Theory

Unit I

Scope of clinical pharmacology. Drug discovery and clinical trials. Pharmacovigilance, pharmacoepidemiology and pharmacoeconomics.

Unit II

Various drug delivery systems-ruminal, intravaginal, intramammary, etc. Targeted drug delivery systems-liposomes, microparticles, nanoparticles, etc. Factors modifying drug delivery.

Unit III

Application of pharmacokinetic principles in therapeutics. PK-PD relationship and its applications.

Unit IV

Alterations in pharmacological behaviour of drugs in clinical conditions, neonates and pregnancy. Drug interactions and adverse drug reactions. Therapeutic drug monitoring. Rationale of drug use. Medication control programs in performance animals.

VI. Practicals

Analysis of pharmacokinetic data and determination of different pharmacokinetic parameters and drugs interactions in normal and diseased animal/ models.

I. Course Title : Pharmacogenomics
II. Course Code : VPT 606
III. Credit Hours : 2+0
IV. Aim of the course

To study the concepts of genomicsin drug development.

V. Theory

Unit I

History, concepts and definitions of pharmacogenomics transcriptomics, proteomics and metabolomics. Genomic basis of species variations in drug response.

Unit II

Genetic polymorphism and its impact on pharmacokinetics, drug target receptors and disease-drug response.

Unit III

Pharmacogenomics and drug development, Pharmacogenomics in clinical practice, role of bioinformatics in pharmacogenomics.

Unit IV

Concept of gene therapy, gene therapy of inherited diseases, DNA repair and inactivation strategies. Synthesis of therapeutic proteins.

I. Course Title : Immunopharmacology and Immunotoxicology

II. Course Code : VPT 607

III. Credit Hours : 2+0

IV. Aim of the course

To study the pharmacological intervention of immune functions.

V. Theory

Unit I

General aspect of immune system and its interaction with nervous and endocrine systems. Chemical mediators of immune system.

Unit II

Immunomodulators; Immunostimulants, Immunosuppressant and Tolerogens; Immunological basis of drug allergy and drug tolerance.

Unit III

Immunotoxic effects of xenobiotics and environmental pollutants.

Unit IV

Immune deficiencies and autoimmune reactions. Immunotherapeutic applications in asthma, arthritis, cancer, dermatology, and organ transplant, etc.

I. Course Title : Molecular Toxicology

II. Course Code : VPT 608

III. Credit Hours : 3+0

IV. Aim of the course

To understand the mechanisms and targets of cellular/ molecular toxicity.

V. Theory

Unit I

Cellular, sub-cellular and molecular targets and mechanism of toxicity.

Unit II

Cellular dysfunctions and their consequences, Mechanism of cell death in toxicity, repair and disrepair of toxic damage.

Unit III

Molecular mechanisms of target organ directed toxicity of xenobiotics- brain, hematopoietic system, GIT, liver, lungs, kidneys, reproductive system, skin, etc.

Unit IV

Mechanism of chemical mutagenesis, carcinogenesis, teratogenesis and radiation toxicity.

I. Course Title : Clinical Toxicology

II. Course Code : VPT 609

III. Credit Hours : 2+1

IV. Aim of the course

To study the concepts of clinical toxicology and forensic toxicology.

V. Theory

Unit I

Scope of clinical and forensic toxicology. Toxicological investigation, management and antidotal therapy of poisonings.

Unit II

Clinical aspects of poisoning due metals, non-metals and pesticides.

Unit III

Clinical aspects of poisoning due to mycotoxins, animal and bacterial toxins, solvents and vapours, drugs and other food/ feed contaminants.

Unit IV

Forensic toxicology. GLP in toxicological evaluation.

VI. Practical

General screening of biological material for toxicants, analysis of clinical samples for poisons, use of biomarkers in the assessment of toxicity.

I. Course Title : Ecotoxicology

II. Course Code : VPT 610

III. Credit Hours : 3+0

IV. Aim of the course

To impart knowledge regarding ecotoxicology for conservation of healthy eco-system.

V. Theory

Unit I

Basic principles of ecotoxicology. Sources of contamination and effects of pollutants on eco-health.

Unit II

Chemical contamination of air, water, soil and food by major agricultural and industrial chemicals – pesticides, hydrocarbons and metals. Fate of chemicals in the environment and target species.

Unit III

Toxic effects of radiations. Marine and wildlife as monitors of environmental quality, Bioaccumulation and Biomagnifications of toxicants.

Unit IV

Biomarkers of monitoring the impact of environmental pollutants, Environmental hazard and Risk identification from Mixture of chemicals, Contamination control and approaches to rehabilitating damaged ecosystems, Nanoparticle toxicology, ecological emergencies.

I. Course Title : Regulatory Toxicology
II. Course Code : VPT 611
III. Credit Hours : 2+1

IV. Aim of the course

To study acts and regulations and risk assessment regarding use of drugs, chemicals and cosmetics.

V. Theory

Unit I

Principles of risk assessment. Test protocols for toxicity studies of various national and international regulatory agencies.

Unit II

Regulatory essential dose levels in chemical risk assessment (NOEL, NOAEL, LOEL, LOAEL and AOEL). Recommended acceptable levels of environmental pollutants.

Unit III

Risk assessment in practice. Classification and marking/ branding of chemicals. Monitoring/ surveillance of chemicals. Exposure assessment and modelling.

Unit IV

Quality control in safety research (GLP). Operation of product register.

VI. Practical

Good laboratory practice in toxicological research. Screening procedures in regulatory toxicology. Determination of MRL, ADI, NOEL, NOAEL, LOEL, LOAEL and AOEL. Visit to nearest industrial area.

I. Course Title : Special Problem
II. Course Code : VPT 690
III. Credit Hours : 0+1

IV. Aim of the course

To provide expertise in handling practical research problem(s).

V. Practical

Short research problem(s) involving contemporary issues and research techniques.

Course Outline-cum-Lecture Schedule for Doctoral Degree Programme

I. Course Title : Molecular Pharmacology

II. Course Code : VPT 601

III. Credit Hours : 3 + 0

IV. Aim of the course

To understand the identification and characterization of receptors and drug receptors interactions and underlying mechanisms of drug receptor interactions and its effects.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Concept of receptors and forces involved in binding of drugs to receptors	2
2.	Methods of identification, isolation and characterization of receptors.	2
3.	Quantitative aspects and theories of drug-receptor interactions	2
4.	Signal transduction mechanisms: transducers, effectors and second messengers	2
5.	Classification and structures of receptors – Receptor conformation and configuration – Iono-receptors	2
6.	G-protein coupled receptors	2
7.	Enzymatic receptors	2
8.	Steroid receptors	2
9.	Molecular mechanisms of drug actions	2
10.	Receptors for physiological regulatory molecules	2
11.	Receptors as pharmaceutical targets.	2
12.	Hepatic and extra-hepatic metabolism of drugs	3
13.	Structures, types and functions of membrane ion channels.	3
14.	Role of cytochrome P450 isozymes in drug metabolism	2
15.	Metabolic enzyme induction and inhibition	2
16.	Factors affecting drug metabolism	2
17.	Mechanism of bioactivation and cytotoxicity – Electrophilic metabolites, free radicals and reactive oxygen species	3
18.	Drug induced mechanism of cell death – Necrosis and apoptosis	2
19.	Cytoprotective mechanisms against bioactive substances – Role of glutathione and other protectants	2
20.	Calcium homeostasis within the cells	2
21.	Pharmacology of mitogen-activated protein (MAP) kinases/ extracellular signal-regulated kinases (ERK) and small G proteins	3
22.	Current topics/ Discussion of library assignments	2

I. Course Title : Advances in Autacoid Pharmacology

II. Course Code : VPT 602

III. Credit Hours : 1 + 0

IV. Aim of the course

To study the pharmacodynamics and clinical implications of autacoids.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1	Histamine and antihistamines	2
2	5-Hydroxytryptamine and anti-5-HT drugs	2
3	Serotonin and its antagonists	2
4	Kinins	1
5	Angiotensins and inhibitors of renin-angiotensin system	2
6	Lipid-derived autacoids-prostaglandins and leukotrienes	2
7	Platelet activating factor	1
8	Cytokines and other autacoids	2
9	Neurohumoral transmission – purine nucleotides, peptides, amino acids and nitric oxide	2
10	Current topics/ Discussion on library assignments	1

I. Course Title : Pharmacology of Herbal Drugs

II. Course Code : VPT 603

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the pharmacological, therapeutic and toxicological aspects of potential medicinal plants.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction to indigenous pharmacology – History, definitions and scope	1
2.	Basic requirements and classification of indigenous drugs	2
3.	Collection and preparations of indigenous drugs	1
4.	Extraction of drugs	2
5.	Purification of drugs by heat processes – Distillation, evaporation, sublimations,	2
6.	Filtration and clarification	1
7.	Plant drugs with proven pharmacological and therapeutic efficacy	1
8.	Indigenous drugs used in treatment of various gastrointestinal ailments	2
9.	Indigenous drugs used as antimicrobials	1
10.	Indigenous drugs used as analgesics	1
11.	Indigenous drugs used in cardiovascular and CNS disorders	2
12.	Indigenous drugs used in behavioural disorders	1
13.	Indigenous drugs used in Renal and Urinary tract disorders	2

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
14.	Indigenous drugs used in	1
15.	Indigenous drugs used in eye, ear and skin disorders	3
16.	Indigenous drugs used in reproductive disorders	1
17.	Therapeutic and adverse effects of potential herbal drugs	1
18.	Alternate systems of medicine in animals – Homeopathy	1
19.	Alternate systems of medicine in animals – Ayurvedic concepts	2
20.	Alternate systems of medicine in animals – Folklore medicine	1
21.	Alternate systems of medicine in animals – Unani medicine	1
22.	Discussion on few review articles on herbal drugs from journals	2
Practical		
1.	Fundamental techniques in indigenous pharmacology	2
2.	Extraction and purification of drugs from medicinal plants	4
3.	Bioassay of indigenous drugs	3
4.	Pharmacological screening of indigenous drugs – Effect on isolated smooth muscle of ileum	2
5.	Effect on skeletal muscle	1
6.	Effect on perfused heart	1
7.	Effect on uterus	1
8.	Effect on trachea	1

I. Course Title : Biotransformation of Xenobiotics

II. Course Code : VPT 604

III. Credit Hours : 2 + 0

IV. Aim of the course

To study the molecular mechanisms of biotransformation of xenobiotics.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1	Introduction, importance of drug metabolism. Mechanisms and processes of drug biotransformation	1
2	Synthetic and non-synthetic pathways of drug metabolism. Phase reactions- oxidative, reductive, and hydrolytic reactions	1
3	Phase II reactions- conjugation (glucuronidation, sulfation, methylation, acetylation), conjugation with glutathione, aminoacids and thiosulfates	1
4	Oxidation- molecular details, cytochrome P 450 system. Types of CYP enzymes with special reference to CYP 3A4, 1A2, 2D6, 2E1	1
5	Important drugs metabolized by different CYP isoforms- molecular mechanisms involved	1
6	Nuclear receptor mediated transcriptional regulation of cytochrome P 450 system- Nuclear receptors and their ligands	1
7	7-ethoxy-resorufin O-deethylation (EROD) and 7-methoxyresorufin O-demethylation (MROD) as markers of Cytochrome P450 1 activities in hepatic microsomes	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
8	Activity of liver enzymes during the acute and chronic phases of diseases- role of Total bilirubin, Aspartate transaminase (AST), AST/ ALT ratio, Alkaline phosphatase (ALP), Gamma glutamyl transpeptidase (GGT)	1
9	Use S9 liver fraction from animals for the prediction of *in vivo* drug metabolism, Chemical inhibition assays of S9 fraction	1
10	Xenobiotic response systems- AhR (aryl hydrocarbon receptor), ER (estrogen receptor), PPAR (peroxisome proliferator-activated receptor)	1
11	Response systems - VDR (Vitamin-D-Receptor), FXR (farsenoid-X-receptor), HNF4 (hepatocyte nuclear factor), Nrf2-Keap1.	1
12	Concept of orphan nuclear receptors in different phases of metabolism	1
13	Role of Pregnane-X-Receptor (PXR), Constitutive-Androstane-Receptor (CAR), Liver-X-Receptor (LXR) in metabolism of commonly used drugs. Cross-talk in metabolism pathways	1
14	Role of genetically modified animals in drug metabolism studies	1
15	Specific studies on PXR, CAR, LXR involving gene knockout mice, transgenic mice. Cholesterol and bile acid homeostasis. Search for new response elements	1
16	Reduction reactions- molecular details with specific reaction examples of drugs undergoing reduction: of hydrogenation, decarboxylation, amination	1
17	Hydrolysis- molecular details with specific reaction examples of drugs undergoing hydrolysis with enzymes like esterases, peptidases, and amidases	1
18	Glucuronidation- mechanism, sites, general influencing factors	1
19	Glucuronidation affected drugs – metabolism of morphine, oxazepam carbamazepine, acetaminophen, testosterone, zidovudine), inhibitors and inducers of glucuronidation (barbiturates, ibuprofen, etc.	1
20	Sulfation-Tyrosine sulfation (function, Regulation, Posttranslational modification)	1
21	Acetylation- Ultrastructural Aspects of the Heterogeneous Acetylation	1
22	Phase II Biotransformation Reactions-Glutathione-S-Transferase, Glutathione S-conjugates as prodrugs to target drug-resistant tumors	1
23	Phase III – further modification and excretion- detoxification of endogenous reactive metabolites such as peroxides and reactive aldehydes, sites	1
24	Membrane transport – permeability barriers and detoxification, receptor mediated transcytosis, role of the solute carrier (SLC) and the ATP-binding Cassette (ABC) transporters; implications in drug resistance	1
25	Drug metabolism in organs other than liver- role of kidney, intestine and placenta	1
26	Drug metabolism in fetus and new born. *In-vitro* and *in-vivo* studies in drug metabolism; metabolic schemes of selected drugs	1
27	Factors influencing drug metabolism: Steriochemical, Physicochemical and biological factors	1
28	Strain difference in biotransformation, sex, age, environment factors, Genetic factors (pharmacogenetics) heritable factors recognized by use of drugs	1
29	Pathological states- Effect of liver dysfunction on the metabolism of drugs; effect on dosage regimens	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
30	Effect of renal dysfunction on the metabolism of different drugs	1
31	Chemical, biological, genetic and environmental factors. Species variations affecting drug biotransformation mechanisms	1
32	Biotechnology involved in drug metabolism studies- Electrophoretic Mobility Shift Assay (EMSA), northern, western/ southern blotting, PCR, real-time PCR	1
33	Preparation and Analysis of Total RNA Extracted from Hepatocytes for metabolism studies. Sulfation assay using P^{32}, Site-directed Mutagenesis, etc.	1
34	Methods to determine glutathione in liver and blood. Importance of Gamma-glutaylcysteine (GGC) as the immediate precursor to GSH	1
35	Cell lines as tools for drug metabolism studies. Predicting *in-vivo* drug metabolism fron *in-vitro* studies, Cultured hepatocytes (cryopreserved or fresh) for induction and down-regulation studies	1

I. Course Title : Clinical Pharmacology and Pharmacokinetics

II. Course Code : VPT 605

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the efficacy and disposition of drugs in clinical conditions.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction and general principles of pharmacokinetics including absorption, distribution, metabolism and excretion	3
2.	Graphical plotting and interpretation of kinetic data	2
3.	Calculation of pharmacokinetic constants	2
4.	Pharmacokinetic models and their application	2
5.	Determination of pharmacokinetic parameters and their significance	3
6.	Computation of dosage regimen	2
7.	Plasma protein binding of drugs	2
8.	Erythrocyte penetration of drugs	2
9.	Factors modifying pharmacokinetics of drugs	2
10.	Pharmacokinetics of drugs in diseased models	3
11.	Urinary excretion of drugs	1
12.	Kinetics following single and multiple doses	2
13.	Non-compartmental pharmacokinetic modelling	2
14.	Application of pharmacokinetics in clinical practice	2
15.	Drug therapy in neonate and geriatric animals	2
16.	Current topics/ Discussion on library assignments	2
Practical		
1.	Estimation of drugs by chemical and microbiological assays	3
2.	Graphical representation of plasma levels of drugs	1
3.	Determination of pharmacokinetic models	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
4.	Calculation of kinetic constants and parameters	2
5.	Calculation of dosage regimen	1
6.	Renal clearance studies of drugs	1
7.	*In-vitro* experiments on plasma protein binding	2
8.	Calculation of constants of plasma protein binding	1
9.	*In-vitro* erythrocytic penetration of drugs	1
10.	Pharmacokinetic parameters and adjustment of dosage regimen in diseased conditions	2

I. Course Title : Pharmacogenomics

II. Course Code : VPT 606

III. Credit Hours : 2 + 0

IV. Aim of the course

To study the concepts of genomicsin drug development.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction- basic pharmacogenomic nomenclature and principle	1
2.	Pharmacogenomics and bioinformatics: past, present and future, species variations affecting drug responses	1
3.	Optimized drug development- Pharmacogenomics impacts on pharmacokinetics and pharmacodynamics	1
4.	Increased and decreased responsiveness to drug effects/ toxicities and novel drug effects- prediction through databases	1
5.	Personalized medicine using genotyping technologies- Optimized drug therapy	1
6.	Challenges of Pharmacogenomic Testing- access, feasibility, cost	1
7.	Genetic basis of disease – Impact of genetic variations on drug metabolism	1
8.	Ethical applications, social and economic implications	1
9.	Genetic polymorphism- Relevance to a drug, Relevance to a disease, Types of nomenclature- Star Nomenclature, Genotype Nomenclature, Haplotype Nomenclature	1
10.	Genetic polymorphism types-Single nucleotide polymorphism (SNP), Variable number tandem repeat, Gene deletion, Copy number variant	1
11.	Single Nucleotide Polymorphism (SNP)- Synonymous polymorphism, Non-synonymous polymorphism, Variable Number Tandem Repeat: UGT1A1	2
12.	Gene Deletions and Copy Number Variants- Ultra-rapid metabolizers, Extensive metabolizers, Intermediate metabolizers, Poor metabolizers	1
13.	Potential Roles for Healthcare Professionals- Implications for Clinical Practice	1
14.	Pharmacogenomic Resources- Centers for Disease Control and Prevention (CDC), Food and Drug Administration (FDA),	1
15.	Gene therapy: gene transfer technology, viral vectors, natural delivery strategies.	1

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
16.	Transient and Stable Transfection, Transfection Methods- Lipid-mediated method	1
17.	Calcium-phosphate mediated method of transfection, diethylaminoethyloethyl-dextran mediated method of transfection	1
18.	Electroporation- Steps of the electroporation transfection, Biolistics (Gene gun/ microparticle bombardment), Laser transfection	1
19.	Drugs and gene therapy of inherited diseases- approaches, cell types, vectors	1
20.	Genetic inactivation strategies- key concepts. RNA interference (RNAi), Chemical modification on siRNA	1
21.	Engineered nucleases- zinc finger nucleases (ZFNs), transcription activator like effector nucleases (TALENs), clustered regularly interspaced short palindromic repeat associated (CRISPR associated) system	1
22.	DNA repair- Sources of damage –Nuclear versus mitochondrial, Senescence and apoptosis. Mechanisms- Direct reversal, Single-strand damage, Double-strand breaks, Translesion synthesis, Medicine and DNA repair modulation	2
23.	Cancer gene therapy- Immunotherapy, Oncolytic virotherapy- history, current clinical trials, future directions	1
24.	Boosting the immune response, Gene therapies to make cancer treatments effective	1
25.	Pro drug gene therapy, Blocking processes that protect cancer cells, Using altered viruses	1
26.	Role of bioinformatics in pharmacogenomic- Bioinformatics and drug discovery, Barriers to bioinformatics progress in drug design process	1
27.	Pharmacogenomics in drug discovery and development- Personalized/ effective medication.	1
28.	Reviving orphan drug, Barriers to pharmacogenomics progress in drug designing and development.	1
29.	Clinical applications of bioinformatics, genomics, and pharmacogenomics, Relationships and exchange of information with other resources	1
30.	Time dependent inhibition of genes involved in cytochrome P450 (CYP450) enzymes (single point, IC 50 shift)	1

I. Course Title : Immunopharmacology and Immunotoxicology

II. Course Code : VPT 607

III. Credit Hours : 2 + 0

IV. Aim of the course

To study the pharmacological intervention of immune functions.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction to immunology	1
2.	General aspect of Immune system	3

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
3.	Cellular components of immune system	2
4.	General principles of immunopharmacology	1
5.	Immunomodulators and their use in animals	2
6.	Immunostimulants and their role in animal health and diseases	2
7.	Immunosuppressants, and tolerogens – clinical applications	2
8.	Immunological basis of drug allergy and drug tolerance	2
9.	Neuroendocrine immune interactions	2
10.	Iimmunotoxic effects of environmental and other pollutants	3
11.	Molecular mechanisms of immunotoxicity	2
12.	Immunomodulatory effect of xenobiotics	2
13.	Implications of immune alterations in health and disease	2
14.	Immune defiencies, autoimmune response to xenobiotics,	2
15.	Immunoregulants and their therapeutic applications in asthma, arthritis, cancer, dermatology and organ transplant etc	2
16.	Other immunological drugs	2
17.	Current discussions and assignments	2

I. Course Title : Molecular Toxicology

II. Course Code : VPT 608

III. Credit Hours : 3+0

IV. Aim of the course

To understand the mechanisms and targets of cellular/ molecular toxicity.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Cellular, sub-cellular and molecular targets and mechanism of toxicity	2
2.	Concept of receptors and forces involved in binding of xenobiotics to receptors	3
3.	Quantitative aspects and theories of xenobiotic-receptor interactions	3
4.	Signal transduction mechanisms: transducers, effectors and second messengers	2
5.	Classification and structures of receptors – Receptor conformation and configuration – Iono-receptors	2
6.	G-protein coupled receptors	2
7.	Enzymatic receptors	2
8.	Steroid receptors	2
9.	Biophysics of toxicants	2
10.	Hepatic and extra-hepatic metabolism of xenobiotics	3
11.	Metabolic enzyme induction and inhibition	3
12.	Mechanism of bioactivation and cytotoxicity – Electrophilic metabolites, free radicals and reactive oxygen species	3
13.	Molecular mechanisms of target organ directed toxicity of xenobiotics- brain, hematopoietic system, GIT, liver, lungs, kidneys, reproductive system, skin, etc.	4
14.	Cellular dysfunctions and their consequences	2
15.	Repair and disrepair of toxic damage	2

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
16.	Xenobiotic induced mechanism of cell death – Necrosis and apoptosis	3
17.	Risk Assessment	2
18.	Mechanism involved in carcinogenesis, mutagenesis, teratogenesis	2
19.	Radiation toxicity	2
20.	Current topics/ Discussion of library assignments	2

I. Course Title : Clinical Toxicology

II. Course Code : VPT 609

III. Credit Hours : 2 + 1

IV. Aim of the course

To study the concepts of clinical toxicology.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction, history, definition and scope of clinical toxicology	1
2.	Importance and processes of forensic toxicology	1
3.	Toxicological investigations	1
4.	Management and antidotal therapy of poisonings	1
5.	Toxicity of metals – Arsenic, lead, mercury, selenium, molybdenum, and other metals	3
6.	Toxicity of non-metals – Fluoride, nitrite/ nitrate, sodium chloride, phosphorus	3
7.	Toxicity of insecticides – Chlorinated hydrocarbons, organophosphates, carbamates, pyrethroids, and botanical and newer insecticides	3
8.	Toxicity of fumigants	1
9.	Toxicity of herbicides	2
10.	Toxicity of fungicides	1
11.	Toxicity of rodenticides	2
12.	Toxicity of fertilizers	2
13.	Toxicity of solvents and vapours	2
14.	Toxic plants – Plants causing cyanide poisoning, photosensitization, thiamine deficiency and oxalate poisoning	3
15.	Mycotoxins	2
16.	Venomous stings and bites – Snake, scorpion, spider, bees and wasps	2
17.	Toxicity of therapeutic agent	2
18.	GLP in toxicological evaluation	2
Practicals		
1.	Extraction, separation and detection of various poisons in suspected materials	3
2.	Use of blood and tissue biomarker enzymes in assessment of toxicity, viz., acetylcholinesterase, carboxylesterase, etc.	3
3.	Demonstration of poisoning and their antidotal treatment	3
4.	Evaluation of antioxidant profile of toxicosed animals	2
5.	Analysis of poisons in biological samples	2

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
6.	Use of biomarkers in the assessment of toxicity	1
7.	Good laboratory practices evaluation	1
8.	Identification and collection of poisonous plants	1

I. Course Title : Ecotoxicology

II. Course Code : VPT 610

III. Credit Hours : 3 + 0

IV. Aim of the course

To impart knowledge regarding ecotoxicology for conservation of healthy eco-system.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction and basic principles of ecotoxicology	2
2.	Sources of environmental contamination	2
3.	Effects of pollutants on eco-health	2
4.	Fate of chemicals in the environment and target species	2
5.	General aspects of hazards associated with Air and water pollutants	2
6.	Radiation and its hazards	2
7.	Toxicity of pesticides in relation to environmental contamination	3
8.	Toxicity of metals related to agriculture	3
9.	Nanoparticle toxicology	2
10.	Ecological emergencies	2
11.	Residues of agrochemicals in food and ecosystem	2
12.	Marine and wildlife as monitors of environmental quality	2
13.	Bioaccumulation and biomagnifications of toxicants	1
14.	Forensic and regulatory toxicology as related to agrochemicals	3
15.	Hazards of toxicants in domestic and wild life	3
16.	Biomarkers of monitoring the impact of environmental pollutants	3
17.	Environmental hazard and risk identification from mixture of chemicals	2
18.	Contamination control measures	3
19.	Approaches to rehabilitating damaged ecosystems	3
20.	Ethical, moral, and professional issues in toxicology	2

I. Course Title : Regulatory Toxicology

II. Course Code : VPT 611

III. Credit Hours : 2 + 1

IV. Aim of the course

To study acts and regulations and risk assessment regarding use of drugs, chemicals and cosmetics.

V. Lecture/ Practical schedule

S. No.	Name of Topic	No. of Tentative Lectures/ Practicals
Theory		
1.	Introduction to toxicology; scope and industrial application	1
2.	Drug and development in modern industry	1
3.	Regulatory toxicology and pre-clinical pharmaceutical testing services-linkage	2
4.	Principles of Hazard Identification	1
5.	Different guidelines for safety assessments	1
6.	Methods of toxic dose estimation	2
7.	Risk assessment and post marking surveillance	2
8.	Procedure for acute, sub-acute and chronic toxicity study	3
9.	Toxicity test guidelines and different routes	2
10.	Guidelines for herbal safety risk assessment evaluation	1
11.	Working principle of FDA and Indian legislations	1
12.	Schedules of drugs and classification of industrial chemicals	1
13.	Approaches to hazard identification-carcinogenicity	2
14.	Modern concept tolerance: classification, evaluation	2
15.	Dose-response assessment LOEL, LOAEL and AOEL, NOEL, NOAEL, ADI, etc.	3
16.	Guidelines for registration of medicines	2
17.	Specific aspects of drug registration legislation abroad	1
18.	Central drugs standard control organization – CDSCO- India	2
19.	Concept of GLP India and abroad; Role of GLP in toxicological evaluation	2
Practical		
1.	Introduction to good laboratory practices in toxicology	2
2.	Screening procedures in regulatory toxicology	3
3.	Evaluation of acceptable daily intake	2
4.	Determination of No-observable effect level and NOAEL	2
5.	Determination of Low-observable effect level and LOAEL	2
6.	Determination of AOEL	2
7.	Mandatory toxicity testing protocols	2

Suggested Reading

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- Vogel HG and Voge WH (Eds). 1997. *Drug Discovery and Evaluation: Pharmacological Assays*. Springer.

ANNEXURE I

List of BSMA Committee Members for Veterinary Para-Clinical Subjects

Name	Address	Specialization
Dr Placid E. D'Souza Former Dean and Retd. Professor-cum-Director CAFT in Veterinary Parasitology CVSc, Bengaluru **Chairman**	Department of Veterinary Parasitology, Veterinary College, KVAFSU, Regional campus Bengaluru -560024	Veterinary Parasitology
Dr K P Singh Principal Scientist-cum-Head **Convener**	Division of Veterinary Pathology Indian Veterinary Research Institute, Izatnagar, Bareilly-243 122 (UP)	Veterinary Pathology
Dr R K Asrani Professor	Department of Veterinary Pathology, Dr G C Negi College of Veterinary and Animal Sciences, CSK HPKV, Palampur-176 062 (HP)	Veterinary Pathology
Dr Veer Singh Professor and Head	Division of Veterinary Parasitology, Dantiwada Agricultural University, Gujarat-385 506	Veterinary Parasitology
Dr Rajesh Katoch Professor and Head	Division of Veterinary Parasitology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009	Veterinary Parasitology
Dr Sunil Maherchandani Professor	Department of Veterinary Microbiology, Rajasthan University of Veterinary and Animal Sciences, Bikaner-334 001	Veterinary Microbiology

Name	Address	Specialization
Dr A K Tiwari Principal Scientist and Head	Division of Veterinary Microbiology, Indian Veterinary Research Institute, Izatnagar, Bareilly-243 122 (UP)	Veterinary Microbiology
Dr N K Mahajan Dean, PGS	Department of Veterinary Public Health and Epidemiology, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar-125 001	Veterinary Public Health
Dr S P Singh Retired Professor	Department of Veterinary Public Health and Epidemiology, G. B. Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand	Veterinary Public Health
Dr Vinod Kumar Professor and Head	Department of Veterinary Pharmacology, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar-125 001, Haryana	Veterinary Pharmacology
Dr V K Dhumka Professor and Head	Department of Veterinary Pharmacology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 012, Punjab	Veterinary Pharmacology

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 3

Animal Production Sciences

- Animal Genetics and Breeding
- Animal Nutrition
- Livestock Production and Management
- Livestock Products Technology
- Poultry Science

Contents

Acknowledgements

At the outset, we, on behalf of all the Members of BSMA on Animal Production Sciences (BSMA-APS), would like to thank the Indian Council of Agricultural Research for nominating us to revise the syllabi.

The BSMA on Animal Production Sciences has been tasked with the revision of the existing ICAR syllabi in respect of five disciplines namely, Animal Genetics and Breeding, Animal Nutrition, Livestock Production and Management, Livestock Products Technology and Poultry Science.

The task of revising the existing syllabi for higher education is always a challenging one. However, this enormous task has been successfully completed thanks to the sincere efforts of all the Members of the BSMA-APS Committee. During this revision process, a total of four workshops were carried out at different parts of the country to facilitate greater participation of the faculty involved in the postgraduate teaching. We would, therefore, like to express my sincere gratitude to the Hon'ble Vice-Chancellors of Chhattisgarh Kamdhenu University (Durg), Assam Agricultural University (Guwahati), PV Narsimha Rao Telangana Veterinary University (Hyderabad) and SK University of Agricultural Sciences and Technology of Kashmir (Srinagar) for their kind consent to host the workshops. We are also thankful to the Deans of the respective colleges (College of Veterinary Sciences, Anjora, Durg; College of Veterinary Sciences, Khanapara, Guwahati; College of Veterinary Science, Rajendranagar, Hyderabad; College of Veterinary Science, Shuhama, Srinagar) alongside the Organizing Secretaries and the respective local faculty from the five disciplines for putting in a lot of efforts to make the workshops successful.

The present syllabus is the outcome of the collective efforts of many senior academicians with longstanding experiences in postgraduate teaching and research. The present syllabi development involved inputs received from more than 25 veterinary colleges/ agricultural universities besides the direct contribution of 64 Subject Matter Experts specially invited to the workshops for their direct contribution to the syllabus development process through collective interactions.

Ashok Kumar Pattanaik
Convener, BSMA-APS

Sita Prasad Tiwari
Chairman, BSMA-APS

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Animal Production Sciences
– Animal Genetics and Breeding

Preamble
(Animal Genetics and Breeding)

Livestock plays an important role in Indian economy. About 20.5 million people depend upon livestock for their livelihood. Livestock contribute 16% to the income of small farm households as against an average of 14% for all rural households. Livestock provides livelihood to two-third of rural community. It also provides employment to about 8.8 % of the population in India. India has vast livestock resources. Livestock sector contributes 4.11% GDP and 25.6% of total Agriculture GDP. The economy of farmer is greatly influenced by livestock keeping. The farmers in India maintain mixed farming system i.e. a combination of crop and livestock where the output of one enterprise becomes the input of another enterprise thereby realize the resource efficiency. The livestock serve the farmers in four different ways: income, employment, food and social security. So the conservation and development of indigenous livestock is the need of the hour. The study of the subject of Animal Genetics and Breeding and its application for conservation and improvement of livestock is very important.

Genetic improvement in domesticated animal populations that are used for agricultural production mainly involves selection of males and females that, when mated, are expected to produce progeny that perform better than the average of the current generation. Performance usually includes a combination of multiple characteristics, or traits, most of which are quantitative in nature. Animal breeding involves the selective breeding of livestock with the intention to improve desirable (and heritable) qualities in the next generation. This course introduces the steps required to design a program for breeding animals and teaches the genetic and statistical concepts that are needed to build a solid breeding program. By following this course the students can learn the key aspects of improving and increasing productivity and learn what it takes to create and maintain a healthy strong population. Students will learn how an animal breeder balances the need for improving the desirable qualities of the animals with the need for genetic diversity and long-term sustainability of the breeding program. Also students will learn about the scientific concepts in genetics that are applied in animal breeding, as well as how to apply the genetic models and computational methods that are used in animal breeding. Professionals working with animals will be able to use the knowledge from this course to understand the impact of breeding on animal populations and use genetic principles to make their decisions. This course will allow an advanced starting point for further studies, such as M.Sc. level courses in breeding.

Although animal breeding was practiced long before the science of genetics and the relevant disciplines of population and quantitative genetics were known, breeding programs have mainly relied on simply selecting and mating the best individuals on their own or relatives' performance. This is based on sound quantitative genetic principles, developed and expounded by Lush, who attributed much of his understanding to Wright, and formalized in Fisher's infinitesimal model. Analysis at the level of individual loci and gene frequency distributions has had relatively little impact. Now with access to genomic data, a revolution in which molecular information is being used to enhance response with "genomic selection" is occurring. The predictions of breeding value still utilize multiple loci throughout the genome and, indeed, are largely compatible with additive and specifically infinitesimal model assumptions.

The main goal in animal breeding is to select individuals that have high breeding values for traits of interest as parents to produce the next generation and, to do so, as quickly as possible. To date, most programs rely on statistical analysis of large data bases with phenotypes on breeding populations by linear mixed model methodology to estimate breeding values on selected candidates. However, there is a long history of research on the use of genetic markers to identify quantitative trait loci and their use in marker-assisted selection but with limited implementation in practical breeding programs. The advent of high-density SNP genotyping, combined with novel statistical methods for the use of this data to estimate breeding values, has resulted in the recent extensive application of genomic or whole-genome selection in dairy cattle and research to implement genomic selection in other livestock species is underway. The high-density SNP data also provides opportunities to detect QTL and to uncover the genetic architecture of quantitative traits, in terms of the distribution of the size of genetic effects that contribute to trait differences in a population. Experimental results show that this genetic architecture differs among traits but that for most traits, over 50% of the genetic variation resides in genomic regions with small effects that are of the order of magnitude expected under a highly polygenic model of inheritance.

In indigenous livestock breed improvement program and conservation of indigenous livestock courses, different schemes like Rastriya Krishi Vikash Yojana (RKVY), Rastriya Gokul Mission (RGM) and National Programme for Bovine Breeding and Dairy Development (NPBBDD) launched by GoI under Ministry of Agriculture, Animal Husbandry, Dairying and Fisheries are included.

Addition of Courses

In M.V.Sc. degree programme, six new courses are proposed namely AGB-611 (Swine Breeding), AGB-612 (Pet Animal Breeding- dogs and cats), AGB-613 (Wild Animal Genetics and Breeding), AGB-614 (Equine Breeding), AGB-615 (Camel Breeding), AGB-616 (Yak and Mithun Breeding) and AGB-617 (Statistical Methods in Animal Breeding).

In Ph.D. degree programme, one new course is proposed namely AGB-707 (Statistical Software in Animal Breeding) based on inputs of stakeholders and contemporary requirement.

The course contents have been decided and modified as per suggestions of all the stakeholders during four workshops held at Durg, Guwahati, Hyderabad and Srinagar. Assuming the priority day-by-day, the areas which need to be strengthened in Animal Genetics and Breeding are: Molecular Techniques in Animal Breeding, Biometrical Techniques in Animal Breeding, Bio-informatics in Animal Genetics and Breeding, Breeding for different species having regional importance, viz., Swine, Camel, Equine, Yak and Mithun Breeding. Pet Animal Breeding is important in the sense that majority of people are fond of keeping pets where pedigreed dog and cats are the choice. Wild Animal Genetics and Breeding is an essential part for conservation of wild life now-a- days.

Deletion of Courses

In Ph.D., one course has been deleted namely AGB-707 (Utilization of non-additive genetic variance in farm animals) which appears to be redundant and/ or contents included elsewhere.

Changes of Name of Courses

Title of five courses in M.V.Sc. and five courses in Ph.D. have been modified as per the following Table:

Course Code	Old Title/ Existing	Modified Title
AGB 601	Animal Cytogenetics and Immunogenetics	Animal Cytogenetics and Immunogenetics I
AGB 602	Molecular Genetics in Animal Breeding	Molecular Genetics I
AGB 605	Biometrical Techniques in Animal Breeding	Biometrical Genetics I
AGB 608	Small Farm Animal Breeding (sheep, goat, swine and rabbit)	Sheep and Goat Breeding
AGB 610	Laboratory Animal Breeding	Laboratory Animal and Rabbit Breeding
AGB 701	Recent Advances in Animal Genetics	Molecular Genetics II
AGB 702	Recent Trends in Animal Breeding	Trends in Animal Breeding
AGB 703	Advances in Biometrical Genetics	Biometrical Genetics II
AGB 705	Bioinformatics in Animal Genetics and Breeding	Bioinformatics in Animal Breeding
AGB 706	Advances in Molecular Cytogenetics	Animal Cytogenetics and Immunogenetics II

Change of Credit Hours

For AGB 604 and AGB 605, credit hours have been reduced from 3+1 to 2+1. For AGB 610, credit hour has been increased from 1+0 to 2+0 to accommodate rabbit breeding components. For AGB 705, credit hour has been modified from 2+0 to 1+1 to accommodate practical classes.

For M.V.Sc. degree programme, out of the total of 20 credit hours from major, 15 credits hours have been decided as core (compulsory) courses and five credit hours from optional major courses. For Ph.D. degree programme, out of the total 12 credit hours 10 credit hours have been decided as core (compulsory) courses and two credits from optional major courses.

Course Title with Credit Load
M.V.Sc. in Animal Genetics and Breeding

Course Code	Course Title	Credit Hours
AGB 601*	Animal Cytogenetics and Immunogenetics I	2+1
AGB 602*	Molecular Genetics I	2+1
AGB 603*	Population and Quantitative Genetics	2+1
AGB 604*	Selection Method and Breeding System	2+1
AGB 605*	Biometrical Genetics I	2+1
AGB 606	Conservation of Animal Genetics Resources	2+0
AGB 607	Cattle and Buffalo Breeding	2+1
AGB 608	Sheep and Goat Breeding	2+0
AGB 609	Poultry Breeding	2+1
AGB 610*	Laboratory Animal and Rabbit Breeding	2+0
AGB 611	Swine Breeding	1+0
AGB 612	Pet Animal Breeding (Dogs and Cats)	1+0
AGB 613	Wild Animal Genetics and Breeding	1+0
AGB 614	Equine Breeding	1+0
AGB 615	Camel Breeding	1+0
AGB 616	Yak and Mithun Breeding	1+0
AGB 617	Statistical Methods in Animal Breeding	2+1
AGB 691	Seminar	1+0
AGB 699	Research	30

Course Contents
M.V.Sc. in Animal Genetics and Breeding

I. Course Title : Animal Cytogenetics and Immunogenetics I

II. Course Code : AGB 601

III. Credit Hours : 2+1

IV. Why this course?

To provide basic and advanced theoretical and practical training in animal cytogenetics and immunogenetics with an ulterior aim of enhancing animal production.

V. Aim of the course

This course is aimed to train students in identifying genetic/ chromosomal abnormalities and reviewing genetic mechanisms responsible for the generation of diversity in genes for immunoglobulin, TLR and MHC, etc., facilitating the better application of both classical and molecular cytogenetics and immunogenetics for animal improvement.

VI. Theory

Unit I (7 Lectures)

Physical and chemical basis of heredity; Development in animal cytogenetics and immunogenetics of farm animals; Inborn errors of metabolism and inherited disorders; immunoglobulin and their types; Antigen-antibody interactions; Immune response; ELISA.

Unit II (10 Lectures)

Chromatin structure of eukaryotes; Chromosome number and morphology in farm animals; Karyotyping and banding; Chromosomal abnormalities and genetic syndromes; DNA packing in chromosomes; Types of DNA; FISH chromosome painting and PRINS; SCH and RH panel mapping.

Unit III (10 Lectures)

Genetic variants in blood group systems of farm animals; Major histocompatibility complex: BoLA, BuLA; Genetics of biochemical variants and their applications; Immune response genes and concepts of disease resistance including major genes; Hybridoma and its significance; Concept of immunofertility; TLRs and interleukins.

Unit IV (3 Lectures)

Mutation and assays of mutagenesis; Sister chromatid exchanges.

VII. Practical (15 Classes)

Identification of Barr bodies; *In-vitro* and *in vivo* preparation of somatic metaphase chromosomes; Screening of chromosomal abnormalities; Microphotography and karyotyping; Banding procedures for comparing the chromosomal complement; FISH and PRINS; ELISA; Immunocompetence tests.

VIII. Teaching methods

Blackboard; PPT-animations; Hands-on practical training; application based practical approach; Visit labs specialising in animal cytogenetics and immunogenetics; Research article discussion in the classroom.

IX. Learning outcome

Upon successful completion, the students will be able to understand the immune response (IR) and its role in disease resistance along with the role of allelic variations in IR genes in animal production in addition to the advances in the field of animal cytogenetics and immunogenetics.

X. Suggested Reading

- Gersen SL and Keagle MB. 2013. *The Principles of Clinical Cytogenetics*. Springer.
- Hare WCD and Singh EL. 1999. *Cytogenetics in Animal Reproduction*. CABI.
- Panayi GS and David CS. 1984. *Immunogenetics*. Elsevier.
- Roitt I. 1997. *Essential Immunology*. Blackwell.
- Summer AT and Chandley AC. 1993. *Chromosome Today*. Chapman and Hall.

I. Course Title : Molecular Genetics in Animal Breeding

II. Course Code : AGB 602

III. Credit Hours : 2+1

IV. Why this course?

To provide basic and advanced concepts of molecular genetics and their application to different species of animals

V. Aim of the course

This aim of this course is to study genes and their functions to understand their role in animal breeding and selection. Also aimed at the genetics of populations including quantitative genetics and its applications in animal breeding.

VI. Theory

Unit I (8 Lectures)

Basic concepts in molecular genetics; Concepts of proteomics and genomics; Genesis and importance of molecular techniques; Genome organization: physical and genetic map, current status of genome maps of livestock; Gene expression and control.

Unit II (8 Lectures)

Molecular markers and their applications; RFLP, RAPD, Microsatellite/ Minisatellite markers, SNP marker, DNA fingerprinting.

Unit III (7 Lectures)

DNA sequencing; Genome sequencing; Genomic Library; Polymerase Chain Reaction (PCR) and its types (PCR-RFLP, AS-PCR, etc.) and applications; Transgenesis and methods of gene transfer; Recombinant DNA technology and applications.

Unit IV (7 Lectures)

Analysis of molecular genetic data; Quantitative Trait Loci (QTL) mapping and its application in animal breeding: Genome scan, candidate gene approach.

VII. Practical (15 Classes)

Extraction and purification of genomic DNA; Gel electrophoresis; Restriction enzyme digestion of DNA and analysis; PCR-RFLP; PCR-SSCP; Bioinformatics tool for DNA sequence analysis; Isolation of RNA; cDNA synthesis; Statistical methods for analyzing molecular genetic data.

VIII. Teaching methods

Blackboard; PPT-animations; Web-courses (if available); Hands-on practical training; Application based practical skills; Visit labs specialising in molecular genetics critical discussion of articles in the area.

IX. Learning outcome

Upon successful completion, the students will have an understanding of how genes control biological functions from cellular activities to development, techniques used to manipulate gene functions in addition to genomics, proteomics and their applications in livestock improvement.

X. Suggested Reading

- Akano IE. 1992. *DNA Technology*. IAP Academic Press.
- Brown TA. 2006. *Genome 3*. Garland Science Publishers.
- Clark D and Pazdernik N. 2012. *Molecular Biology*, 2nd ed. Elsevier.
- Micklos DA, Fryer GA and Crotty DA. 2003. *DNA Science.* Cold Spring Harbor.
- Setlow JK. 2006. *Genetic Engineering – Principles and Methods,* Springer.

I. Course Title : Population and Quantitative Genetics

II. Course Code : AGB 603

III. Credit Hours : 2+1

IV. Why this course?

To study the genetic structure of the animal population and the importance of genetic variation and covariation among quantitative traits.

V. Aim of the course

To impart knowledge on the general structure of animal population and factors affecting it and estimation of genetic and phenotypic parameters of different quantitative traits.

VI. Theory

Unit I (15 Lectures)

Genetic structure of population; Hardy Weinberg Law; Idealized population; Factors affecting changes in gene and genotypic frequencies; Systematic processes; Approach to equilibrium under different situations: Single autosomal locus with two alleles, single sex-linked locus, two pairs of autosomal linked and unlinked loci; Linkage equilibrium and disequilibrium; Combined effect of all forces changing gene frequency.

Unit II (10 Lectures)

Dispersive process - small population: random genetic drift; Effective population size; Regular and irregular inbreeding systems; Founder effect and bottleneck; Effective number of founders and ancestors.

Unit III (10 Lectures)

Quantitative genetics: Gene effects, population mean, breeding value; Variance and its partitioning; Genotype-environment interaction and correlation; Resemblance between relatives.

Unit IV (10 Lectures)

Genetic and phenotypic parameters (heritability, repeatability, correlations): Methods of estimation, uses, possible biases, precision, optimal designs; Scale effects and threshold traits.

VII. Practical (15 Classes)

Estimation of gene and genotypic frequencies under different conditions; Estimation of inbreeding in regular and irregular systems; Estimation of effective population size; Computation of quantitative genetic effects; Estimation of variance components; Computation of heritability, repeatability, genetic, phenotypic and environmental correlations and their standard errors.

VIII. Teaching methods

Lectures; PPT-Presentations; MS-Excel for estimation of data.

IX. Learning outcome

Understanding the effect of gene and genotype frequencies on the genetic structure of populations, and estimation of genetic variation and covariation among different quantitative traits.

X. Suggested Reading

- Bulmer MG. 1980. *The Mathematical Theory of Quantitative Genetics*. Clarendon Press.
- Crow JF and Kimura M. 2009. *An Introduction to Population Genetics*. Harper and Row.
- Falconer DS and Mackay TFC. 1996. *An Introduction to Quantitative Genetics*. Longman.
- Jain JP. 1982. *Statistical Techniques in Quantitative Genetics*. Tata McGraw-Hill.
- Pirchner F. 1983. *Population Genetics in Animal Breeding*. Springer.

I. Course Title : Selection Method and Breeding System

II. Course Code : AGB 604

III. Credit Hours : 2+1

IV. Why this course?

To explain the methodology of selection and breeding systems for improvement of livestock and poultry.

V. Aim of the course

To study different methods of selection and factors affecting it, various mating systems and their use in animal genetics and the concepts of recent selection techniques.

VI. Theory

Unit I (6 Lectures)

Types of selection and their genetic consequences; Response to selection: Prediction and improvement.

Unit II (12 Lectures)

Theoretical aspects of accuracy and efficiency of selection bases; Prediction of breeding value using different criteria; Combined selection; Correlated response and efficiency of indirect selection.

Unit III (12 Lectures)

Selection for several traits; Different types of selection indices; Evaluation of short term and long term selection experiments: bidirectional selection, asymmetry of response, selection limit.

Unit IV (15 Lectures)

Different mating systems: assortative mating, inbreeding, out-breeding; Genetic and phenotypic consequences and applications of various mating systems in animal improvement; Heterosis; Selection for general and specific combining abilities; Genetic polymorphism and its application in genetic improvement: Basic concepts of marker-assisted selection (MAS) and genomic selection.

VII. Practical (15 Classes)

Prediction of direct and correlated response; Computation of realized heritability and genetic correlation; Computation of selection index; Estimation of breeding values from different sources of information; Determining the accuracy of selection; Estimation of heterosis for different types of crosses; Estimation of GCA and SCA.

VIII. Teaching methods

Blackboard; PPT-animations; Hands-on practical training; application based practical approach; Visit labs specialising in animal cytogenetics and immunogenetics; Research article discussion in the classroom.

IX. Learning outcome

Good knowledge of the application of selection methods and mating systems in animal improvement, and application of selection for combining abilities.

X. Suggested Reading

- Falconer DS and Mackay TFC. 1996. *An Introduction to Quantitative Genetics*. Longman.
- Jain JP. 1982. *Statistical Techniques in Quantitative Genetics*. Tata McGraw-Hill.
- Tomar SS. 1996. *Text Book of Population Genetics,* vol. I. *Qualitative Inheritance*. Universal Publishers.
- Tomar SS. 2010. *Text Book of Animal Breeding*. Universal Publishers.
- Tomar SS. 2014. *Text Book of Population Genetics,* vol II. *Quantitative Inheritance*. Universal Publishers.

I. Course Title : Biometrical Genetics I

II. Course Code : AGB 605

III. Credit Hours : 2+1

IV. Why this course?

To educate about the various biometrical techniques for data analysis and their applications

V. Aim of the course

To impart knowledge about common diseases and disorders of poultry, diagnosis, vaccination, prevention, control and treatment.

VI. Theory

Unit I (8 Lectures)

Nature and structure of animal breeding data; Source of variation; Adjustment of data; Outliers and their removal; Basic concepts in statistical inference and experimental designs.

Unit II (7 Lectures)

Introduction to matrix algebra; Types of matrices and their operations; Determinants and their properties; Matrix inversion and its applications.

Unit III (15 Lectures)

Multiple regression and correlations; Fisher's discriminant function and its application; D^2 statistics in divergent analysis; Cluster analysis; Fixation index; Genetic distance estimation and phylogeny construction; Linear models and their types; Least-squares (LS) analysis; Generalized LS and weighted LS; BLUE, BLUP; Methods of estimation of variance components: ANOVA, ML, REML, MINQUE, MIVQUE; Bayesian approach.

Unit IV (15 Lectures)

Animal model; Reduced animal model; Sire model; Maternal grandsire model; Maternal effects model; Repeatability model; Random regression model; Threshold model; Multidimensional scaling (MDS) and principal component analysis (PCA); Database management and use of software in animal breeding.

VII. Practical (15 Classes)

Collection, compilation, coding and transformation of animal breeding data; Matrix applications, determinant and inverse of matrices; Building of models for various types of data; Least-squares analysis of data; Estimation of BLUE and BLUP solutions; Formation of numerator relationship, dominance and identical by descent matrix; Estimation of variance components.

VIII. Teaching methods

Blackboard; PPT-Presentations; Application based practical approach; Research article discussion in the classroom.

IX. Learning outcome

Students will develop skills in analyzing breeding data using different biometrical techniques.

X. Suggested Reading

- Henderson CR. 1984. *Application of Linear Models in Animal Breeding*. University of Guelph Press.
- Mather K and Jinks JL. 1977. *Introduction to Biometrical Genetics*. Chapman and Hall.
- Searle SR. 2014. *Linear Models*. John Wiley and Sons.
- Singh RK and Chaudhary BD. 2012. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers.

I. Course Title : Conservation of Animal Genetics Resources

II. Course Code : AGB 606

III. Credit Hours : 2+0

IV. Why this course?

To study the concepts of conservation of animal genetic resources (AnGR)

V. Aim of the course

To impart knowledge on AnGR in India and their characterization, concepts and methods of conservation and national and international strategies for conservation of AnGR.

VI. Theory

Unit I (12 Lectures)

Domestic animal diversity in India: Origin, history and utilization; Present status and flow of AnGR and its contribution to livelihood security; Methodology for phenotypic and genotypic characterization of livestock and poultry breeds through systematic surveys; Management of breed; Physical, biochemical and performance traits and uniqueness of animals of a breed; Social, cultural and economic aspects of their owners/ communities rearing the breed.

Unit II (12 Lectures)

Methods for increasing effective population size of endangered breed/ species: Effective number of alleles, inbreeding effective size, variance effective size, minimum viable population size; Methodology for characterization of AnGR; nuDNA and mtDNA based diversity analysis and relationship among the breeds; Concept of conservation: *In-situ* and *ex-situ* (in-*vivo* and *in-vitro*); Models of conservation; Prioritization of breeds for conservation; Strategies for conservation of livestock and poultry genetics resources; Gene bank concept; Preservation of ecosystem.

Unit III (6 Lectures)

Status, opportunities and challenges in the conservation of AnGR; IPR issues on animal genetic resources/ animal products or by-products; Registration of livestock breeds and protection of livestock owner's rights in India; Breed societies and their role in conservation.

VII. Practical -

VIII. Teaching methods

Blackboard; PPT-Presentations; Application based practical approach; Research article discussion in the classroom

IX. Learning outcome

Conservation strategies of AnGR, their characterization and methods of conservation to protect biodiversity

X. Suggested Reading

- Nivsarkar AE, Vij RK and Tantia MS. 2000. *Animal Genetic Resources of Indian Cattle and Buffaloes*. ICAR.
- Oldenbroek K. 2007. *Utilisation and Conservation of Farm Animal Genetic Resources*. WA Publishers.
- Sahai R and Vij RK. 1997. *Domestic Animal Diversity, Conservation and Sustainable Development*. SI Publishers.
- Van Vleck LD, Pollak E and Bltenacu EAB. 1987. *Genetics for Animal Sciences*. WH Freeman.

I. Course Title : Cattle and Buffalo Breeding

II. Course Code : AGB 607

III. Credit Hours : 2+1

IV. Why this course?

To educate the concept of cattle and buffalo breeding and improvement in dairy production

V. Aim of the course

To impart knowledge on different breeds of cattle and buffalo and their economic traits, sire evaluation methods and breeding systems and different cattle and buffalo breeding programmes.

VI. Theory

Unit I (15 Lectures)

History of dairy cattle and buffalo breeding; Evolution of cattle and buffalo breeds and their characteristics; Population dynamics and production systems; Inheritance of important economic traits; Recording and handling of breeding data; Standardization of records; Computation of correction factors for the adjustment of the data; International Committee on Animal Recording (ICAR) and INAPH.

Unit II (12 Lectures)

Progeny testing under farm and field conditions; Evaluation of bulls by different models; Estimation of breeding values of the cows; Nucleus breeding system; Marker-assisted selection and genomic selection.

Unit III (12 Lectures)

Crossbreeding in cattle in India and abroad; Development of new breeds; Conservation of threatened breeds of cattle and buffaloes; Role of breed associations in dairy improvement; Breeding policy: national and state.

Unit IV (6 Lectures)

Import of exotic germplasm for breeding cattle in the tropics; Appraisal of buffalo and cattle breeding programme; Role of breed associations in dairy improvement.

VII. Practical (15 Classes)

Performance recording; Standardization of records; Estimation of economic traits; Computation of genetic parameters; Genetic gain; Sire evaluation methods; Estimation of heterosis; Culling and replacement.

VIII. Teaching methods

Blackboard; PPT-Presentations; Application based practical approach; Research article discussion in the classroom

IX. Learning outcome

After completion of the course, the students get good knowledge of different breeds of cattle and buffalo and breeding programmes

X. Suggested Reading

- Chakravarty AK and Vohra V. 2011. *Sustainable Breeding in Cattle and Buffalo. Satish Serial Publications.*
- Lasley JF. 1972. *Genetics of Livestock Improvement*. IBH.
- Oldenbroek K and van der Waaij L. 2014. *Text book of Animal Breeding and Genetics*. Wageningen University and Research Centre (Free Online).
- Schmidt GM, Van Vleck LD and Hutjens MF. 1988. *Principles of Dairy Science*. WH Freeman.
- Van Vleck LD, Pollak EJ and Bltenacu EAB. 1987. *Genetics for Animal Sciences*. WH Freeman.

I. Course Title : Sheep and Goat Breeding
II. Course Code : AGB 608
III. Credit Hours : 2+0

IV. Why this course?

To educate about sheep and goat breeding concepts and development in small ruminants

V. Aim of the course

To impart knowledge on different breeds of sheep and goat and their economic traits, breeding systems and selection strategies, and different sheep and goat breeding policies.

VI. Theory

Unit I (8 Lectures)

Breeds; Economic traits; Population dynamics and production systems; Prolificacy; Breeding records and standardization; Computation of correction factors.

Unit II (12 Lectures)

Genetic parameters; Selection of males and female; Selection indices for sheep and goat; Breeding systems; Breeding strategies for improvement of production (meat, milk and wool) and reproduction (fertility and fecundity); Inbreeding and its effects on production traits; Group breeding schemes; Development of new breeds; Strategies for introgression of genes (fecundity and growth).

Unit III (10 Lectures)

Breeding policy; Sheep and goat improvement programme in India; Conservation of breeds; Culling and replacement; Equivalent Animal Death Rate (EADR).

VII. Teaching methods

Blackboard; PPT-presentations

VIII. Learning outcome

After completion of the course, the students get a good knowledge of different breeds of sheep and goat and their breeding policies

IX. Suggested Reading

- Jindal SK. 2013. *Goat Production and Health Management*. New India Publishers.
- Karim SA. 2010. *Climate Change and Stress Management: Sheep and Goat Production*. Satish Serial Publications.
- Mulugeta A. 2016. *Sheep and Goat Production Text Book*. Lambert Academic Publishers.
- Prasad J. 2018. *Goat, Sheep and Pig, Production and Management*. Kalyani Publishers.
- Ross CV. 1988. *Sheep Production and Management*. Prentice-Hall.

I. Course Title : Poultry Breeding

II. Course Code : AGB 609

III. Credit Hours : 2+1

IV. Why this course?

To educate about advances in poultry breeding practices

V. Aim of the course

To impart knowledge on different species of poultry and their economic traits, selection criteria and selection indices, and conservation of poultry genetic resources.

VI. Theory

Unit I (10 Lectures)

Origin and history of poultry species: Chicken, turkey, duck and quail; Poultry classes and breeds; Important qualitative traits in poultry including lethal; Economic traits of egg and meat-type chicken and their standardization; Different mating systems.

Unit II (10 Lectures)

Selection criteria and selection indices; Response to selection; Genetic controls; Genotype and environment interaction; Inbreeding and its effects on production traits in egg and meat-type chickens; Development of inbred lines and strains; Strain and line crosses; Introduction to diallel cross; Utilisation of heterosis and reciprocal effect; Recurrent selection, reciprocal recurrent selection and modified RRS; Specialized sire and dam lines; Genetic improvement programs in poultry; Selection strategies for the improvement of layers and broilers; Performance testing of commercial strains; Backyard poultry.

Unit III (4 Lectures)

Industrial breeding; Artificial insemination in chicken; Auto-sexing; Random Sample Test.

Unit IV (6 Lectures)

Biochemical variants and immunogenetics of poultry; Use of molecular genetics in poultry breeding; Quantitative trait loci; Marker-assisted selection and genomic selection; Conservation of poultry genetic resources.

VII. Practical (15 Classes)

Inheritance of qualitative traits; Economic traits of egg-type and meat-type chicken; Procedures of standardization; Estimations of heritability, the correlation between various production traits; Inbreeding co-efficient and heterosis; Selection of sires and dams; Osborne index; Restricted selection index; Collection and evaluation of semen and insemination; Estimation of GCA and SCA.

VIII. Teaching methods

Blackboard; PPT-presentations

IX. Learning outcome

Students get acquainted with different poultry species, applications of selection methodology and molecular genetics in poultry for higher productivity.

X. Suggested Reading

- Brereton G and Roadnight S. 2000. *21st Century Poultry Breeding*. Gold Cockerel Books.
- Crawford RD. 1990. *Poultry Breeding and Genetics*. Elsevier.
- Hutt FB. 2003. *Genetics of Fowl*. Norton Greek Press.
- Muir WM and Aggrey SE. 2003. *Poultry Genetics, Breeding and Biotechnology*. CABI.
- Singh RP and Kumar J. 1994. *Biometrical Methods in Poultry Breeding*. Kalyani Publishers.

I. Course Title : Laboratory Animal and Rabbit Breeding

II. Course Code : AGB 610

III. Credit Hours : 2+0

IV. Why this course?

To educate about laboratory animal breeding principles and commercial rabbit breeding.

V. Aim of the course

To impart knowledge on different laboratory animals and their importance, selection and mating methods, and commercial rabbit production and management.

VI. Theory

Unit I (6 Lectures)

Introduction to laboratory animal genetics; Breeding colonies of mice, rats, hamsters, guinea pigs and rabbits and their maintenance; Use of primates in animal research.

Unit II (4 Lectures)

Selection methods and mating systems: Monogamous, polygamous and others.

Unit III (12 Lectures)

Development of genetically controlled laboratory animals; Rules for nomenclature: Inbred strains, outbred stocks, mutant stocks, recombinant inbred strains, transgenic strains; Gene targeting and production of 'gene knock-out' animals; Production and use of specific pathogen-free animals; Guidelines and SOPs for the establishment of lab animal house; Genetic control and monitoring; Record-keeping; Ethics of laboratory animal research: FELASA, CPCSEA and IAEA regulations.

Unit IV (8 Lectures)

Rabbit production and management systems; Rabbit breeds for meat and wool; Economic traits and their inheritance; Breeding records and standardisation; Selection methods and breeding systems.

VII. Teaching methods

Blackboard; PPT-presentations

VIII. Learning outcome

Students get a view on breeding importance of laboratory animals and their applications in animal genetics. Additionally, knowledge of commercial rabbit production will also be developed

IX. Suggested Reading

- Hafez ESE. 1970. *Reproduction and Breeding Techniques for Laboratory Animals*. Philadelphia.
- Peter RC, Nephi MP, Steven DL and James IM. 1987. Rabbit Production, 6th ed. Vero Media Inc.
- Shinde AK, Swarnkar CP and Naqvi SMK. 2013. *Sheep and Rabbit Production and Utilization Technologies*. CSWRI Publications.
- Sirosis M. 2004. *Laboratory Animal Breeding: Principles and Procedures*. Elsevier.
- Tuffery AA. 1995. *Laboratory Animals: An Introduction for Animal Experimenters*. J Wiley and Sons.
- USDA. 2014. *A Complete Hand Book of Backyard and Commercial Rabbit Production*. Peace Corps (Free Online).
- Van Vleck LD, Pollak EJ and Bltenacu EAB. 1987. *Genetics for Animal Sciences*. WH Freeman.
- Weichbrod RH, Thompson GAH and Norton JN. 2018. *Management of Animal Care and Use Programs in Research, Education, and Testing*, 2nd ed. CRC Press.

I. Course Title : Swine Breeding

II. Course Code : AGB 611

III. Credit Hours : 1+0

IV. Why this course?

To educate about swine breeding principles and swine improvement programme in India

V. Aim of the course

To impart knowledge on different breeds of swine and their economic traits, breeding systems and selection methods, and breeding policies and conservation methods.

VI. Theory

Unit I (7 Lectures)

History and development of swine industry; Different breeds of pigs; Economic traits; Breeding records and standardization; Computation of correction factors; Culling and replacement; Equivalent Animal Death Rate (EADR).

Unit II (6 Lectures)

Genetic parameters; Bases and methods of selection; Selection of boars and sows; Breeding systems; Breeding strategies for improvement of indigenous and pure exotic breeds; Inbreeding and its effects on performance traits; Exploitation of heterosis; Development of synthetic varieties/ breeds.

Unit III (2 Lectures)

Swine breeding policy; National swine improvement programme; Conservation of breeds.

VII. Teaching methods

Blackboard: PPT-presentations: Research article discussion in the classroom

VIII. Learning outcome

Get acquainted with different breeds of swine, breeding methods and swine improvement programmes in India

IX. Suggested Reading

- ATARI. 2019. *Pig Farming: Promising Agri-business in Punjab*. ATARI-I Publication (Free Online).
- Board E. 2008. *Handbook of Pig Farming*, Engineers India Research Institute Publications.
- Das A, Tamuli AK, Mohan NH and Thomas R. 2013. *Handbook of Pig Husbandry,* Today and Tomorrow Printers.
- Das A, Tamuli, MK, Thomas R and Banik S. 2012. *Scientific Pig Production Practices*, NRC on Pig Publication.
- FAO. 2009. *Farmer's Hand Book on Pig Production*. FAO Publication.
- Oldenbroek K and van der Waaij L. 2014. *Text Book of Animal Breeding and Genetics*. Wageningen University and Research Centre (Free Online).

I. Course Title : Pet Animal Breeding (Dogs and Cats)

II. Course Code : AGB 612

III. Credit Hours : 1+0

IV. Why this course?

To educate about pet animal breeding principles which are contemporary in the defence establishment and affluent civic society

V. Aim of the course

To impart knowledge on different breeds of cats and dogs besides the principles of breeding management.

VI. Theory

Unit I (9 Lectures)

Breeds of dogs: Classification of breeds, important Indian and exotic breeds; Pedigree breeding and maintenance of breeding records; Kennel Club; Breed associations; Breeding management of dog.

Unit II (6 Lectures)

Breeds of cats: Classification of breeds, important Indian and exotic breeds; Pedigree breeding and maintenance of breeding records; Breeding management of cat.

VII. Teaching methods

Blackboard; PPT-animations; research article discussion in the classroom

VIII. Learning outcome

Different breeds of cats and dogs and their breeding management

IX. Suggested Reading

- Battaglia CL. 1990. *Dog Genetics: How to Breed Better Dogs*. TFH Publications.
- Harmer H. 1974. *Dogs and How to Breed Them*, 2nd ed. Gifford Publications.
- Hedberg K. 1992. *The Dog Owner's Manual on Selecting, Raising and Breeding Dogs*. Watermark Press.
- Moore AS. 1981. *Breeding Purebred Cats: A Guide for the Novice and Small Breeder*. Abraxes Publication.
- Robinson R. 1997. *Genetics of Cat Breeders*. Science Direct Publications.
- Vella CM and McGonagle JJ. 1997. *Breeding Pedigreed Cats*. Howell Book House.
- Vella C and Shelton L. 1999. *Genetics for Cat Breeders and Veterinarians*. Elsevier.
- Vine LL. 1977. *Breeding, Whelping and Natal Care of Dogs*. Acro Publication, NY.
- White K. 1980. *Dog Breeding: A Guide to Mating and Whelping*. Bartholomew Publications.

I. Course Title : Wild Animal Genetics and Breeding

II. Course Code : AGB 613

III. Credit Hours : 1+0

IV. Why this course?

To educate about wild animal breeding

V. Aim of the course

To impart knowledge on wildlife biodiversity in India, wild animal breeding in nature and captivity, and conservation of wild animals.

VI. Theory

Unit I (4 Lectures)

Wildlife biodiversity of India; Adaptation and natural selection; Species and speciation; Population dynamics; Variation; Loss of genetic variation; Hardy-Weinberg equilibrium.

Unit II (6 Lectures)

Inbreeding: Inbreeding depression, effective population size, demographic bottleneck; Genetic considerations in the translocation of wild animals; Wild animal breeding in nature and captivity; Captive breeding projects and principles; Concept of landscape genetics.

Unit III (5 Lectures)

Conservation of wild animals; Cryopreservation of semen and embryos of endangered species; Frozen zoo concept; Genetic markers; Application of molecular and cytogenetic techniques in wildlife breeding; Genetic defects in wild animals; Wildlife Protection Act.

VII. Teaching methods

Blackboard; PPT-animations; research article discussion in the classroom

VIII. Learning outcome

Breeding and conservation methods of wild animals

IX. Suggested Reading

- Devera GK, Katerina VT and Charlotte KB. 2012. *Wild Animals in Captivity: Principles and Techniques of Zoo Management*. University of Chicago Press.
- Kleiman DG, Allen ME, Thompson KV and Lumpkin S. 1997. *Wild Mammals in Captivity-Principles and Techniques*. Chicago Press.
- Linda JS. 2017. *A Field Guide of Tracking Mammals in North East*. Countryman Press.
- Nicholas FW. 1987. *Veterinary Genetics*. Oxford Science Publication.
- Parragon. 2006. *The Encyclopaedia of Wildlife*. Parragon Books Service Ltd.
- Ranjitsinh MK. 2017. *A Life with Wildlife: From Princely India to the Present*, Harper Collins Publications.
- Saha GK and Mazumdar S. 2017. *Wildlife Biology: An Indian Perspective*. PHI Learning Pvt Ltd.

I. Course Title : Equine Breeding

II. Course Code : AGB 614

III. Credit Hours : 1+0

IV. Why this course?

To educate about breeding practices in equines

V. Aim of the course

To impart knowledge on classification of light and work-horses, breeding management and selection strategies in equines, and biotechnology in equine breeding programmes requirements of poultry and factors influencing the same.

VI. Theory

Unit I (4 Lectures)

Equine population in India; Domestic diversity, its origin, history and utilization; Breeds of native and exotic horses; Types and classes of light and work-horses.

Unit II (6 Lectures)

Cytogenetics of horses and donkeys; Breeding of horses and donkeys and production of mules; Foaling and care of foal; Important quantitative and qualitative traits and their inheritance; Recording and handling of breeding data; Standardization of records.

Unit III (5 Lectures)

Stallion and mare complementation; Judging criteria for elite animals; Conservation strategies; Selecting the mare and the stallion for breeding; Ongoing breed improvement programmes; Biotechnology in equine breeding programmes.

VII. Teaching methods

Blackboard; PPT-presentations

VIII. Learning outcome

Breeding and conservation methods of equines

IX. Suggested Reading

- McKinnon AO, Squres EL, Vaala WE and Varner DD. 2011. *Equine Reproduction*. Wiley Blackwell.
- Morel MCGD. 2008. *Equine Reproductive Physiology, Breeding and Stud Management*. CABI.
- Samper JC. 2008. *Equine Breeding Management and Artificial Insemination*. Science Direct Publications.

I. Course Title : Camel Breeding

II. Course Code : AGB 615

III. Credit Hours : 1+0

IV. Why this course?

To educate about camel breeding, an emerging economically important species of livestock

V. Aim of the course

To impart knowledge on breeding management of camels, breed improvement programmes, and application of molecular genetic methods in camel breeding.

VI. Theory

Unit I (7 Lectures)

Population dynamics and economic importance; Breeds of the camel; Production systems and herd structure; Inheritance of important economic traits; Recording and handling of breeding data; Standardization of records; Cytogenetics of the camel; Behaviour and breeding management.

Unit II (5 Lectures)

Judging criteria for elite animals; Selection of breeding stock; Breeding seasons; Methods for detection of heat; Natural service and artificial insemination; Breed improvement programmes.

Unit III (3 Lectures)

Conservation strategies; Immune status of camel; Molecular genetics in camel breeding.

VII. Teaching methods

Blackboard; PPT-presentations; Research article discussion in the classroom

VIII. Learning outcome

Breeding and conservation methods of camels

IX. Suggested Reading

- Dmitriez NG and Ernst LK. 1989. *Animal Genetic Resources of the USSR*. FAO.
- Wilson RT. 1984. *The Camel*. Longman.
- Selected Research Articles

I. Course Title : Yak and Mithun Breeding

II. Course Code : AGB 616

III. Credit Hours : 1+0

IV. Why this course?

To educate about Yak and Mithun breeding

V. Aim of the course

To impart knowledge on breeds/ types of Yak and Mithun, production systems in Yaks and Mithun, their behaviour and breeding management including conservation strategies and molecular genetics in Yak and Mithun breeding.

VI. Theory

Unit I (7 Lectures)

Population dynamics and economic importance; Breeds/ types of yak and mithun; Production systems; Inheritance of important economic traits; Recording and handling of breeding data; Standardization of records; Cytogenetics of yak and mithun; Behaviour and breeding management.

Unit II (5 Lectures)

Judging criteria for elite animals; Selection of breeding stock; Breeding seasons; Methods for detection of heat; Natural service and artificial insemination; Breed improvement. programmes

Unit III (3 Lectures)

Conservation strategies; Molecular genetics in yak and mithun breeding.

VII. Teaching methods

Blackboard; PPT-presentations; Research article discussion in classroom

VIII. Learning outcome

Breeding and conservation methods of yak and mithun

IX. Suggested Reading

- Das PJ, Deori S and Deb SM. 2017. *Arunachali Yak*. NRC on Yak, Dirang, India.
- Gupta SC, Gupta N and Nivsarkar AE. 1996. *Mithun - A Bovine of Indian Origin*.
- Nivsarkar AE, Gupta SC and Gupta N. 1997. *Yak Production*. ICAR Publication.
- Pal RN. 2003. *The Yak,* 2nd ed. FAO; RAP Publication.
- *Selected Research Articles*

I. Course Title : Statistical Methods in Animal Breeding

II. Course Code : AGB 617

III. Credit Hours : 2+1

IV. Why this course?

To educate about Statistical Methods in Animal breeding

V. Aim of the course

To impart knowledge on the transformation of data, sampling, standard error and importance, basics of statistical inferences, and analysis of variance.

VI. Theory

Unit I (12 Lectures)

Measures of central tendency; Measures of dispersion; Correlation and regression; Probability; Theory of distributions; Transformation of data; Sampling: Theory, need and properties; Estimators: Concept, standard error and importance.

Unit II (8 Lectures)

Basics of statistical inferences; Parametric tests: Z, t and F distribution; Non-parametric test: c^2 sign test, run test and rank test; Confidence interval.

Unit III (10 Lectures)

Analysis of variance: One and two way; Experimental designs: CRD, RBD and LSD; Missing plot techniques; Analysis of covariance.

VII. Practical (15 Classes)

Measures of central tendency; Measures of dispersion; Correlation and regression; Transformation of data; Probability; Z, t, F and c^2 tests; CRD, RBD and LSD; Analysis of covariance

VIII. Teaching methods

Blackboard; PPT-presentations

IX. Learning outcome

Application of statistical methods in animal breeding

X. Suggested Reading

- Gianola D and Hammond K. 1990. *Advances in Statistical Methods for Genetic Improvement of Livestock*. Springer.
- Gupta SC and Kapur VK. 2014. *Fundamentals of applied statistics*. Sultan Chand and Sons.
- Gupta SC. 2016. *Fundamentals of Statistics*. Himalaya Publishing House Pvt Ltd.
- Pillai SK and Sinha HC. 1968. *Statistical Methods for Biological Workers*. Ram Prasad and Sons.
- Snedecor GW and Cochran WG. 1989. *Statistical Methods*. Wiley India Publications.

Course Title with Credit Load
Ph.D. in Animal Genetics and Breeding

Course Code	Course Title	Credit Hours
AGB 701*	Molecular Genetics II	2+0
AGB 702*	Trends in Animal Breeding	2+0
AGB 703*	Biometrical Genetics II	2+1
AGB 704*	Advances in Selection Methodology	2+1
AGB 705	Bioinformatics in Animal Breeding	1+1
AGB 706	Animal Cytogenetics and Immunogenetics II	2+0
AGB 707	Statistical Software in Animal Breeding	1+1
AGB 791	Seminar I	1+0
AGB 792	Seminar II	1+0
AGB 799	Research	75

*Core courses

Course Contents
Ph.D. in Animal Genetics and Breeding

I. Course Title : Molecular Genetics II

II. Course Code : AGB 701

III. Credit Hours : 2+0

IV. Why this course?

To educate about the latest tools and techniques of animal genetics and their uses in animal sciences

V. Aim of the course

To impart knowledge on the eukaryotic genome, gene editing, gene knock-out and silencing, transgenic animals their benefits in livestock production, and genomic selection.

VI. Theory

Unit I (10 Lectures)

Eukaryotic genome: Gene families, pseudogenes, SnRNPs; Types of RNA including miRNA; Gene conversion; Tandem repeats; Minisatellites and microsatellites; Sequencing of EST.

Unit II (10 Lectures)

Transposable elements; Transcription and RNA processing; Translation; Regulation of gene expression; Differential expression analysis; Serial analysis of gene expression; Selective gene amplification; The proteasome and longevity of proteins; Gene editing; Gene targeting; Gene knock-out and silencing.

Unit III (10 Lectures)

Transgenic animals: Application, ethical issues; Gene therapy; Bio-pharming; Cloning; Genome imprinting; Epigenetic modification; Creation of SNP chips and microarray technology; Next-generation sequencing; Genomic selection.

VII. Teaching methods

Blackboard; PPT-animations; Research article discussion in classroom

VIII. Learning outcome

Epigenetic Modification and transgenic animal production

IX. Suggested Reading

- Brown TA. 2006. *Genome 3*. Garland Science Publishers
- Clark DP. 2012. *Molecular Biology*. Academic Cell
- Hugo van den Berg. 2015. *Cell Biology and Molecular Genetics*. IPO Publishers
- Pasternak JJ. 2005. An Introduction to Human Molecular Genetics*: Mechanisms of Inherited Diseases*. Wiley
- Puehler A and Timmis KN. 1984. *Advanced Molecular Genetics*. Springer
- Watson, JD, Tania AB, Bell SP, Gann A, Levine A and Losick R. 2017. *Molecular Biology of the Gene*. Pearson Education Publication

I. Course Title : Trends in Animal Breeding

II. Course Code : AGB 702

III. Credit Hours : 2+0

IV. Why this course?

To acquaint with recent trends in animal breeding and designing of need-based breeding strategies

V. Aim of the course

To impart knowledge on identification of novel traits and their role in breed improvement programme, development of mixed model equations, formulation of detailed breeding plans and advanced techniques in genetic manipulation for multiplication and improvement of livestock species.

VI. Theory

Unit I (12 Lectures)

Identification of novel traits and their role in breed improvement programme; Development of mixed model equations; Advancement in biometrical methods including artificial neural network and Bayesian approach; Detection of QTL; Ancestry informative markers for admixture analysis.

Unit II (10 Lectures)

Formulation of detailed breeding plans; Breeding for disease resistance and functional traits; Breeding for climate resilience; Inheritance of animal behavior traits; Breeding for animal welfare; Impact analysis of different breed improvement programme in various livestock species.

Unit III (8 Lectures)

Advanced techniques in genetic manipulation for multiplication and improvement of livestock species: Use of sexed semen, gene introgression, and cloning, etc.

VII. Teaching methods

Blackboard; PPTs; Research article discussion in the classroom

VIII. Learning outcome

Breeding for disease resistance and functional traits; Breeding for climate resilience

IX. Suggested Reading

- Brah GS. 2016. *Animal Breeding: Principles and Applications. Kalyani Publishers.*
- Lynch M and Walsh B. 1998. *Genetics and Analysis of Quantitative Traits.* Oxford University Press.
- Morde RA and Thompson R. 2014. *Linear Models for the Prediction of Animal Breeding Values*. CABI.
- Oldenbroek K and van der Waaij L. 2014. *Text book of Animal Breeding and Genetics*. Wageningen University and Research Centre (Free Online).
- Tomar SS. 2010. *Textbook of Animal Breeding*. Universal Publishers.
- Zeggini E and Morris A. 2010. *Analysis of Complex Disease Association Studies.* Academic Press.

I. Course Title : Biometrical Genetics II

II. Course Code : AGB 703

III. Credit Hours : 2+1

IV. Why this course?

To impart knowledge about recent advances in population genetic theory and application in animal breeding.

V. Aim of the course

To impart knowledge on multivariate analysis, QTL gene mapping, mating designs and other advanced biometrical techniques pertaining to animal breeding.

VI. Theory

Unit I (8 Lectures)

Multivariate analysis; Discriminant function; D^2 analysis; Principal component analysis; Path analysis.

Unit II (8 Lectures)

Mating designs: Basis, diallel, partial diallel, NCD-1, 2, 3 for reciprocal and maternal effects.

Unit III (5 Lectures)

Prediction of recombinant inbred lines using genetic parameters; Advances in genotype-environment interaction and selection indices.

Unit IV (9 Lectures)

QTL mapping; Analysis of SNP data for genomic selection; Advances in the estimation of variance component and prediction of breeding value: Threshold, dominance, random regression and survival models.

VII. Practical (15 Classes)

Discriminant function; D^2 analysis; Principal component analysis; Path analysis; Estimation of GCA and SCA through diallel, partial diallel, NCD-1, 2, 3; Advances in construction of selection indices; QTL mapping; Analysis of SNP data for genomic selection; Advances in estimation of variance components.

VIII. Teaching methods

Blackboard; PPTs; Research article discussion in the classroom

IX. Learning outcome

Students can analyze data on Animal Genetics using different Biometrical Techniques

X. Suggested Reading

- Choudhuri S. 2014. *Bioinformatics for Beginners*. Academic Press.
- Daniel S and Daniel G. 2012. *Likelihood, Bayesian, and MCMC Methods in Quantitative Genetics*. Springer.
- Kute N and Shinde G. 2016. *Principles of Biometrical Genetics*. Daya Publications.
- Marther K. 1997. *Biometrical Genetics*. Springer.
- Michael JK and Harpal SP. 1996. *The Genetical Analysis of Quantitative Traits*. Springer.
- Pawar IS and Singh S. 2010. *Theory and Application of Biometrical Genetics*. CBS Publications.
- Weller JI. 2016. *Genomic Selection in Animals*. John Wiley and Sons.
- Womack JE. 2012. *Bovine Genomics*. John Wiley and Sons.

I. Course Title : Advances in Selection Methodology

II. Course Code : AGB 704

III. Credit Hours : 2+1

IV. Why this course?

To educate about the latest advances in selection theory and their application in animal breeding

V. Aim of the course

To impart knowledge on design of selection experiments, information on single and multiple trait animal models, construction of various selection indices and their relationship with BLUP including the fundamentals of MAS and gBLUP.

VI. Theory

Unit I (8 Lectures)

Fundamental theorem of natural selection; Selection in finite populations; Effect on genetic structure and variance; Design of selection experiments for testing selection theory.

Unit II (6 Lectures)

Measurement of genetic and environmental trends; Advances in selection indices: Multistage, restricted and retrospective selection indices.

Unit III (6 Lectures)

Empirical evaluation of selection theory: genetic slippage, limits to the selection, asymmetry of response, selection experiments, the effect of selection on variance.

Unit IV (10 Lectures)

Selection for threshold traits; Selection under single and multiple trait animal models; Direct and correlated response through various selection indices; Relationship between BLUP and selection index; Selection using markers and entire genome; Methods for analysing GS data like RR-BLUP, Bayes-1, 2 and 3, etc.

VII. Practical (15 Classes)

Determination of culling levels and selection intensity; Estimation of direct and correlated response; Estimation of relative economic values; Construction of various selection indices; Prediction of breeding value using advance methods; QTL analysis using LDMAS and LEMAS.

VIII. Teaching methods

Blackboard; PPT; Research article discussion in classroom

IX. Learning outcome

They will be acquainted with all the theoretical techniques of the advanced selection methodology

X. Suggested Reading

- Balakrishnan N, Nagaraja HN and Kannan N. 2007. *Advances in Ranking, Multiple Comparisons and Reliability*. Springer.
- Cameron ND. 1997. *Selection Indices and Prediction of Genetic Merit in Animal Breeding.* CABI.
- Daniel S and Daniel G. 2012. Likelihood, Bayesian and MCMC *M*ethods in *Q*uantitative

Genetics. Springer.
- Draper NR and Smith H. 1998. Applied Regression Analysis. J Wiley and Sons.
- Henderson CR. 1984. *Applications of Linear Models in Animal Breeding*. CABI.
- Legarra A, Lourenco DAL and Vitezica ZG. 2018. *Bases for Genomic Prediction*. INRA (Free Online).
- Morde RA and Thompson R. 2014. *Linear Models for the Prediction of Animal Breeding Values*, CABI.

I. Course Title : Bioinformatics in Animal Breeding

II. Course Code : AGB 705

III. Credit Hours : 1+1

IV. Why this course?

To educate about basic concepts of bioinformatics and their applications in animal breeding

V. Aim of the course

To impart knowledge on the concepts of bioinformatics, information resources for protein and genome databases, genetic characterization and selection using bioinformatic tools, and modern bioinformatic tools like GWAS.

VI. Theory

Unit I (4 Lectures)

Overview of bioinformatics; Database concepts; Algorithms; Information resources for protein and genome databases: GenBank, EMBL, SWISSPROT, PROSITE.

Unit II (5 Lectures)

Nucleotide and protein sequence analysis; Pair-wise and multiple sequence alignments; Phylogeny; Big SNP data analysis methods; Micro-array processing; Clustering; Software for secondary database search and analysis.

Unit III (6 Lectures)

Genetic characterization; Use of bioinformatics tools for identifying QTL and selection of elite germplasm; GWAS; Development of DNA chips; NGS data analysis.

VII. Practical (15 Classes)

Database development; Algorithms; Nucleotide and protein sequence analysis; Pair-wise and multiple sequence alignments; Phylogeny and dendrogram; Micro-array processing; Clustering; Secondary database search and analysis; Genetic characterization; Identification of QTL; GWAS; NGS data analysis.

VIII. Teaching methods

Blackboard; PPT-animations; Research article discussion in the classroom

IX. Learning outcome

Nucleotide and protein sequence analysis and phylogenetic analysis

X. Suggested Reading

- Attwood TK and Parry-Smith DJ. 2001. *Introduction to Bioinformatics*. Benjamin-Cummings Publishing Company.
- Bishop M. 1999. *Genetics Databases*. Elsevier.
- Jiang R, Zhang X and Zhang MQ. 2013. *Basics of Bioinformatics*. Springer.

- Luke A. 1997. *DNA Sequencing: From Experimental Methods to Bioinformatics*. BIOS Scientific Publishers.
- Ramsden J. 2009. *Bioinformatics: An Introduction*. Springer.
- Stekel D. 2003. *Microarray Bioinformatics*. Cambridge University Press.
- Wu CH and McLarty JW. 2000. *Neural Networks and Genome Informatics*. Elsevier Science.
- Xiong J. 2006. *Essential Bioinformatics*. Cambridge University Press.

I. Course Title : Animal Cytogenetics and Immunogenetics II

II. Course Code : AGB 706

III. Credit Hours : 1+1

IV. Why this course?

To educate about the advances in cytogenetics and their application in animal genetics and breeding

V. Aim of the course

To impart knowledge on somatic cell genetics, stem cell genetics, image analysis of advanced karyotyping techniques, and molecular cytogenetics and gene mapping techniques.

VI. Theory

Unit I (8 Lectures)

Structure of eukaryotic chromosomes; Evolution of karyotype; Various *in- vitro* cell culture techniques; Cell lines and utility; Genotoxicity

Unit II (10 Lectures)

Somatic cell genetics; Stem cell genetics; Molecular cytogenetics and gene mapping; Linkage mapping; ISH; FISH; Radiation hybrid mapping; Fibre-FISH; PRINS; Positional cloning; Spectral karyotyping

Unit III (12 Lectures)

Image analysis; Chromosome painting; Chromosome walking; Micro-dissection of chromosomes; Structure and functions of major histocompatibility complex; T Cell receptor; CD4; Interleukins; Toll-like receptors and their functions

VII. Teaching methods

Blackboard; PPT-animations; Research article discussion in the classroom

VIII. Learning outcome

Students get a good grip on different gene mapping techniques and image analysis

X. Suggested Reading

- Agarwal S and Naik S. 2008. *Fundamentals of Immunogenetics Principles and Practices.* IBD Publisher.
- Christiansen FT and Tait BD. 2012. *Immunogenetics: Methods and Applications in Clinical Practice.* Springer.
- Gersen SL and Keagle MB. 2013. *The Principles of Clinical Cytogenetics.* Springer.
- Litwin SD. 1989. *Human Immunogenetics.* CRC Press.
- Tyagi R. 2009. *Textbook of Cytogenetics.* Discovery Publishers.

I. **Course Title** : **Statistical Software in Animal Breeding**

II. **Course Code** : **AGB 707**

III. **Credit Hours** : **1+1**

IV. **Why this course?**

To educate about the standard statistical software packages in animal breeding

V. **Aim of the course**

To impart knowledge on the use of software for computation of different statistical data

VI. **Theory**

Unit I (4 Lectures)

Data preparation and job control commands for statistical analysis of data; Introduction to statistical and standard software packages.

Unit II (6 Lectures)

Use of software for t-test, Chi-squares test, F-test, ANOVA (CRD, RBD and LSD), correlation and regression (simple, multiple, curvilinear, stepwise) and discriminant analysis.

Unit III (5 Lectures)

Graphic features of the software packages; Linear programming using appropriate software package; Least-squares analysis; Data mining techniques such as neural networks, genetic algorithms and fuzzy logic for predictive modelling.

VII. **Practical (15 Classes)**

Data preparation and generation; Import and export of data from spreadsheet and database packages; Use of software for t-test, Chi-squares test, F-test, ANOVA (CRD, RBD and LSD), correlation and regression (simple, multiple, curvilinear, stepwise) and discriminant analysis; Graphic features of the software packages; Use of software for linear programming problem; Least-squares analysis; Use of software for neural networks and fuzzy logic models for prediction.

VIII. **Teaching methods**

Blackboard; PPTs; Research article discussion in the classroom

IX. **Learning outcome**

Students get an idea on the availability of different statistical and standard software packages and their application in Animal Breeding.

X. **Suggested Reading**

- Balding DJ, Bishop M and Cannings C. 2001. *Handbook of Statistical Genetics*. J Wiley and Sons.
- Boldman K, Kriese LA, Van Vleck LD, Van Tassell CP and Kachman SD. 1995. *Manual for Use of MTDFREML*. ARS, USDA (Free online).
- Dempfle L. 1990. *Statistical Aspects of Design of Animal Breeding Programs*. Springer.
- Freund RJ, Mohr D and William WJ. 2010. *Statistical Methods*. Academic Press.
- Henderson CR. 1984. *Applications of Linear Models in Animal Breeding*. University Guelph Press.
- Isik F, Holland J and Maltecca C. 2017. Genetic *Data Analysis for Plant and Animal Breeding*. Springer.
- Lynch M and Walsh B. 1990. *Genetics and Analysis of Quantitative Traits*. Oxford.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Animal Production Sciences
– Animal Nutrition

Preamble

(Animal Nutrition)

As is true for all branches of science, the science of nutrition has seen a lot of progress during the last decade or so in understanding underlying metabolic processes and the application. Accordingly, it has become imperative to update the course curricula of Animal Nutrition to make a student of Animal Nutrition conversant with the latest development in the field. Therefore, a consorted effort was made by the Committee to gather inputs from all concerned, including experts from academics and industry and incorporate the same after thorough deliberations. The followings are the aspects that were taken into consideration while revising the Animal Nutrition syllabi to make it up to date with the aim of making it knowledge-based while at the same time making it rewarding from a career point of view:

- Latest developments in the science of nutrition and food bioscience and integrating the newer concepts from human and laboratory animal nutrition into the curriculum of animal nutrition
- A particular focus was given to the use of molecular biology (nutrigenomics), which has become a key to understanding the outcome of various nutritional interventions in health and more so in diseases including the rumen metabolism.
- Because of the changing perspectives of livestock and environment, greater thrust on the role of feeding and nutrition on minimizing and/ or mitigating the (adverse) environmental impacts of rearing various classes of farm animals
- Sound feeding practices and evolving nutritional concepts for ensuring safe food production for consumers
- The potential use of nutrition (involving specific nutrients and emerging nutraceuticals) for promotion of health: both for preventive and prophylactic use of clinical nutrition for farm, companion and captive and zoo animals
- Greater focus on the industrial application of nutritional concepts in order to make the students more industry-ready. It also aimed to inculcate a sense of entrepreneurship among animal nutrition students.
- Continued focus on making better use of local and alternate feed resources strategically to make livestock production economic and rewarding while maintaining the sustainability for various classes of livestock farmers.

Summary of Changes Made

Course	Title	Remarks
M.V.Sc. Courses		
ANN 601	Energy and Protein Nutrition	Contents updated
ANN 602	Minerals and Vitamin Nutrition and Feed Additives	Contents updated
ANN 603	Feed and Fodder Technology	Merging of ANN 603 and ANN 604
ANN 604	Ruminant Nutrition	Contents updated
ANN 605	Non-Ruminant Nutrition	Contents updated
ANN 606	Companion Animal Nutrition	ANN 607 split into two courses (AAN 606 and ANN 607)
ANN 607	Nutrition of Laboratory, Wild and Zoo Animals	
ANN 608	Research Methodology in Animal Nutrition	Contents updated
ANN 609	Non-Conventional Feed Resources	Contents updated
ANN 610	Nutritional Biochemistry	New Course
ANN 611	Clinical Nutrition	New Course
ANN 612	Rumen Biotechnology	New Course
Ph.D. Courses		
ANN 701	Modern Concepts in Feeding of Ruminants	ANN 701 split into two courses (ANN 701 and ANN 702)
ANN 702	Forages in Animal Nutrition	
ANN 703	Modern Concepts in Feeding of Non-Ruminants	Contents updated
ANN 704	Emerging Concepts in Rumen Metabolism	Contents updated
ANN 705	Advances in Mineral and Vitamin Nutrition	Contents updated
ANN 706	Advanced Techniques in Nutritional Research	Contents updated
ANN 707	Recent Trends in Feed Technology	Contents updated
ANN 708	Clinical Nutrition of Farm and Pet Animals	Merging of two courses: ANN 707 and ANN 708
ANN 709	Toxicants and Antimetabolites in Animal Nutrition	Contents updated
ANN 710*	Nutrigenomics in Animal Nutrition	New Course
ANN 711	Equine Nutrition	New Course

Course Title with Credit Load
M.V.Sc. in Animal Nutrition

Course Code	Course Title	Credit Hours
ANN 601*	Nutritional Biochemistry	1+0
ANN 602*	Energy and Protein Nutrition	2+0
ANN 603*	Minerals and Vitamin Nutrition and Feed Additives	2+1
ANN 604*	Feed and Fodder Technology	1+1
ANN 605*	Ruminant Nutrition	2+1
ANN 606*	Non-Ruminant Nutrition	2+1
ANN 607*	Research Methodology in Animal Nutrition	0+2
ANN 608	Companion Animal Nutrition	1+0
ANN 609	Nutrition of Laboratory, Wild and Zoo Animals	2+1
ANN 610	Non-Conventional Feed Resources	1+1
ANN 611	Introductory Clinical Nutrition	1+0
ANN 612	Rumen Biotechnology	1+0
ANN 691	Seminar	1+0
ANN 699	Research	30

Course Contents
M.V.Sc. in Animal Nutrition

I. Course Title : Nutritional Biochemistry

II. Course Code : ANN 601

III. Credit Hours : 1+0

IV. Why this course?

Biochemistry is the mother of all sciences. To understand the mechanism of nutrient metabolism a clear understanding of the various biochemical events is essential for a student specialising in animal nutrition.

V. Aim of the course

To help to develop the concepts of biochemical pathways involving nutrient metabolism.

VI. Theory

Unit I (12 Lectures)

Classification of carbohydrates and their functions. Digestion and metabolism of carbohydrate in ruminants and non-ruminants. Carbohydrate synthesis.

Unit II (8 Lectures)

Classification and properties of fats and their functions. Digestion and metabolism of fat in ruminants and non-ruminants. Fat synthesis

Unit III (12 Lectures)

Classification, structure, properties and function of proteins, amino acids and nucleic acids. Digestion and metabolism of proteins and other nitrogenous compounds in ruminants and non-ruminants. Protein synthesis. Control of metabolism

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Understanding of biochemical basis of nutrient metabolism.

IX. Suggested Reading

- Cheeke PR and Dierenfeld E. 2010. *Comparative Animal Nutrition and Metabolism*. CAB International.
- D'Mello JPF. 2003. *Amino Acids in Animal Nutrition*, 2nd ed. CAB International.
- Leeson S and Summers JD. 2001. *Scott's Nutrition of The Chicken*, 4th ed. University Books.
- Maynard LA, Loosli JK, Hintz HF and Warner RG. 1987. *Animal Nutrition*. Tata McGraw-Hill.
- McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA and Wilkinson RG. 2011. *Animal Nutrition*, 7th ed. Benjamin Cummings.
- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry*, 7th ed. Macmillan Learning.

I. Course Title : Energy and Protein Nutrition

II. Course Code : ANN 602

III. Credit Hours : 2+0

IV. Why this course?

Energy and protein constitute the major nutrients driving the maintenance and production in farm animals. A clear understanding of underlying concepts is key to the application of the same under practical feeding situation.

V. Aim of the course

To understand the metabolic pathways involved in energy and protein utilization including their requirements for various classes of animals for different physiological functions.

VI. Theory

Unit I (8 Lectures)

Measures of feed energy. Partitioning of feed energy. Energy balance, Fasting catabolism. Direct and indirect calorimetry. Efficiency of energy and protein utilization.

Unit II (12 Lectures)

Rumen degradable protein (RDP), and rumen undegradable protein (UDP) and fermentation kinetics. Protein turnover. Quantification of microbial protein synthesis. Protein quality determination in ruminants and monogastrics. Supplementary value of amino acids. NPN metabolism, urea fermentation potential and metabolizable protein. Amino acids imbalance, antagonism and toxicity.

Unit III (12 Lectures)

Feeding standards: comparative appraisal and limitations. Determination of energy and protein requirements. Nutrients metabolism with special reference to milk, meat and wool production. Energy and protein requirement for maintenance, growth, pregnancy and lactation in farm animals.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Development of comprehensive knowledge of basic nutrition involving energy and protein.

IX. Suggested Reading

- Blaxter K. 1989. *Energy Metabolism in Animal and Man*. Cambridge University Press.
- Bondi A. 1987. *Animal Nutrition*. Wiley InterScience.
- Cheeke PR and Dierenfeld E. 2010. *Comparative Animal Nutrition and Metabolism*. CAB International.
- Crampton EW and Harris LE. 1969. *Applied Animal Nutrition*. WH Freeman.
- Dryden GM. 2008. *Animal Nutrition Science*, 1st ed. CAB International.
- Maynard LA, Loosli JK, Hintz HF and Warner RG. 1987. *Animal Nutrition*. Tata McGraw-Hill.
- McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA and Wilkinson RG. 2011. *Animal Nutrition*, 7th ed. Benjamin Cummings.

- Pond WG, Church DB, Pond KR and Schoknecht PA. 2004. *Basic Animal Nutrition and Feeding*, 5th ed. Wiley.
- Singh UB. 1987. *Advanced Animal Nutrition for Developing Countries*. Indo-Vision.

I. Course Title : Minerals and Vitamin Nutrition and Feed Additives

II. Course Code : ANN 603

III. Credit Hours : 2+1

IV. Why this course?

Mineral and vitamins are key drivers of intermediary metabolism besides playing an important role in health and production

V. Aim of the course

To impart knowledge on sources, functions, analysis, signs of deficiency and signs of toxicity of various minerals and vitamins

VI. Theory

Unit I (12 Lectures)

General role of minerals, factors affecting mineral requirements. Macro-minerals and micro-minerals, their, distribution, metabolism, physiological functions, deficiencies and excesses, and sources and requirements. Probable essential minerals.

Unit II (6 Lectures)

Mineral interactions. Chelated minerals and concept of nano-minerals. Bioavailability studies in minerals. Impact of minerals on reproduction, fertility, and immunity. Soil-plant-animal-human relationship, development of area-specific minerals. Toxic minerals; their role in health and production of farm animals. Newly recognized trace minerals.

Unit III (10 Lectures)

Definition, history, classification, chemistry, functions, deficiencies and excesses, requirements and sources of water-soluble and fat-soluble vitamins. Role of vitamins in energy metabolism. Vitamin-mineral interrelationship. Vitamin toxicosis. Role of vitamins in reproduction, fertility and immunity.

Unit IV (4 Lectures)

Feed additives and nutraceuticals. Probiotics, prebiotics and synbiotics; eubiotics. Feed enzymes. Phytochemical feed additives; polyphenols and essential oils; organic acids and acidifiers.

VII. Practical (16 Classes)

General principles of mineral estimation. Sampling and processing techniques. Use of atomic absorption spectrometry and ICP in mineral estimation. Estimation of macro- and micro-minerals. Formulation of mineral mixture for various species. Estimation of some important vitamins (vitamin A, E and C). Purified diets for mineral and vitamin studies. Calculation of mineral and vitamin requirements.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions

- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

- Comprehensive knowledge about mineral and vitamin metabolism and their requirements for farm animals
- Capacity for estimation of various minerals and vitamins using advanced analytical techniques

X. Suggested Reading

- McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA and Wilkinson RG. 2011. *Animal Nutrition*, 7th ed. Benjamin Cummings.
- McDowell RL. 1989. *Vitamins in Animal Nutrition*. Academic Press.
- McDowell RL. 2003. *Minerals in Animal and Human Nutrition*, 2nd ed. Elsevier Science.
- Suttle NF. 2010. *Mineral Nutrition of Livestock*, 4th ed. CAB International.

I. Course Title : Feed and Fodder Technology

II. Course Code : ANN 604

III. Credit Hours : 1+1

IV. Why this course?

Processing of feed and fodder are important means to augment the utilization for efficient animal production.

V. Aim of the course

To understand various technological options available for processing of classes of food, feeds and fodders and their potential application in feeding management of farm animals.

VI. Theory

Unit I (4 Lectures)

Various feed mill equipment and their handling; layout and operations in feed mill (small, medium and large feed plants); automated feed mill: merits and demerits. Procurement of feed ingredients: specification and guidelines. Quality control of feed ingredients and finished feeds. BIS standard.

Unit II (4 Lectures)

Principles and process of material handling, weighing, grinding, mixing, pelleting, packaging and other major processing operations. Crumbling, flaking, popping and extrusion. Premixes. Codex Alimentarius, HACCP.

Unit III (4 Lectures)

Feed and fodder processing and preservation techniques. Densification, chemical and biological treatment of feeds/ fodders. Fodder conservation through hay and silages; Microbiological evaluation of processed and preserved feeds; Effect of preservation on the nutritional value of feed.

Unit IV (4 Lectures)

Feed storage and godown management; goods sanitation and hygiene of go-down. Traditional and modern farm-level storage structures. Factors affecting feedstuffs during storage. Liquid feed ingredients. Storage losses; insect pests and rodents control measures; Mycotoxins in feedstuffs and its control measures.

VII. Practical (16 Classes)

Quality control and inspection of feed materials. Qualitative tests for adulterants urea, urease, thiram. Identification of insect pests and fungi in stored products. Feed microscopy. Formulation and preparation premixes. Quality evaluation of silage and hay, Laboratory preparation of silage. Visit to feed plant: Hands-on training on preparation of feed and mineral mixture. Preparation of project report on plant layout and design, problems related to feasibility, record-keeping in different sections of a feed mill.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

Practical understanding and application of feed processing technologies

X. Suggested Reading

- Dryden G. 2008. *Animal Nutrition Science*. CAB International.
- Kundu SS, Mahanta SK, Singh S and Pathak PS. 2016. *Animal Feed Technology*. Satish Publishers
- Perry TW, Cullison AE and Lowrey RS. 2003. *Feeds and Feeding*, 6th ed. Pearson.
- Pond WG, Church DB, Pond KR and Schoknecht PA. 2004. *Basic Animal Nutrition and Feeding*, 5th ed. Wiley.
- Schofield EK (Ed.). 2005. *Feed Manufacturing Technology V*. American Feed Industry Association, Arlington.

I. Course Title : Ruminant Nutrition

II. Course Code : ANN 605

III. Credit Hours : 2+1

IV. Why this course?

Ruminants possess unique digestive capabilities involving rumen microbes that utilize diverse feed resources which are otherwise not fit for monogastric animals.

V. Aim of the course

To develop an understanding of the rumen metabolism and its manipulation for improving nutrient utilization for enhancing ruminant production.

VI. Theory

Unit I (6 Lectures)

Functional anatomy of the digestive system of ruminants. Introduction to rumen microflora and fauna. Development of rumen. Feeds and fodders for ruminant feeding.

Unit II (12 Lectures)

Water requirements. Nutrient requirements and feeding of calves, heifers, dry, pregnant and lactating cows, buffaloes, sheep and goat. Peculiarities of digestive physiology, nutrition and feeding management of camels.

Unit III (6 Lectures)

Voluntary feed intake. Determination of digestibility, factors affecting digestibility. Manipulation of rumen fermentation.

Unit IV (12 Lectures)

Concept of complete feed and total mixed ration. Precision feeding. Phase feeding. Limiting nutrients and strategic feeding of high yielding ruminants. Concept of by-pass nutrients and their impact on production, reproduction and immune status.

Unit V (12 Lectures)

Nutritional approaches for increasing the functional properties of milk: role of CLA, omega fatty acids. Different systems of feeding buffalo for beef production. Feeding during stress and natural calamities. Feeding management of migratory/ nomadic small ruminants.

VII. Practical (16 Classes)

Design and planning of feeding experiments. Identification of feed and fodder based on its composition. Ration formulation for large and small ruminants for different physiological stages. Estimation of digestibility and nutritive value of feeds and fodders by metabolism trial in dairy cattle. Determination of nutritive value of pastures by the use of range techniques. Collection and processing of rumen liquor. Estimation of rumen metabolic profile (pH, ammonia, lactate, and TVFA, etc.). Estimation of purine derivatives.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

In-depth knowledge of feeding ruminants in light of their metabolic peculiaritiesFeed evaluation based on an assessment of various rumen functions

X. Suggested Reading

- Church DC. 1988. *The Ruminant Animal: Digestive Physiology and Nutrition*, 2nd ed. Prentice-Hall.
- Dehority BA. 2003. *Rumen Microbiology*. Nottingham University Press.
- D'Mello JPF. 2003. *Amino Acids in Animal Nutrition*, 2nd ed. CAB International.
- Givens D, Axford R and Owen E. (Ed.). 2000. *Forage Evaluation in Ruminant Nutrition*. CAB International.
- Hynd PI. 2019. *Animal Nutrition: From Theory to Practice*. CAB International.
- McDowell RL. 2012. *Nutrition of Grazing Ruminants in Warm Climates*. Academic Press.
- Moran J. 2005. *Tropical Dairy Farming: Feeding Management for Small Holder Dairy Farmers in the Humid Tropics*. Landlinks Press
- NRC. 2001. *Nutrient Requirements of Dairy Cattle*, 7th rev. ed. National Research Council. National Academies Press.
- NRC. 2016. *Nutrient Requirements of Beef Cattle*, 8th rev. ed. National Academies of Sciences, Engineering, and Medicine. National Academies Press.
- NRC. 2007. *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids*. National Research Council. National Academy Press.
- Pond WG, Church DB, Pond KR and Schoknecht PA. 2004. *Basic Animal Nutrition and Feeding*, 5th ed. Wiley.
- Shirley RL. 2012. *Nitrogen and Energy Nutrition of Ruminants*. Academic Press.10.
  Van Soest PJ. 1994. *Nutritional Ecology of the Ruminant*. Cornell University Press.

I. Course Title : Non-Ruminant Nutrition

II. Course Code : ANN 606

III. Credit Hours : 2+1

IV. Why this course?

The nutritional attributes of non-ruminants differ among various species as well as their characteristic digestive physiology.

V. Aim of the course

To impart knowledge on the nutrient metabolism of various classes of monogastric animals involving poultry, swine, equines and rabbits under different physiological stages.

VI. Theory

Unit I (20 Lectures)

Feeding of poultry for meat and egg production. Ideal protein concept. Standard ileal digestible amino acids. Nutrient requirements for broilers and layers. Feeding of breeder hens; nutritional factors affecting hatchability. Feeding systems for poultry. Feed additives for poultry. Nutritional approaches for designer egg and meat production. Nutritional disorders in poultry and the role of nutrition in diseases prevention. Water intake and quality in poultry production.

Unit II (16 Lectures)

Nutrition and feeding of swine in different stages of growth and production. Nutritional factors affecting the quality of the products: lean meat production. Water intake and quality in pig production.

Unit III (12 Lectures)

Feeding of equines. Feeding of rabbits. Hindgut fermentation and its importance. Nutrient requirements of equines. Special features of equine feeding management. Nutritional management of colic and other health disorders. Nutrient requirements of rabbits for wool and meat production. Nutrition-related disorders in rabbits.

VII. Practical (16 Classes)

Design and planning for poultry and swine feeding experiments. Calculation of nutrient requirements for broilers and layers. Formulation and compounding of general and least-cost rations, determination of the nutritive value of poultry and swine feeds by balance experiments. Formulation of rations for horses and rabbits. Visit poultry and piggery units, feed and fodder stores. Calculation of different measures of protein quality.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

Knowledge of practical feeding management of various classes of non-ruminant species.

X. Suggested Reading

- Adamo G and Costanza A (Eds.). *Rabbits Biology, Diet and Eating Habits and Disorders*. Nova Biomedical.
- Cheeke PR. 1987. *Rabbit Feeding and Nutrition*. Academic Press, Inc.
- Chiba LI (Ed.). 2012. *Sustainable Swine Nutrition*. Wiley-Blackwell.
- de Blas C and Wiseman J. (Eds.). 2010. *Nutrition of the Rabbit*, 2nd ed. CAB International.
- D'Mello JPF. 2003. *Amino Acids in Animal Nutrition*, 2nd ed. CAB International.
- Frape D. 2010. *Equine Nutrition and Feeding*, 4th ed. Wiley-Blackwell.
- Hynd PI. 2019. *Animal Nutrition: From Theory to Practice*. CAB International.
- Leeson S and Summers JD. 2009. *Commercial Poultry Nutrition*, 3rd ed. Nottingham University Press.
- Leeson S and Summers JD. 2019. *Scott's Nutrition of The Chicken*, 4th ed. CBS Publishers and Distributors.
- NRC. 2007. *Nutrient Requirements of Horses*, 6th Rev. ed. National Research Council. National Academy Press.
- NRC. 1994. *Nutrient Requirements of Poultry*, 9th Rev. ed. National Research Council. National Academy Press.
- NRC. 2012. *Nutrient Requirements of Swine*, 11th Rev. ed. National Research Council. National Academy Press.
- Varga M. 2013. *Textbook of Rabbit Medicine*, 2nd ed. Butterworth-Heinemann.

I. Course Title : Research Methodology in Animal Nutrition

II. Course Code : ANN 607

III. Credit Hours : 0+2

IV. Why this course?

Nutritional evaluation involving feed analysis and nutrient metabolism is vital in the interpretation of the outcomes of nutritional studies.

V. Aim of the course

Preparedness in part of the students to understand the basics of various analytical techniques and their application in nutritional research.

VI. Practical

Unit I (6 Classes)

Principles of animal experimentation. Common statistical tools for nutritional research.

Unit II (20 Classes)

Preparation of standard solutions. Proximate analysis of feeds and fodders. Cell-wall partitioning using Van Soest methods. Markers in digestibility determination. *In-vitro/ in sacco* determination of digestibility and digestion kinetics. Determination of energy content of feed, faeces and urine using bomb calorimeter. Determination of blood metabolic profile.Unit III (6 *Classes*)Introduction and principles of GC, HPLC, AAS, ICP, tracer technique, flame photometer, NIR, SF_6, rumen-simulation technique, and amino acid analyzer.

VII. Teaching methods/ activities

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on training of laboratory techniques

VIII. Learning outcome

Capacity building of the students to undertake animal nutrition research.

IX. Suggested Reading

- Bate ST and Clark RA. 2014. *The Design and Statistical Analysis of Animal Experiments*. Cambridge University Press.
- Hofmann A and Clokie S (Eds.). *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*, 8th ed. Cambridge University Press.
- Maynard LA, Loosli JK, Hintz HF and Warner RG. 1987. *Animal Nutrition*. Tata McGraw-Hill.
- McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA and Wilkinson RG. 2011. *Animal Nutrition*, 7th ed. Benjamin Cummings.
- Pounis G. 2018. *Analysis in Nutrition Research*. Academic Press.

I. Course Title : Companion Animal Nutrition

II. Course Code : ANN 608

III. Credit Hours : 1+0

IV. Why this course?

The philosophy of companion animal nutrition is altogether different from that of the farm animals.

V. Aim of the course

To impart knowledge in the fundamental and applied aspects of the nutrient metabolism for ensuring health and wellbeing of companion animals.

VI. Theory

Unit I (4 Lectures)

Philosophy of companion animal nutrition. Digestion and absorption of nutrients in dogs and cats. Nutrient requirements for dogs and cats during different life stages: energy, protein, fat, minerals and vitamins. Critical nutrients for cats.

Unit II (4 Lectures)

Common feed ingredients and supplements for pets. Homemade diets. Commercial pet foods: types and nutritional profile. Processing techniques in pet food manufacturing. Pet food evaluation and quality control.

Unit III (4 Lectures)

Feeding management for dogs and cats of different age groups, viz., pregnancy, lactation, neonatal puppies and kitten, growth, adult maintenance, stress and geriatrics including feeding behaviour. Water requirements.

Unit IV (4 Lectures)

Deficiencies and excesses of nutrients. Nutritionally responsive disorders: inherited disorders of nutrient metabolism, diabetes mellitus, obesity, urinary tract health and kidney diseases. Parenteral nutrition for hospitalized pets.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Understanding of the nutritional concepts for feeding management of companion animals.

IX. Suggested Reading

- Buffington C, Holloway C, Abood S. 2004. *Manual of Veterinary Dietetics*. Elsevier.
- Case LP, Daristotle L, Hayek MG, Raasch MF. 2010. *Canine and Feline Nutrition: A Resource for Companion Animal Professionals*, 3rd ed. Elsevier.
- Case LP. 2005. *The Dog: Its Behavior, Nutrition, and Health*, 2nd ed. Blackwell Publishing.
- McNamara JP. 2013. *Principles of Companion Animal Nutrition*, 2nd ed. Pearson.
- NRC. 2006. *Nutrient Requirements of Dogs and Cats*. National Research Council. National Academy Press.

I. Course Title : Nutrition of Laboratory, Wild and Zoo Animals

II. Course Code : ANN 609

III. Credit Hours : 2+1

IV. Why this course?

The nutrition of laboratory animals is important to ensure their health performance making them ready for use in biomedical research. On the contrary, wild and zoo animals as a part of the ecosystem call for an entirely different approach in terms of their nutritional management.

V. Aim of the course

To understand the mechanism involved in the nutrient metabolism in laboratory and wild animals and their diverse applications for effective health management and wellness.

VI. Theory

Unit I (12 Lectures)

Digestive structure and functions of laboratory animals: rats, mice, and guinea pigs. Nutritional requirements of various species of laboratory animals. Feeding of laboratory animals. Concept of purified diets in laboratory animals. Nutrition of non-human primates.

Unit II (10 Lectures)

Natural dietary habits of zoo animals. Feeding schedules of various classes captive and zoo animals and birds. Feeding orphan and neonates. Role of nutrition in the management of health disorders in zoo animals. Feeding of sick and old animals: parenteral nutrition.

Unit III (10 Lectures)

Feeding habits, and behaviour of wild animals. General aspects of digestive physiology of herbivores and carnivores. Nutrition of semi-wild animals like mithun and yak. Nutritive characteristics of forages for wild animals. Adequacy of forage plants for wild and zoo animals.

VII. Practical (16 Classes)

Formulation and preparation of hygienic, balanced diets and feeding of laboratory animals. Characteristics of ration formulation and feeding schedules wild and zoo animals. Visit zoological parks and wildlife sanctuary, and collection of information on the feeding schedule of different categories of captive animals.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

Understanding of nutritional management of the laboratory, wild and zoo animals

X. Suggested Reading

- Barboza PS, Parker KL and Hume ID. 2008. *Integrative Wildlife Nutrition*. Springer.
- Clemons DJ and Seeman JL. 2011. *The Laboratory Guinea Pig*, 2nd ed. CRC Press/ Taylor and Francis.
- Gordon IJ and Prins HHT. 2008. *The Ecology of Browsing and Grazing*. Springer.
- Lane-Patter W and Pearson AEG. 1971. *The Laboratory Animal: Principles and Practice*, 2nd ed. Academic Press.
- NRC. 1995. *Nutrient Requirements of Laboratory Animals,* 4th rev. ed. National Research Council. National Academy Press.
- NRC. 2003. *Nutrient Requirements of Nonhuman Primates*. National Research Council. National Academy Press.
- NRC. 2011. *Guide for the Care and Use of Laboratory Animals,* 8th ed. National Research Council. National Academy Press.
- Pond WG, Church DB, Pond KR and Schoknecht PA. 2004. *Basic Animal Nutrition and Feeding*, 5th ed. Wiley.
- Robbins C. 1993. *Wildlife Feeding and Nutrition*, 2nd ed. Elsevier.
- Weichbrod RH, Thompson GAH and Norton JN (Eds.). 2018. *Management of Animal Care and Use Programs in Research, Education, and Testing*, 2nd ed. CRC Press/ Taylor and Francis.

I. Course Title : Non-Conventional Feed Resources

II. Course Code : ANN 610

III. Credit Hours : 1+1

IV. Why this course?

Exploration of alternative feed resources for farm animals is a continuous process considering the scarcity of quality feeds and fodders for efficient livestock production.

V. Aim of the course

To build-up concepts involving the availability and potential use of various classes of non-conventional feed resources including ameliorative measures to ensure feed and food safety.

VI. Theory

Unit I (8 Lectures)

Present and future feed requirements and current availability for livestock and poultry. Use of non-conventional feeds; By-products of agricultural, industrial, food processing units and forest by-products. Slaughterhouse by-products, aquatic weeds. Permissible levels of inclusion of various non-conventional feeds in the ration of different kinds of livestock. Formulation of economical rations using the non-conventional feed.

Unit II (5 Lectures)

Classification of toxic principles in animal feedstuffs. Chemico-physical properties of various anti-nutritional factors (ANFs). Rumen microbial adaptation to various ANFs. Effect of anti-nutritional factors on health and production indifferent species of livestock.

Unit III (3 Lectures)

Detoxification of toxin principles by various physical, chemical and biological techniques. Insecticide and pesticide residues, heavy metals residues in feeds and fodders.

VII. Practical (16 Classes)

Qualitative methods for the presence/ detection of ANFs in feedstuffs. Estimation of mycotoxins in various feeds and fodders. Estimation nitrates, HCN, oxalates, protease inhibitors, tannins, saponins, gossypol, mimosine and heavy metals.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

Comprehensive knowledge on the integration of alternative feed resources in practical farm animal production.

X. Suggested Reading

- Devendra C. 1985. *Non-conventional Feed Resources in Asia and the Pacific*, 2nd ed. APHCA, FAO.
- FAO. 1995. *Tropical Feeds and Feeding Systems*. Proceedings of the First FAO Electronic Conference. Food and Agriculture Organization of the United Nations, Rome.
- FAO. 2004. *Assessing Quality and Safety of Animal Feeds*. Food and Agriculture Organization of the United Nations, Rome.
- Liner IE. 1980. *Toxic Constituents of Animal Food Stuffs*, 2nd ed. Academic Press.
- Singh UB. 1987. *Advanced Animal Nutrition for Developing Countries*. Indo-Vision.
- Speedy A and Sansoucy R. 1991. *Feeding Dairy Cows in the Tropics*. Food and Agriculture Organization of the United Nations, Rome.
- *Select articles from journals*

I. Course Title : Introductory Clinical Nutrition

II. Course Code : ANN 611

III. Credit Hours : 1+0

IV. Why this course?

Nutrition forms the basis of health and therefore could be strategically used for prevention and/ or therapeutic management of various diseases.

V. Aim of the course

To understand the role of nutrients in the development of various disease processesTo elucidate the potential of various nutrients and nutraceuticals in amelioration and management of disease of diverse nature.

VI. Theory

Unit I (8 Lectures)

Metabolic disorders and peri-parturient diseases: milk fever, ketosis, downer cow syndrome, retained placenta, sub-acute ruminal acidosis, laminitis, abomasal displacement, mastitis. Nutrient parasite interaction. Enterotoxaemia

Unit II (8 Lectures)

Nutritional amelioration of biotic and abiotic stress: heat and cold stress, transportation stress. Potential plant toxicity to grazing animals. Toxicity of grazing animals: signs of poisoning. Nitrite poisoning, toxic effects of goitrogens, glucosinolates. Nutritional management of reproductive disorders.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Understanding of nutritional management of health disorders.

IX. Suggested Reading

- Constable P, Hinchcliff KW, Done S and Gruenberg W. 2016. *Veterinary Medicine*, 11th ed. Saunders Ltd.
- Knight AP and Walter R. 2001. *A Guide to Plant Poisoning of Animals in North America*. Teton NewMedia.
- McDowell RL. 2012. *Nutrition of Grazing Ruminants in Warm Climates*. Academic Press.
- Select articles from Journals

I. Course Title : Rumen Biotechnology

II. Course Code : ANN 612

III. Credit Hours : 1+0

IV. Why this course?

Rumen being a distinctive digestive organ typical to ruminants harbouring diverse microbial communities offers opportunities for their manipulation using molecular biological approaches.

V. Aim of the course

To understand the basics of rumen metabolism employing molecular biology tools

VI. Theory

Unit I (8 Lectures)

Rumen ecology. Manipulation of rumen fermentation for better utilization of fibrous feeds and reduction in methane production. Biotechnological applications for lignin degradation. Role of feed additives, chemicals, antibiotics and probiotics and their effect on rumen metabolism. Degradation of anti-nutritional factors in the rumen.

Unit II (8 Lectures)

Genetic manipulation, DNA recombinant technology for improvement in rumen fermentation. Factors influencing the fate of introduced microbes. Metagenomics for microbial diversity: concept and application.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Basic knowledge of molecular biology as applicable to rumen functions.

IX. Suggested Reading

- Dehority BA. 2003. *Rumen Microbiology*. Nottingham University Press.
- Dijkstra J, Forbes J and France J. 2005. *Quantitative Aspects of Ruminant Digestion and Metabolism*. CAB International.
- Kebreab E, Dijkstra J, Bannink A, Gerrits W and France J. 2006. *Nutrient Digestion and Utilization in Farm Animals*. CAB International.
- Millen DD, Arrigoni MDB and Pacheco RDL. (Eds.). 2016. *Rumenology*. Springer Nature.
- Van Soest PJ. 1994. *Nutritional Ecology of the Ruminant*. Cornell University Press.

Course Title with Credit Load
Ph.D. in Animal Nutrition

Course Code	Course Title	Credit Hours
ANN 701*	Modern Concepts in Feeding of Ruminants	2+0
ANN 702*	Forages in Animal Nutrition	1+0
ANN 703*	Recent Concepts in Feeding of Non-Ruminants	1+0
ANN 704*	Advances in Rumen Metabolism	1+1
ANN 705*	Advances in Mineral and Vitamin Nutrition	2+0
ANN 706*	Advanced Clinical Nutrition	1+1
ANN 707	Advanced Techniques in Nutritional Research	1+1
ANN 708	Advances in Feed Technology	1+0
ANN 709	Toxicants and Anti-Metabolites in Animal Nutrition	1+0
ANN 710	Nutrigenomics in Animal Nutrition	1+0
ANN 711	Equine Nutrition	1+0
ANN 791	Seminar-I	1+0
ANN 792	Seminar-II	1+0
ANN 799	Research	75

*Core courses

Course Contents
Ph.D. in Animal Nutrition

I. Course Title : Modern Concepts in Feeding of Ruminants
II. Course Code : ANN 701
III. Credit Hours : 2+0
IV. Why this course?

The feeding management of ruminants is undergoing rapid changes because of scientific and technological advances to augment productivity.

V. Aim of the course

To understand the emerging concepts involving feeding management of high producing ruminant animals.

VI. Theory

Unit I (20 Lectures)

Developments in ruminant digestive physiology. Advanced concepts in the determination of energy and protein requirements. Importance of energy and protein quality for milk and meat production. Recent concepts in protein and energy systems like CNCPS, net energy, metabolizable and available protein. Methods of estimation of energy and protein values of feeds for different physiological functions of livestock. Kinetics of nutrient metabolism. Hindgut fermentation. Efficiency of nutrient utilization for different production purposes. Hormonal regulation of nutrient partitioning.

Unit II (12 Lectures)

Concept of limiting amino acids for high yielders. Strategic feeding of high yielding dairy cows and meat-producing ruminants. Concept of phase feeding and precision feeding. Feeding during the transition period. Bypass nutrient technology. Rumen manipulation to optimize productivity and reduce methanogenesis.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Knowledge of the newer concepts for its application in the feeding management of ruminants.

IX. Suggested Reading

- D'Mello JPF. 2003. *Amino Acids in Animal Nutrition*, 2nd ed. CAB International.
- McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA and Wilkinson RG. 2011. *Animal Nutrition*, 7th ed. Benjamin Cummings.
- McDowell RL. 2012. *Nutrition of Grazing Ruminants in Warm Climates*. Academic Press.
- NRC. 2001. *Nutrient Requirements of Dairy Cattle*, 7th rev. ed. National Research Council. National Academies Press.

- NRC. 2016. *Nutrient Requirements of Beef Cattle*, 8th rev. ed. National Academies of Sciences, Engineering, and Medicine. National Academies Press.

I. Course Title : Forages in Animal Nutrition

II. Course Code : ANN 702

III. Credit Hours : 1+0

IV. Why this course?

Forages are the principal component of the animal feeding system and therefore their effective utilization is the key for efficient animal production.

V. Aim of the course

To impart knowledge on the fodder management including different forage production systems and their utilization.

VI. Theory

Unit I (10 Lectures)

Forages in ruminant production. Improvement in productivity of fodders and pasture: feed-food crops, silvi-pasture, horti-pasture, shrubs. Use of conserved forages in ruminant feeding. Factors affecting the nutritive value of cultivated and conserved forages. Hydroponics as an alternate to green fodder production.Top feeds, fodder trees and their effective utilization. Tree leaves as a source of condensed tannins: role in protein protection and GI parasite control.

Unit II (6 Lectures)

Methods in forage evaluation: calculated *in-vitro* DOMD and ME by using *in-vitro* gas production technique. Pasture consumption and evaluation studies.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Understanding of various aspects of forage production, fodder evaluation and their integration into the different animal production system.

IX. Suggested Reading

- Givens D, Axford R and Owen E. (Ed.). 2000. *Forage Evaluation in Ruminant Nutrition*. CAB International.
- McDowell RL. 2012. *Nutrition of Grazing Ruminants in Warm Climates*. Academic Press.
- Minson D. 1990. *Forage in Ruminant Nutrition*. Academic Press.
- Shirley RL. 2012. *Nitrogen and Energy Nutrition of Ruminants*. Academic Press.

I. Course Title : Recent Concepts in Feeding of Non-Ruminants

II. Course Code : ANN 703

III. Credit Hours : 1+0

IV. Why this course?

Increased consumer awareness has necessitated a relook into the feeding management of food animals leading to the production of safe and healthy food.

V. Aim of the course

To derive knowledge regarding the nutritional manipulation of food animals for the production of quality food for human consumption.

VI. Theory

Unit I (18 Lectures)

Latest concepts in nutrition and feeding in different phases of broiler, layer and breeder stocks. In-ovo and early chick nutrition. Nutritional disorders in modern poultry production and their amelioration. Nutritional factors affecting egg quality and hatchability in poultry. Feeding strategies for the production of designer eggs and meat. Omega fatty acids. Recent trends in amino acid nutrition. Advances in new generation feed and feed additives.

Unit II (14 Lectures)

Nutrition and feeding of pigs in various stages of production. Modern concepts in amino acids nutrition in swine production. Emerging concepts in feeds and feed additive for pigs. Role of vitamins and minerals in health and disease. Nutritional manipulation for lean meat and designer pork production. Carcass modifiers.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Comprehensive knowledge on the scope of nutritional management of non-ruminant animals for the production of healthy food.

IX. Suggested Reading

- Chiba LI (Ed.). 2012. *Sustainable Swine Nutrition*. Wiley-Blackwell.
- D'Mello JPF. 2003. *Amino Acids in Animal Nutrition*, 2nd ed. CAB International.
- Hendriks WH, Verstegen MWA and Babinszky L. (Eds.). 2019. *Poultry and Pig Nutrition: Challenges of the 21st Century*. Wageningen Academic Publishers.
- Leeson S and Summers JD. 2001. *Scott's Nutrition of The Chicken*, 4th ed. University Books.
- Lewis AJ and Southern LL. 2000. *Swine Nutrition*, 2nd ed. CRC Press.

I. Course Title : Advances in Rumen Metabolism

II. Course Code : ANN 704

III. Credit Hours : 1+1

IV. Why this course?

An in-depth of the understanding of the rumen function is key to devise strategies for augmenting the efficiency of production besides ensuring environmental sustainability.

V. Aim of the course

To understand the metabolic aspects of rumen function and its application for eco-friendly ruminant production.

VI. Theory

Unit I (8 Lectures)

Rumen development. Rumen microflora: classification and their role in fermentation and digestion, microbial interactions, rumen kinetics, the nutrient requirement of rumen microbes. Dynamics of nitrogen metabolism in the rumen.

Unit II (8 Lectures)

Manipulation of rumen fermentation: physical, chemical and biological approaches. Trans-faunation and defaunation. Concept of metagenomics in rumen manipulation. Green-house gas production from rumen and mitigation strategies

VII. Practical (16 Classes)

Rumen microbial and protozoal count. Estimation of rumen microbial protein. Estimation of nitrogen-fractions in rumen liquor. Volatile fatty acid fractionations. Rumen enzymes assay. Extraction of nucleic acids and quantification of rumen microbes by PCR.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

Comprehensive knowledge of various concepts of rumen metabolism for efficient ruminant production.

X. Suggested Reading

- Dehority BA. 2003. *Rumen Microbiology*. Nottingham University Press.
- Dijkstra J, Forbes J and France J. 2005. *Quantitative Aspects of Ruminant Digestion and Metabolism*. CAB International.
- Kebreab E, Dijkstra J, Bannink A, Gerrits W and France J. 2006. *Nutrient Digestion and Utilization in Farm Animals*. CAB International.
- Millen DD, Arrigoni MDB and Pacheco RDL. (Eds.). 2016. *Rumenology*. Springer Nature.
- Van Soest PJ. 1994. *Nutritional Ecology of the Ruminant*. Cornell University Press.

I. Course Title : Advances in Mineral and Vitamin Nutrition

II. Course Code : ANN 705

III. Credit Hours : 2+0

IV. Why this course?

Molecular mechanisms driving the metabolism of minerals and vitamins have opened up a new vista in the nutrition of farm animals.

V. Aim of the course

To understand advances in mineral and vitamin metabolism for its application in ensuring optimized health and efficient production in farm animals.

VI. Theory

Unit I (18 Lectures)

Role of minerals in nutrient metabolism. Mineral absorption, transport, metabolism and its regulation. Bio-availability of macro and micro minerals: factors affecting the bioavailability; bio-markers for mineral status. Mineral interactions. Dietary cation-anion difference (DCAD). Identification and correction of deficiencies and toxicities of minerals. Mineral tolerance in animals. Mineral requirements for growth, reproduction and lactation. Mineral toxicities concerning livestock feeding and their amelioration. Methods of mineral supplementation.

Unit II (14 Lectures)

Chemical nature of fat-soluble and water-soluble vitamins. Role of vitamins in nutrient metabolism. Advances in physiological functions and metabolism of vitamins. Vitamin deficiency: clinical signs and their management. Antimetabolites to vitamins. Hypervitaminosis. Vitamins as antioxidants. Role of vitamins in immunity and stress. Dietary supplementation of vitamins: forms, storage and stability.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Knowledge on the latest understanding of mineral and vitamins and its application in practical feeding conditions.

IX. Suggested Reading

- McDowell RL. 1989. *Vitamins in Animal Nutrition*. Academic Press.
- McDowell LR. 2003. *Minerals in Animal and Human Nutrition*, 2nd ed. Elsevier Science B.V.
- Suttle N. 2010. *The Mineral Nutrition of Livestock*, 4th ed. CAB International.

I. Course Title : Advanced Clinical Nutrition

II. Course Code : ANN 706

III. Credit Hours : 1+1

IV. Why this course?

Approaches involving preventive, therapeutic and convalescent nutrition have been recognized as a sustainable means of ensuring health and wellbeing of animals besides the production of safe and healthy food.

V. Aim of the course

To understand the disease-induced alterations in nutrient metabolism and the potential of select nutrients to prevent and/ or support disease management in prone animals.

VI. Theory

Unit I (12 Lectures)

Metabolic disorders in farm animals. Modern concepts in the metabolic alterations leading to production diseases, viz., milk fever, ketosis, downer cow syndrome, retained placenta, sub-acute ruminal acidosis, laminitis, abomasal displacement and mastitis Optimum nutrition for peri-parturient dairy animals.

Unit II (10 Lectures)

Metabolic effects of infection: metabolism of carbohydrates, fats, protein and amino acids and minerals during various infection and inflammatory diseases. Role of cytokines in nutrient homeorrhesis. Nutrition-immunity interaction: Role of nutrients (fats, amino acids, minerals and vitamins) in the immune response. Metabolic alterations during abiotic stress and feeding management during stress situations.

Unit III (10 Lectures)

Nutritional manipulation and feeding of sick and hospitalized animals. Preventive and therapeutic nutrition. Optimum nutrition for the management of diseases of the hepatic, renal and gastrointestinal system. Convalescence diet. Feeding management of pre- and post-operated animals.

VII. Practical (16 Classes)

Assessment of immunity: humoral immune response, cell-mediated immune response. Assessment of antioxidant status: Superoxide dismutase, Catalase, Glutathione peroxidase, reduced glutathione (GSH), lipid peroxides. Formulation of diet for sick and diseased animals.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

IX. Learning outcome

Understanding the potential of nutrition for prophylaxis and therapeutic purposes.

X. Suggested Reading

- Cheeke PR and Dierenfeld E. 2010. *Comparative Animal Nutrition and Metabolism*. CAB International.
- Constable P, Hinchcliff KW, Done S and Gruenberg W. 2016. *Veterinary Medicine*, 11th ed. Saunders Ltd.
- Naylor JM and Ralston SL. 1991. *Large Animal Clinical Nutrition*. Mosby Inc.
- Walker S, Beckett G, Rae P and Ashby P. 201. *Clinical Biochemistry: Lecture Notes*, 9th ed. Wiley-Blackwell

I. Course Title : Advanced Techniques in Nutritional Research

II. Course Code : ANN 707

III. Credit Hours : 1+1

IV. Why this course?

Cutting edge technologies in analytical science have revolutionized food science research.

V. Aim of the course

To become conversant with the use of advanced techniques in nutritional research.

VI. Theory

Unit I (16 Lectures)

Good laboratory practices. Analytical equipment in animal nutrition research. Estimation of minerals using atomic absorption spectrophotometer and ICP. Principles and applications and of GC, HPLC, amino acid analyzer, SF6, and electron microscopy. Remote sensing and geographic information system (GIS) in animal nutrition research. Analysis of feeds and fodders using NIR. Faecal inoculum as an alternative to rumen liquor for *in-vitro* studies.

VII. Practical (16 Classes)

RUSITEC. Estimation of minerals by atomic absorption spectrophotometer. Estimation of mycotoxins, oxalate, nitrates and tannin. Fatty acid analysis. Vitamin estimation.

VIII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments
- Hands-on training of laboratory techniques

VIII. Learning outcome

Skill development in terms of efficient use of modern analytical techniques related to animal nutrition research.

IX. Suggested Reading

- Kaneko J, Harvey J, Bruss M.(Eds.) 2008. *Clinical Biochemistry of Domestic Animals*, 6th ed. Academic Press.
- Krishna 2012. *Livestock Nutrition- Analytical Techniques*. New India Publishing Agency.

I. Course Title : Advances in Feed Technology

II. Course Code : ANN 708

III. Credit Hours : 1+0

IV. Why this course?

The translation of nutritional knowledge for its wider application involves industrial-scale technological adaptations.

V. Aim of the course

To understand the basic as well as applied aspects of various feed processing technologies.

VI. Theory

Unit I (10 Lectures)

Good manufacturer practices (GMP) in feed plants. Planning and designing of feed plants of different capacities. Recent developments in feed processing: particle size reduction, pelleting, extrusion, expanding, conditioning, micronizing. Post pelleting applications. Automation in feed processing. Flow charts for preparation of feeds for various species. Mixer efficiency test, pellet durability test. Densification of bulk feeds. Silos of various capacity, silage preparation and silage additives.Laws and regulations of the feed manufacturing industry. Introduction to labour laws and standards, planning and production programme. Record-keeping.

Unit II (6 Lectures)

Roughage processing. Whole plant processing. Solid-state fermentation technology. Preparation of complete feeds and its processing.Formulation of premixes. Carriers and diluents. Liquid feed handling. Latest concepts in feed microscopy. Qualitative tests for rancidity.

VII. Teaching methods

- Classroom lectures using audio-visual aids

- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Skill development in terms of increased employment and entrepreneurship

IX. Suggested Reading

- Langham J. 2013. *Recent Advances in Animal Feed Technology*. Random Exports.
- Moughan PJ and Hendricks WH. (Eds.). 2018. *Feed Evaluation Science*. Academic publishers.
- Perry TW, Cullison AE and Lowrey RS. 2003. *Feeds and Feeding*, 6th ed. Pearson.
- Schofield EK (Ed.). 2005. *Feed Manufacturing Technology V*. American Feed Industry Association, Arlington.

I. Course Title : Toxicants and Anti-Metabolites in Animal Nutrition

II. Course Code : ANN 709

III. Credit Hours : 1+0

IV. Why this course?

In-feed anti-metabolites in incriminating factor poses a threat not only to the animal health but also for human health and safe food production.

V. Aim of the course

To impart knowledge on the various toxicants and anti-metabolites in the feeding system and their amelioration.

VI. Theory

Unit I (12 Lectures)

Classification of toxicants in animal feeds. Plant origin toxicants, microbial origin toxicants, acquired toxicants (heavy metals, pesticide residues, drug residues), and their effects on animal health and production. Ameliorative measures. Detoxification of plant origin toxicants. Residual effects on animal products and the environment.

Unit II (4 Lectures)

Anti-metabolites in animal feedstuffs. Effects of anti-metabolites on animal health and production. Anti-vitamins

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Safe use of animal feed resources for ensuring food safety.

IX. Suggested Reading

- Cheeke PR and Shull LR. 1985. *Natural Toxicants in Feeds And Poisonous Plants*. AVI Publishing Company Inc.
- FAO. 2004. *Assessing Quality and Safety of Animal Feeds*. Food and Agriculture Organization of the United Nations, Rome.
- Gremmels JF (Ed.). 2010. *Animal Feed Contamination Effects on Livestock and Food Safety*. Woodhead Publishing Ltd.
- Keeler RF, Van Kampen KR and James LF. 1978. *Effects of Poisonous Plants on Livestock*. Academic Press.

- Knight AP and Walter R. 2001. *A Guide to Plant Poisoning of Animals in North America*. Teton NewMedia.
- Liner IE. 1980. *Toxic Constituents of Animal Food Stuffs*, 2nd ed. Academic Press.
- Osweiler G. (Ed.) 2011. *Ruminant Toxicology. An issue of Veterinary Clinics: Food Animal Practice*. Elsevier.

I. Course Title : Nutrigenomics in Animal Nutrition

II. Course Code : ANN 710

III. Credit Hours : 1+0

IV. Why this course?

The establishment of a functional relationship between nutrition and gene expression has become recognized as a tool to unravel the mechanisms involving the role of nutrition in health and disease.

V. Aim of the course

To impart the knowledge on the basics of nutrigenomics and its application in nutrition.

VI. Theory

Unit I (4 Lectures)

Basic concepts of genetics and molecular biology. Nucleic acid structure and replication, transcription and translation.

Unit II (8 Lectures)

Introduction to nutrigenomics and nutrigenetics. Nutritional regulation of gene expression. Introduction to epigenetics, and its influence on early life nutrition and health.

Unit III (4 Lectures)

Concepts of proteomics and metabolomics. Microbiome and diseases of nutritional importance. Dietary influences on the microbiome.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

Development of concepts on nutrigenomics.

IX. Suggested Reading

- Carlberg C, Ulven SM and Molnár F. 2016. *Nutrigenomics*. Springer
- Caterina RDE, Martinez, JA and Kohlmeier M.(Eds.) 2020. *Principles of Nutrigenetics and Nutrigenomics*. Elsevier Inc.
- Dodds JW and Laverdure DR. 2015. *Canine Nutrigenomics - The New Science of Feeding Your Dog for Optimum Health*. Dogwise Publishing.
- Select articles from Journals

I. Course Title : Equine Nutrition
II. Course Code : ANN 711
III. Credit Hours : 1+0

IV. Why this course?

Nutrition of equines calls for special attention considering their use for mankind.

V. Aim of the course

To impart a comprehensive knowledge on the nutrition of horses and other equids.

VI. Theory

Unit I (8 Lectures)

Digestive function and metabolism of nutrients. Nutrient requirements of equines in different physiological stages. Feed ingredient for horses. Digestive disorders.

Unit II (8 Lectures)

Feeding foal, yearlings, mares and stallions for production and reproduction. Feeding for performance and nutrient metabolism during exercise. Nutritional management of race-horses. Diet formulation for all classes of horses.

VII. Teaching methods

- Classroom lectures using audio-visual aids
- Instructional conversations and discussions
- Hands-on learning and assignments

VIII. Learning outcome

In-depth knowledge of equine nutrition including its application.

IX. Suggested Reading

- Frape D. 2010. *Equine Nutrition and Feeding*, 4th ed. Wiley-Blackwell.
- Geor R, Harris P and Coenen M (Eds). 2013. *Equine Applied and Clinical Nutrition*. Saunders, Elsevier.
- NRC. 2007. *Nutrient Requirements of Horses*, 6th Rev. ed. National Research Council. National Academy Press.
- Pagan JD. (Ed.). 2009. *Advances in Equine Nutrition IV*. Kentucky Nutrition Research.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Animal Production Sciences
– Livestock Production and Management

Preamble
(Livestock Production and Management)

Veterinarians with higher qualifications are increasingly being involved in devising means and methods of production. Temporal aspirations of knowledge seekers ought to be addressed through building knowledge and skill portfolio suiting the job market and thus enhancing the marketability of the veterinary post graduates.

At undergraduate level, veterinary students acquire comprehensive knowledge and skills in basic, para-clinical and clinical subjects required for performing multi-tasking role of a veterinarian. However, at post graduate level, in-depth knowledge of theory, practical aspects and research methodology in each subject is of paramount importance.

In this perspective the proposed course curriculum and syllabus in Livestock Production Management have been developed. There have been unprecedented advancements in all the branches of veterinary sciences including Livestock Production Management. The guiding principle of the proposed new approach is to impart comprehensive and practical knowledge by covering all important aspects of the subject area of study at Master's level. The new and restructured Post-Graduate syllabus in respect of LPM contain several innovative and practically applicable courses and extensively revamped course contents, viz., production aspects, business and entrepreneur ship skills, environment and climate change issues, behaviour and welfare aspects of animals, wildlife management and recycling of waste or wealth from waste, etc.

Apart from the existing syllabus 3 new PG course have been incorporated keeping in view of the demand

1. LPM-607 Companion animal production management
2. LPM-613 Livestock farm machinery management
3. LPM-615 Regional animal production management

Salient features of the M.V.Sc. courses

- To acquaint students on basic aspects of dairying in India comparing with developed countries, problems and prospects of dairying, detailed aspects of care and management of different categories of dairy cattle and buffaloes.
- To impart knowledge on various aspects of swine farming in India, principles of housing, breeding, feeding and health care of pigs, management practices at different stages of growth and economic pig production systems.
- To familiarize students on climate, weather, various climatic factors and their role in production and health of animals in both temperate and tropics, micro and macroclimatic conditions of animal house and assessing the heat tolerance of bovines.
- To acquaint students on principles of farm animal behaviour with regard to environmental influence, group formation, social behaviour and and behavioural adaptations under domestication.
- To acquaint with dog and cat breeds their feeding, breeding, health management and socialization.
- To acquaint students with the principles and concepts of wild life sanctuaries and national parks, classification of wild animals, role of authorities in conservation and

management of wild animals in captivity
- To familiarize students on principles of air and water hygiene with reference to impurities and inclusions of water, collection and disposal of waste from the animal house, modern techniques in manure disposal and biosecurity measures to be adapted for hygienic production of livestock products.
- To familiarize students on various aspects, viz., scope and limitations of integrated livestock farming system, recent approach and economic feasibility of different integration models for sustainable production
- To familiarize the students with various aspects of lab animals, problems and prospectus, principles of housing, breeding, feeding and health care of rabbits, rats, mice and guinea pigs, measures to reduce the mortality in young ones at different seasons.
- To acquaint students with knowledge in principles, planning, technical approach and preparing financial statement in Livestock Business Management and preparing projects for financing.
- To familiarize the students with different farm machines and milking machine, different parts and their functions for better utilization

New Ph.D. Courses

1. LPM-704 Livestock and Environment
2. LPM-705 Organic livestock production
3. LPM-706 Recent developments in welfare of farm animals
4. LPM-707 Entrepreneurship in livestock production
5. LPM-708 Precision livestock farming

Salient features of Ph.D. Courses

- To impart knowledge related to application of technologies that improve the efficiency of land use and feed use can mitigate the negative effects of livestock production on biodiversity, ecosystems and global warming. Technologies that increase livestock efficiency include improved breeds, improved grazing-land management, improved herd-health management, etc.
- To impart knowledge on key considerations, organic farming standards, certifying agencies, role of organic livestock farming in environmental protection and biodiversity enhancement and economics of organic livestock products.
- To familiarize students with the concept and practice of ethical livestock production and production from content ended animals - Animal Welfare Management
- To understand livestock entrepreneurship, concept, incubation centre, PPP prospective in animal husbandry sector, business communication, inter-personnel skills for establishing an enterprise.
- To educate the students with a concept of precision in livestock farming, implementation of sensor system, automation, use of software and analysis

Course Title with Credit Load
M.V.Sc. in Livestock Production and Management

Course Code	Course Title	Credit Hours
LPM 601*	Cattle and Buffalo Production Management	2+1
LPM 602*	Sheep and Goat Production Management	2+1
LPM 603*	Swine Production Management	1+1
LPM 604*	Climatology and Livestock Production	1+1
LPM 605*	Behaviour and Welfare of Farm Animals	1+1
LPM 606*	Equine Production Management	1+1
LPM 607*	Companion Animal Production Management	1+1
LPM 608	Farm Hygiene and Waste Management	1+1
LPM 609	Integrated Livestock Farming Systems	1+1
LPM 610	Management and Conservation of Wild and Zoo Animals	1+1
LPM 611	Laboratory Animal Production Management	1+1
LPM 612	Livestock Business Management	1+1
LPM 613	Livestock Farm Machinery Management	0+2
LPM 614	Poultry Farm and Hatchery Management	1+1
LPM 615	Regional Animal Production Management	1+1
LPM 691	Seminar	1+0
LPM 699	Research	30

*Core courses

Course Contents
M.V.Sc. in Livestock Production and Management

I. Course Title : Cattle and Buffalo Production Management

II. Course Code : LPM 601

III. Credit Hours : 2+1

IV. Why this course?

Important species of livestock are a source of employment and cater to nutritional demands and socio-economic upliftment of people.

V. Aim of the course

To acquaint students with basic aspects of dairying in India comparing with developed countries, problems and prospects of dairying, detailed aspects of care and management of different categories of dairy cattle and buffaloes.

VI. Theory

Unit I (2 Lectures)

Development of dairy industry in India and the world. Present status and future prospects of dairying in India and the world. SWOT analysis of the dairy sector in different agro-climatic zones. Production systems in vogue under Indian conditions. Breeds of cattle and buffalo with more emphasis on breeds of economic importance.

Unit II (6 Lectures)

Housing/ Shelter management. Housing and equipment requirements for different classes of cattle and buffaloes. Layout plans and construction details for different sized farms in different climatic zones of India. Ventilation and lighting systems in dairy farms.

Unit III (8 Lectures)

Feed and fodder resources used for feeding cattle and buffaloes. Scientific technique and regimen of feeding and watering of different categories of cattle and buffaloes. Feed and fodder requirements of different categories of cattle and buffaloes. Supply of green fodder round the year. Enrichment of poor quality roughages. Non-conventional feeding resources. Pasture management.

Unit IV (8 Lectures)

Traits of economic importance and their inter-relationships. Selection and methods of breeding. Reproduction management - Pre-natal and post-natal care and management of dams. Care of neonates and young calves. Management strategies for reducing mortality in calves, optimizing age at first calving and calving interval. Improving breeding efficiency of dairy animals.

Unit V (8 Lectures)

Farm management - Routine management practices and farm labour management. Milking management - Machine milking and hand milking. Clean milk production-Techniques of harvesting clean milk, cooling and transportation. Different laws and practices governing the dairy sector to produce quality products on par with international standards. Health management of dairy animals. Summer and winter management of dairy animals. Draughtability and management of draught animals.

VII. Practical (14 Classes)

Visits to different sized dairy farms and assessment of routine managemental practices. Analysis of various farm records for economic evaluation. Computation of practical and economical rations. Layout plans and housing details. Housing, milking, calf, heifer and adult management. Dairy Cattle and Buffalo judging and body condition scoring (BCS). Project preparation for commercial farms.

VIII. Teaching methods

Blackboard, ICTs, success stories, group discussions and farm visits

IX. Learning outcome

By the end of this course, the student will come out with practical knowledge of cattle and buffalo production management aspects, entrepreneurship skills.

X. Suggested Reading

- Arora SP. 1997. *Feeding of Dairy Cattle and Buffaloes*. Kalyani Publication.
- Dutta G. 1994. *Care and Management of Dairy Cattle and Buffaloes*, 3rd ed. ICAR.
- Flanders F and Gillespie J. 2015. *Modern Livestock and Poultry Production*, 9th ed. Delmar Cengage Learning Edition.
- Gupta PR. 2017. *Dairy India-2017*, 7th ed. Dairy India Yearbook, Thomson Press Ltd.
- ICAR. *Livestock Production and Management* - ICAR eCourse PDF eBook (online free).
- Phillips CJC. 2011. *Principles of Cattle Production*. CABI Publishing.
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
- Thomas CK, Sastry NSR and Ravikiran G. 2012. *Dairy Bovine Production*, 2nd ed. Kalyani Publishers.
- Tyler HD and Ensminger ME. 2006. *Dairy Cattle Science*, Pearson Prentice Hall Publishing.
- Selected articles from journals.

I. Course Title : Sheep and Goat Production Management

II. Course Code : LPM 602

III. Credit Hours : 2+1

IV. Why this course?

To know the production and management of small ruminants. Important species of livestock provide employment and supplementary income besides meeting the nutritional demands and are of commercial importance.

V. Aim of the course

To acquaint students on the status of sheep and goat farming in India, principles of housing and feeding, breeding management to improve the reproductive efficiency and detailed account on care and management of different classes of sheep and goat.

VI. Theory

Unit I (2 Lectures)

Population structure and importance. Sheep farming under different systems of management. Advantages and limitations of sheep and goat farming. Genetic resources of sheep and goats with special emphasis on breeds of economic importance.

Unit II (6 Lectures)

Shelter management. Housing and equipment requirements for different classes of sheep and goats. Designing feeders and waterers. Layout plans and construction details for different size farms in different agro-climatic zones of India.

Unit III (8 Lectures)

Feed and fodder resources for small ruminants. Common property resources (CPR's) and their management. Principles and systems of feeding and watering different categories of sheep and goat. Pasture utilization and improvement.

Unit IV (8 Lectures)

Breeding Management, Traits of economic importance and their inter-relationship. Breeding seasons. Selection of breeding animals. Methods of detection of heat, use of teaser, flushing, tupping. Estrous synchronization, Natural Service, artificial insemination and off-season breeding in small ruminants. Care and management of pregnant animals and breeding stock. Culling.

Unit V (4 Lectures)

Disease Management. Prevention and control measures including vaccination, deworming, dipping and spraying, etc. Transportation of small ruminants.

Unit VI (4 Lectures)

Meat, Methods of slaughter, dressing percentage. Wool: Shearing methods. Importance of wool, wool quality. Goat fibers: mohair, pashmina - Marketing of goat fibers/ wool. Milk, Milking, avoidance of goaty odour in milk, clean milk production and its therapeutic uses.

VII. Practical (14 Classes)

Visits to modern sheep and goat farms and critical analysis of various managerial practices under different conditions. Study of practical housing management. Diseases control management. Shearing management. Record keeping and economics of sheep and goat farming for mutton/ chevon, wool/ fibre and milk. Preparation of project for commercial farming. Daily and periodical farm operations. Dipping and vaccination.

VIII. Teaching methods

Blackboard, ICTs, success stories, group discussions and farm visits

IX. Learning outcome

By the end of this course, the students get practical exposure to different aspects of sheep rearing, production and management.

X. Suggested Reading

- Bhat PN and Khan BU. 2009. *Goat Production*. Studium Press (India) Pvt. Ltd.
- Bhatt PN and Arora CL. 2009. *Sheep Production*. Studium Press (India) Pvt. Ltd.
- Devendra C and McLeroy GB. 1982. *Goat and Sheep Production in Tropics*. Longman.
- Devendra C and Burns M. 1983. *Goat Production in the Tropics*. CABI Publishing.
- Gupta JL. 2006. *Sheep Production and Management*. BS Publ.
- ICAR. 2014. *Handbook of Animal Husbandry*, 3rd ed. ICAR.
- Jindal SK. 2013. *Goat Production and Health Management*. New India Publishing Agency.
- Kaushik SK. 2017. *Sheep Production*. ICAR Publ.
- Peacock CP. 1996. *Improving Goat Production in the Tropics: A Manual for Development Workers*, OXFam, UK.
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.

- Solaiman SG. 2010. *Goat Science and Production*. Wiley-Blackwell.
- *Selected articles from journals.*

I. Course Title : Swine Production Management

II. Course Code : LPM 603

III. Credit Hours : 1+1

IV. Why this course?

Majority of people are rearing pigs under traditional and small scale production.

V. Aim of the course

To impart knowledge on various aspects of swine farming in India, principles of housing, breeding, feeding and health care of pigs, management practices at different stages of growth and economic pig production systems.

VI. Theory

Unit I (2 Lectures)

Population dynamic, Economic contribution of pigs, Advantages and limitations of swine rearing, Systems of management. Breeds of economic importance.

Unit II (2 Lectures)

Housing and rearing systems. Housing and equipment requirements for different classes of swine, layout plans and construction for different sized farms.

Unit III (3 Lectures)

Feeding principles and nutritional requirement of different classes of swine. Feeding schedule for different classes of swine. Traditional and scientific methods of swine feeding.

Unit IV (4 Lectures)

Traits of economic importance and their interrelationship. Selection of breeding stock. Reproductive parameters of swine. Methods for detection of heat. Mating systems. Care and management of pregnant sows, piglets, growers and boar. Summer management in swine.

Unit V (3 Lectures)

Health Management, Prevention and control measures including sanitation, vaccination, deworming, etc. Piglet anaemia and its management.

Unit VI (2 Lectures)

Methods of slaughter, dressing percentage, Methods of marketing and transportation. Use of by-products from the swine industry

VII. Practical (14 Classes)

Visit modern piggeries and critical analysis of various types of managemental practices. Practical feeding and breeding management, disease control measures, Judging. Record-keeping. Economics of pig production. Formulation of economic rations for different classes of swine. Project formulation of commercial swine production.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

The students will come up with scientific principles, production and management techniques in swine production.

X. Suggested Reading

- Acharya RM and Puneet Kumar. 2017. *Pig Production*. Satish Serial Publishing, Delhi
- Beyno N. 2014. *Pigs: A Guide to Management*, 2nd ed. Replika Press Ltd.
- Boden E. 1995. *Swine Practice*. WB London.
- ICAR. 2014. *Hand Book of Animal Husbandry*, 3rd ed. ICAR
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
- Sharda DP. 2000. *Swine Production*. ICAR publication
- *Selected articles from journals.*

I. Course Title : Climatology and Livestock Production

II. Course Code : LPM 604

III. Credit Hours : 1+1

IV. Why this course?

This course is important to know the climatic changes that affect the health and production of livestock and vice versa.

V. Aim of the course

To familiarize students on climate, weather, various climatic factors and their role in production and health of animals in both temperate and tropics, micro and macroclimatic conditions of the animal house and assessing the heat tolerance of bovines.

VI. Theory

Unit I (4 Lectures)

Climatology and agro-climatic regions of India. Study of climatic factors and their measurement. Climatic stress in livestock (heat stress/ cold stress): effects, measurement and amelioration. Temperature-humidity index and thermo-neutral zone. Adaptation and acclimatization.

Unit II (4 Lectures)

Light: natural and artificial, photoperiod, mechanism of light action and responses. Application in livestock production.

Unit III (4 Lectures)

Performance of livestock introduced in different climates. Micro-climate modification in animal houses. Livestock and global warming.

Unit IV (4 Lectures)

Climate-resilient livestock production systems. Natural disasters-effects on livestock and mitigation measures.

VII. Practical (14 Classes)

Visit modern weather forecast stations. Assessment of climate: Microclimatic conditions within the animal house, Measurement of Temperature, Relative humidity, wind velocity and intensity of light. Ambient temperature. Construction of climographs and hythergraphs. Heat tolerance test in bovines.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits.

IX. Learning outcome

The student is expected to know the different climatic conditions and adaptations for better production and managing livestock.

X. Suggested Reading

- Collier RJ and Collier JL. 2012. *Environment Physiology of Livestock*. Wiley-Blackwell Co.
- Lal DS. 1998. *Climatology*. Sharda Pustak Bhavan, Allahabad.
- McDowell RE. 1972. *Improvement of Livestock Production in Warm Climates*. WH Freeman.
- Payne WJ and Wilson RT. 1999. *An Introduction to Animal Husbandry in the Tropics*. Blackwell Publishing, USA.
- Rainwater MCF. 1962. *Animal Climatology*. Indian Veterinary Research Institute, Izatnagar.
- Sejian V, Gaughan J, Baumgard L and Prasad C. 2015. *Climate Change Impact on Livestock: Adaptation and Mitigation*, 5th ed. Springer.
- Siddhartha K and Roger B. 1996. *Atmosphere, Weather and Climate*. ELBS.
- *Selected articles from journals.*

I. Course Title : Behaviour and Welfare of Farm Animals

II. Course Code : LPM 605

III. Credit Hours : 1+1

IV. Why this course?

Improving the behaviour of livestock for better productivity and welfare.

V. Aim of the course

To acquaint students on principles of farm animal behaviour concerning environmental influence, group formation, social behaviour and behavioural adaptations under domestication.

VI. Theory

Unit I (4 Lectures)

Introduction to Animal behaviour. Evolution of animal behaviour: Theories of animal behaviour. Importance of animal behaviour studies. Physiological basis of behaviour. Natural selection, proximate and ultimate causes, fitness, optimality theory, selfish genes, kin selection, and game theory. Influence of genetic, environmental and physiological influence. Daily and seasonal cycles of behaviour. Patterns of behaviour. Favourable and unfavourable behaviours of domestication.

Unit II (4 Lectures)

Ethogram construction for general behaviour management – interpretation - behaviour assisted animal management - flight zone, Animal learning and training-conditioning- operant and classical, animal behaviour based housing designs – Methods of studying animal behaviour- Vices – causes and prevention.

Unit III (2 Lectures)

Group formation. Social relationships like hierarchy and aggression, the process of socialization, locality and behaviour. Behavioural characters for management practices.

Unit IV (6 Lectures)

Animal welfare – concepts – animal rights – animal freedoms – animal welfare organizations Measurement of animal welfare: - indicators of animal welfare-improvement of animal welfare through selection- the welfare of livestock in commercial farms and captivity, environmental enrichment- Welfare of livestock during various management activities such as handling, transportation, etc., Legislation and regulations of animal welfare – welfare and economics.

VII. Practical (14 Classes)

Behavioural characters for managemental practices. Behavioural adaptations under domestication. Analysis of behaviour in relation to climate. Analysis of social behaviour. Preparation of ethogram (time budgeting).

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

The student will apply the understanding of animal behaviour to draw conclusions about animal welfare, Consider how common management practices for livestock influence behaviour and welfare, Interpret and critically evaluate scientific literature in the field of animal behaviour

X. Suggested Reading

- Agarwal VK. 2013. *Animal Behaviour* (Ethology) S. Chand and Company
- Albright JL and Arave CW. 1997. *The Behaviour of Cattle*. CAB International.
- Arora MP. 1995. *Animal Behaviour*. WB London.
- Benson BJ and Rollin BE. 2004. *The Well-being of Farm Animals: Challenges and Solutions*. Blackwell Publishing, USA.
- Bouenger EG. 1994. *Animal Behaviour*. WB London.
- Broom DM and Fraser AF. 2007 *Domestic Animal Behaviour and Welfare*, 4th ed. CABI.
- Fraser AF and Broom DM. 1990. *Farm Animal Behaviuor and Welfare*. CAB international
- Hafez ESE. 1969. *The Behaviour of Domestic Animals*, 2nd ed. Balliere, Timdall and Cassell.
- Houpt KA. 2018. *Domestic Animal Behavior for Veterinarians and Animal Scientists*. 6th ed. Wiley Blackwell.
- Kumar V. 1996. *Animal Behaviour*. WB London.
- Selected articles from journals.

I. Course Title : Equine Production Management
II. Course Code : LPM 606
III. Credit Hours : 1+1

IV. Why this course?

Equines are important sports and pack animals

V. Aim of the course

To make the students become familiarize with principles of housing, breeding, feeding and health care of different classes of horse, stable routines and measures to reduce the mortality in young ones at different seasons.

VI. Theory

Unit I (2 Lectures)

Scope of equine husbandry in India. Equine population dynamics. Types and classes in equines. Breeds of economic importance.

Unit II (2 Lectures)

Housing and stable management, behaviour, stable vices and their management

Unit III (4 Lectures)

Feeding and breeding of equines. Care and management of stallion, broodmare, pregnant mare and foal.

Unit IV (2 Lectures)

Stud farms, Race clubs, Race-horses and their care, training, exercising, doping and horsemanship.

Unit V (4 Lectures)

Foot care and dental care in equines. General health management and diseases control. Colic, equine azoturia - prevention and management. Regulatory acts in equine disease control and welfare.

Unit VI (2 Lectures)

Transportation, Laws governing the import and export of equines, Horse passport and trading

VII. Practical (14 Classes)

Visit institutional stables. Identification, ageing, soundness and selection. Passing of nasogastric tube, Shoeing and covering. Saddle fitting, Gaits of horses and horse colours.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of the course, the student gains knowledge on management practices of equine production

X. Suggested Reading

- Blanchard T, Varner D, Love C, Brinsko S, Rigby R and Schumacher J. 2002. *Manual of Equine Reproduction*. Mosby.
- Brown JH and Powell-Smith V. 1984. *Horse and Stable Management*. Blackwell Science.
- Frape D. 1986. *Equine Nutrition and Feeding*. Blackwell.
- Kacker RN and Panwar BS. 1996. *Text Book of Equine Husbandry*. Vikas Publ.
- Mills DS and Nankervis KJ. 1998. *Equine Behaviour: Principles and Practice*. Blackwell.
- Panwar BS and Yadav KN. 2010. *Equine Husbandry and Equestrian Sports*. IBDC Publishers.
- Pilliner S. 1994. *Care of the Competition Horse*. BT Batsford.
- Rose RJ and Hodgson DR. 2000. *Manual of Equine Practice*. WB Saunders.

I. Course Title : Companion Animal Production Management

II. Course Code : LPM 607

III. Credit Hours : 1+1

IV. Why this course?

To know the different practices of dog and cats

V. Aim of the course

To acquaint with dog and cat breeds their feeding, breeding, health management and socialization.

VI. Theory

Unit I (4 Lectures)

Various companion animals, evolutionary history, the process of domestication of dog and cat. Breeds of dogs and cats. Ownership. Selection of dog, cat and other companion animals. Dogs/ cat body: structure, movement and special senses.

Unit II (4 Lectures)

Reproduction and breeding management, care of newborn, weaning, reproductive problems of bitch/ queen, Socialization.

Unit III (4 Lectures)

Principles of the feeding of dog and cat, Feeding during different life stages and disease conditions, feeding behaviour, common nutritional problems and their preventive measures.

Unit IV (4 Lectures)

Basic Kennel and health management. Principles of training of dogs/ cats. Dog shows. Preparation for the shows, kennel clubs, important characters for judgment. Vaccination/ deworming schedules.

VII. Practical (14 Classes)

Recognizing various breeds. Handling and Restraining of dogs/ cats, Routine management practices of dogs/ cats. Detection of oestrus, mating, whelping/ kittening (through demonstration). Kennel/ cattery design and management. Hygiene of kennel/ pens. Licensing and identification of companion animals. Visit dog hostels and dog park/ shows.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and visits to kennels

IX. Learning outcome

By the end of the course, the student will be able to gain knowledge on different aspects of breeds and management of companion animals.

IX. Suggested Reading

- Case LP, Daristotle L, Hayek MG and Raasch MF. 2011. *Canine and Feline Nutrition: A Resource for Companion Animal Professionals*. 3rd ed. Mosby Elsevier Publishing.
- Chakrabarti A. 2006. *Train Your Dog: At Work and Show*, 2nd ed. Kalyani Publishers.
- Chakrabarti A. 2014. *Dogs their Care and Treatment*, 4th ed. Kalyani Publishers.
- Sharma MC, Pathak NN and Bhat PN. 1993. *Dogs, Breeding, Nutrition, Diagnosis, and Health Management*. CBS Publishers and Distributors.
- Smith FWK. 2012. *Veterinary Medical Guide to Dog and Cat Breeds*. Teton New Media, NY.
- Selected articles from journals.

I. Course Title : Farm Hygiene and Waste Management

II. Course Code : LPM 608

III. Credit Hours : 1+1

IV. Why this course?

Maintenance of farm hygiene and proper waste management promotes animal health

V. Aim of the course

To familiarize students on principles of air and water hygiene concerning impurities and inclusions of water, collection and disposal of waste from the animal house, modern techniques in manure disposal and biosecurity measures to be adapted for hygienic production of livestock products.

VI. Theory

Unit I (4 Lectures)

Animal air hygiene. Measure air pollutants and their sources. Factors affecting outdoor and indoor pollution. Methods to control these factors.

Unit II (4 Lectures)

Water Hygiene. Sources of drinking water-Impurities and inclusions. Hygienic requirements and standards for drinking water. Purification of water. Water conservation.

Unit III (4 Lectures)

Manure, Quantity of manure voided by domestic animals. Animal excreta a factor in the spread of disease. Hygienic and economic disposal of farm wastes. Drainage in livestock farms. Lagoons, Sewers, septic tanks, drains and traps.

Unit IV (2 Lectures)

Environmental protection act: Air (Prevention and control of pollution) act and water (Prevention and control of pollution) act.

Unit V (2 Lectures)

Factors affecting environmental pollution and their effect on livestock and livestock products for human consumption. Controlling measures thereof.

VII. Practical (14 Classes)

Assessment of air pollutants on animal health and production. Collection of water samples: Physical, chemical, bacteriological and microscopic examination. Bio-security measures. Modern techniques used in the disposal of farm wastes. Value-added products from farm wastes. Visit water filtration plants and study of filtration systems (rapid and slow-sand, etc.). Testing of drains in livestock farms.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of the course, the students know the practical knowledge and experiences in hygiene and waste management and control methods.

X. Suggested Reading

- Baba MD. 2007. *Environmental Changes and Natural Disasters*. New India Publ.
- Overcash MR. 1983. *Livestock Waste Management*. CRC Press.
- Thapliyal DC and Misra DS. 1996. *Fundamentals of Animal Hygiene and Epidemiology*. International Book Distr. Co.

I. Course Title : Integrated Livestock Farming Systems

II. Course Code : LPM 609

III. Credit Hours : 1+1

IV. Why this course?

To know the Integration of livestock farming systems which in turn helps improves the overall profitability of the livestock system.

V. Aim of the course

To familiarize students on various aspects, viz., scope and limitations of integrated livestock farming system, recent approach and economic feasibility of different integration models for sustainable production

VI. Theory

Unit I (4 Lectures)

Classification of livestock-based farming systems. Principles, Scope, drivers and tradeoffs in integrated livestock farming systems. Sustainability and ecological advantages of integrated livestock farming systems and their economic importance.

Unit II (4 Lectures)

Integration of various components of farming systems. Livestock-fish, arable farming, plantation crops and different livestock enterprises (cattle, buffalo, sheep, goat, pig, rabbit, poultry, beekeeping, silkworm, etc.) along with the bio-gas plant, FYM, vermicompost, solar and wind energy utilization

Unit III (4 Lectures)

New approach for changing farming systems in the light of global warming, carbon sequestration and mitigation of GHGs (reducing carbon and water footprints)

Unit IV (4 Lectures)

Project formulation and evaluation of various integrated livestock enterprises in light of reducing poverty, livelihood diversification, environmental sustainability and resource conservation.

VII. Practical (14 Classes)

Visit modern integrated livestock farming units. Critical analysis of different subunits, economic analysis and preparation of feasibility reports

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of the course, the students are expected to know with different integrated farming systems and their application in the field of their study.

X. Suggested Reading

- Ghosh B. 2007. *Integrating Crops and Livestock*, 1st ed. Gene-Tech Books.
- Little DC and Edwards P. 2003. *Integrated Livestock-fish Farming Systems*. FAO.
- Mukherjee TK, Moi PS, Panandam JM and Yang YS. (Eds.) 1992. *Integrated Livestock Fish Production Systems*. FAO/ IPT Workshop on Integrated Livestock-Fish Production Systems, University of Malaya, Kuala Lumpur.
- Raman KV and Balaguru T. (Eds.). 1992. *Farming Systems Research in India: Strategies for Implementation*. NAARM, Hyderabad.

- Rana SS. 2015. *Recent Advances in Integrated Farming Systems*. CSK HPKV, Palampur.
- Rangasamy A and Annadurai K. 2002. *Farming System in the Tropics*. Kalyani Publishers.
- Renard C. (Ed.). 1997. *Crop Residues in Sustainable Mixed Crop / Livestock Farming Systems*. CABI.
- Speirs M and Opsen O. 1992. *Indigenous Integrated Farming System in the Sahel*. World Bank.
- Sunil Kumar and DR Palsaniya DR and Kiran Kumar T. 2017. *Farming systems: Issues and Strategies*. Satish Serial Publishing, New Delhi.
- Selected articles from journals.

I. Course Title : Management and Conservation of Wild and Zoo Animals

II. Course Code : LPM 610

III. Credit Hours : 1+1

IV. Why this course?

The course is useful to know about the zoo, wild animals and their biodiversity conservation

V. Aim of the course

To acquaint students with the principles and concepts of wildlife sanctuaries and national parks, classification of wild animals, the role of authorities in conservation and management of wild animals in captivity.

VI. Theory

Unit I (2 Lectures)

Taxonomy and distribution of important Indian wild animals and birds – Ecology of wildlife sanctuaries and National parks - Principles and concepts of Zoo and captive wild animals- Status of forest in India - Biological and ecological basis of management of wildlife

Unit II (2 Lectures)

Rules and regulations of Zoo Authority of India - Wildlife protection act - Conservation of wild animals – feeding of captive animals and birds- Habitat Components-Cover, food, water, space and their development and conservation

Unit III (6 Lectures)

Wildlife health control - Population dynamics- and it’s manipulation Movements – Corridors, – Mortality - Predator and prey relationship - Human-animal conflict - Refuge rehabilitation

Unit IV (6 Lectures)

Principles for the protection of wild and zoo animals - Breeding seasons - Breeding characteristics – puberty - pregnancy - parturition - postnatal survival of the young. Social factors among various species. Miscellaneous management procedures. Wildlife Census methods- captive animal breeding

VII. Practical (14 Classes)

Visit wildlife sanctuary/ national park/ biosphere reserves/ conservation breeding centre and zoo. Restraining methods. Funding agencies for wildlife research and preparation of project proposals, Habitat analysis and design.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of the course, the students gain knowledge in zoo animals and wildlife management and conservation methods.

X. Suggested Reading

- Agrawal KC. 2000. *Wildlife of India: Conservation and Management*. Nidhi Publishers.
- Berwick SH and Saharia VB. (Eds.). 1995. *The Development of International Principles and Practices of Wildlife Research and Management*. Oxford University Press.
- Bobbins CT. 1983. *Wildlife Feeding and Nutrition*. Daya Publ. House.
- Giles RH, Jr. 1978. *Wildlife Management*. WH Freeman.
- Giles RH, Jr. 1984. *Wildlife Management Techniques*, 3rd ed. Wildlife Society, Washington, DC.
- Hosetti BB. 2005. *Concepts in Wildlife Management*, 2nd ed. Daya Publ. House.
- Saha GK and Mazumdar S. 2017. *Wildlife Biology: an Indian Perspective*. PHI Learning Pvt. Ltd.
- Santra AK. 2008. *Handbook on Wild and Zoo Animals: A Treatise for Students of Veterinary, Zoology, Forestry and Environmental Science*. International Book Distributing Co.
- Sinclair ARE, Fryxel JM and Caughley G. 2006. *Wildlife Ecology, Conservation and Management*, 2nd ed. Blackwell.
- Singh SK. 2005. *Text Book of Wildlife Management*. International Book Distributing Co.
- Wildlife (Protection) Act 1972 (as amended up to 1991). Natraj Publ.
- *Selected articles from journals.*

I. Course Title : Laboratory Animal Production Management

II. Course Code : LPM 611

III. Credit Hours : 1+1

IV. Why this course?

Laboratory animals are important components of research for conducting animal experiments.

V. Aim of the course

To familiarize the students with various aspects of lab animals, problems and prospectus, principles of housing, breeding, feeding and health care of rabbits, rats, mice and guinea pigs, measures to reduce the mortality in young ones at different seasons.

VI. Theory

Unit I (2 Lectures)

Importance of rabbit, rats, mice, hamster and guinea pigs as laboratory animals.

Unit II (4 Lectures)

Systems of housing, layout and design for laboratory animals house. Feeding management of laboratory animals. Feeding regimen, Types of diets.

Unit III (6 Lectures)

Production of laboratory animal models for various experiments. Management of specific pathogen-free, gnotobiotic and germ-free animals. Concepts related to the welfare of laboratory animals. Sanitary and hygienic measures. Common diseases and their control measures. Biosecurity measures. Transportation.

Unit IV (4 Lectures)

Breeding, growth, sexual maturity, mating, gestation, parturition, litter size, weaning. Selection of breeding stock for replacement.

VII. Practical (14 Classes)

Visit to laboratory animal house and critical analysis of various types of managerial practices. Handling and restraining of laboratory animals. Practical breeding methods. Disease control and special management. Ageing and identification. Economics of production.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and experimental lab visits

IX. Learning outcome

By the end of the course, the students get practical exposure on different experimental laboratory animals, their production and management.

X. Suggested Reading

- Anonymous.1993. *Rabbit Management*. IBH and Oxford
- Banday MT, Shrivastava HP and Hamdani H. 2014. *Rabbit Production and Management*. New India Publishing Agency.
- Chakrabarti A and Biswas S. 2014. *Rabbit Health and Production*. Kalyani Publishers.
- Hau J and Van Hoosier GL, Jr. 2002. *Handbook of Laboratory Animal Science*, 2nd ed. CRC Press.
- ICAR. 2014. *Hand Book of Animal Husbandry*, 3rd ed. ICAR, New Delhi.
- NRC. 2011. *Committee for the Update of the Guide for the Care and Use of Laboratory Animals. Guide for the Care and Use of Laboratory Animals*, 8th ed. National Research Council, National Academy Press, Washington, DC.
- Rao TKS, Chauhan IS and Chauhan A. 2018. *Handbook of Laboratory Animal Production Management*. Kalyani Publishers.
- Reddy DV. 2007. *Applied Nutrition: (Livestock, Poultry, Human, Pet, Rabbit and Laboratory Animal Nutrition)*. IBH and Oxford.
- Ronald N and Penman S. 1991. *A Manual for Small Scale Rabbit Production*. South Asia Publ.
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
- Selected articles from journals.

I. Course Title : Livestock Business Management

II. Course Code : LPM 612

III. Credit Hours : 1+1

IV. Why this course?

Study of livestock business management will improve marketing of livestock and livestock products and enhance the profitability

V. Aim of the course

To acquaint students with knowledge in principles, planning, technical approach and preparing financial statement in Livestock Business Management and preparing projects for financing.

VI. Theory

Unit I (3 Lectures)

Management principles, Planning Techniques, strategic planning, organization structure, co-ordination and controlling techniques, Approaches to management.

Unit II (5 Lectures)

Key economic concepts, factors of production, farm enterprises, cost of production, opportunity cost, value of production, gross margin, farm profit, net farm family income, substitution, and efficiency: return to scarce resources, risk. SWOT analysis for different livestock species and products, Livestock production economics, theory of supply and demand, production relationships, production function, cost input variables, profit maximization.

Unit III (4 Lectures)

Economics and the market, market intelligence, newer concepts in marketing, market research and opinion polling, advertising research, market surveillance, etc.

Unit IV (3 Lectures)

Marketing channels, Marketing of livestock and livestock products and laws governing them, Pricing strategies, supply chain management, marketing agencies.

VII. Practical (14 Classes)

Accounting records, fund flow statement, Cost and benefit analysis. Budgeting and control. Preparation of financial statements, depreciation accounting methods, trend and variance analysis, cost-volume profit analysis. Financial planning and forecasting. Estimation of working capital requirement. Break even analysis. Visit to livestock business firms and banks. Preparing projects for financing.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of course the students gain knowledge in planning and handling business records.

X. Suggested Reading

- Acharya RM and Kumar P. 2013. *Dairy Production and Business Management*. Satish Serial Publishing, New Delhi.
- Bardhan D. 2013. *Textbook on Livestock Economics, Marketing and Business*. Satish Serial Publishing House.
- Bhaskaran S and Mohanty S. 2007. *Marketing of Livestock and Livestock Products in India*. ICFAI University Press.
- Das N. 2009. *Forage for Sustainable Livestock*. Satish Serial Publishing House.
- Gangadhar KS. 2009. *Livestock Economics: Marketing, Business Management and Accountancy*. New India Publishing Agency.
- George RP and Raj Kamal PJ. 2015. *Farm Economics, Entrepreneurship and Marketing*. Satish Serial Publishing, New Delhi.
- Kahan D. 2008. *Economics for Farm Management Extension*. FAO, Rome.
- Koontz H and O'Donnel C. 1999. *Essentials of Management*. Tata McGraw Hill.
- Kotler P. 2000. *Marketing Management - Analysis, Planning and Control*. Prentice Hall of India.
- Maheswari SN. 1998. *Management Accounting*. Tata McGraw Hill.
- Massie JL. 1995. *Essential of Management*. Prentice Hall of India.

- Moran J. 2009. *Business Management for Tropical Dairy Farmers*. Land Links Publishing.
- Srinivasan NP. 1998. *Management Accounting*. Sterling Publications.
- Selected articles from journals.

I. Course Title : Livestock Farm Machinery Management

II. Course Code : LPM 613

III. Credit Hours : 0+2

IV. Why this course?

The course will facilitate effective utilization and maintenance of farm machinery with their practical knowledge.

V. Aim of the course

To familiarize the students with different farm machines and milking machine, different parts and their functions for better utilization

VI. Theory

Unit I (2 Lectures)

Visit to Instructional Livestock Farm Complex, Identification of various livestock farm machineries

Unit II (2 Lectures)

Familiarization with different parts and their functions of tractor and power tiller (for tillage implements for fodder land development).

Unit III (2 Lectures)

Irrigation of fodder field. Familiarization with different electric motors and diesel engines, use of sprinkler for irrigation.

Unit IV (2 Lectures)

Non-conventional energy source-Wind energy and its utilization in livestock farm.

Unit V (2 Lectures)

Post-harvest equipment/ machineries. Common terms used in harvesting of fodder crops; hay and forage harvesting equipment, mowers, field choppers, chaff cutters for silage making, different types of silos, forage harvesters, mechanical hay driers, conventional balers, hay stackers, straw combine.

Unit VI (2 Lectures)

Familiarization with different parts of milking/ shearing machines, handling, operation and cleaning after use, instruments used for milk packaging. Automatic feeders and waterers

Unit VII (2 Lectures)

Milk storing equipment, pasteurization equipment and transportation of milk, handling of equipment for preparation traditional milk products.

Unit VIII (2 Lectures)

Forage densifying machine/ Feed block machine and its use- preparation of complete feed block (CFB).

Unit IX (2 Lectures)

Visit to feed mill- use and maintenance of feed grinder and mixture machines in the farms. Visit milk processing unit

VII. Teaching methods

Practical demonstration of prescribed machinery in different farms/ processing plants

VIII. Learning outcome

By the end of course the students get knowledge on different farm machineries including milking machine.

IX. Suggested Reading

- Kutz M. 2007. *Handbook of Farm, Dairy, and Food Machinery*. William Andrew Inc.
- Malhotra K. 2012. *Handbook of Farm, Dairy, and Food Machinery*. Centrum Press.
- Selected articles from journals.

I. Course Title : Poultry Farm and Hatchery Management

II. Course Code : LPM 614

III. Credit Hours : 1+1

IV. Why this course?

Poultry rearing provides employment opportunities and is an important component of food security

V. Aim of the course

To impart knowledge on housing, flooring and management of poultry. They also learn incubation and hatching of eggs.

VI. Theory

Unit I (4 Lectures)

Poultry housing systems - cage vs floor system, litter management and lighting for poultry, rearing turkey, duck and quails, backyard poultry.

Unit II (4 Lectures)

Management of chicks, growing, laying and breeding flocks, broiler production, selection and culling of laying flocks. Health management. Management of birds during disease outbreaks.

Unit III (3 Lectures)

Procuring, care and pre-incubation storage of hatching eggs - Method of incubation, sanitation disinfection and management of hatchery. Biosecurity in poultry farms

Unit IV (2 Lectures)

Embryonic development and factors affecting fertility and hatchability of eggs.

Unit V (3 Lectures)

Chick sexing, packing and hatchery business - Transporting management of farm and hatchery waste.

VII. Practical (14 Classes)

Observation and recording of Poultry Farm management - Brooding of chicks; selection of laying flocks - Disease preventive measures - Selection and care of hatching eggs; incubator operation, fumigation and candling setting and hatching, packaging of chicks - Waste management - Marketing of products.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of the course, the students gain knowledge on poultry farm management, brooding and hatching management including health.

X. Suggested Reading

- Ensminger ME. 1992. *Poultry Science*. International Book Distr. Co.
- Hued LM. 2003. *Modern Poultry Farming*. Greenworld.
- Powell-Owen W. 2008. *Poultry Farming and Keeping*. Daya Books.
- Prasad J. 2005. *Poultry Production and Management*. Kalyani Publication
- Singh RA. 1996. *Poultry Production*. 3rd ed. Kalyani Publication

I. Course Title : Regional Animal Production Management

II. Course Code : LPM 615

III. Credit Hours : 1+1

The course content will be developed as per the need of the university

Course Title with Credit Load
Ph.D. in Livestock Production and Management

Course No.	Course Title	Credits
LPM 701*	Recent Developments in Large Ruminants Production Management	2+1
LPM 702*	Recent Developments in Small Ruminants Production Management	2+1
LPM 703*	Recent Developments in Swine Production Management	1+1
LPM 704*	Livestock and Environment	1+0
LPM 705*	Organic Livestock Production	1+0
LPM 706	Recent Developments in Welfare of Farm Animals	1+0
LPM 707	Entrepreneurship in Livestock Production	1+1
LPM 708	Precision Livestock Farming	1+1
LPM 709	Recent Developments in Poultry Production Management	2+1
LPM 791	Seminar-I	1+0
LPM 792	Seminar-II	1+0
LPM 799	Research	75

*Core courses

Course Contents
Ph.D. in Livestock Production and Management

I. Course Title : Recent Developments in Large Ruminants Production Management

II. Course Code : LPM 701

III. Credit Hours : 2+1

IV. Why this course?

Large ruminants are a source of employment and cater to nutritional demands and socio-economic upliftment of people.

V. Aim of the course

To know modern trends on housing, feeding, health and milking management in dairy bovines.

VI. Theory

Unit I (2 Lectures)

Present status of dairying in India *vis-à-vis* Global and south Asian scenarios, Production dynamics, Recent policy initiatives in dairy development. Conservation of indigenous germplasm

Unit II (4 Lectures)

Advances in housing management, viz., design, layout, construction materials, cost of construction suits to various agro-climatic zones of India. Low-cost houses for large ruminants. Ideal shelter management practices for better productivity, Advances in manure and waste disposal.

Unit III (6 Lectures)

Recent approaches in breeding and reproductive Management of dairy animals, Optimization of reproductive traits, Estrus synchronization, MOET, Sexed semen, Cloning and IVF.

Unit IV (4 Lectures)

Recent approaches in Feeding, Phased feeding, Transition period, Hydroponic fodder, Eco-feeding, standards for drinking water and water hygiene.

Unit V (4 Lectures)

Advances in health management of dairy animals, preventive measures for production-related diseases, bio-security measures, etc.

Unit VI (4 Lectures)

Milking management, automation, Sanitary and phytosanitary standards for the production of quality milk, post-harvest processing.

Unit VII (4 Lectures)

Establishing a Dairy Enterprise suitable for various economic strata with different sizes, SWOT analysis. Computerization of dairy enterprises, Best management practices.

Unit VIII (4 Lectures)

Advances in herd management and data analysis, Advances in the management aspects of buffaloes, salvaging of buffalo calves, Advances in work animal management.

VII. Practical (14 Classes)

Critical analysis of various types of managerial practices at farms. Preparation of layout and designs for construction of sheds of various sizes in different agro-climatic zones. Cost analysis of dairy bovine housing. Organization of milking machines. Dairy Cattle and Buffalo judging – BCS. Farm record analysis. Project report preparation for commercial dairy farms.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of the course, the student gain knowledge and experience in different aspects of advanced methods of large ruminants management in different fields of housing, feeding, breeding and milking of dairy animals.

X. Suggested Reading

- Clarence HE. 2007. *Dairy Cattle and Milk Production*. Daya Publ. House.
- Moran J and Chamberlain P. 2017. *Blueprints For Tropical Dairy Farming: Milk Production in Developing Countries*. CSIRPO Publishing.
- Moran J. 2013. *Tropical Dairy Farming: Feeding Management for Small Holder Dairy Farmers in the Humid Tropics*. Landlinks Press.
- Singh U, Kumar S, Kumar A, Deb R and Sharma A. 2013. *Advances in Cattle Research*. Satish Serial Publishing House, New Delhi.
- Thomas CK, Sastry NSR and Ravi Kiran. 2012. *Dairy Bovine Production*, 2nd ed. Kalyani Publishers.

I. Course Title : Recent Developments in Small Ruminants Production Management

II. Course Code : LPM 702

III. Credit Hours : 2+1

IV. Why this course?

Small ruminants are an important source of livelihood security to rural masses and study/ application of recent advances will improve the profitability of small ruminant rearing.

V. Aim of the course?

To familiarize the students with advanced methods of housing, feeding, breeding, reproduction and health management.

VI. Theory

Unit I (4 Lectures)

Relevance of small ruminants in the Indian economy. Population and production dynamics of small ruminants. Systems of rearing. Needs and possibilities for research in future.

Unit II (8 Lectures)

Recent approaches in breeding and reproductive management. Management during the breeding season, Mating seasons and their control. Recent approaches in reproductive biotechnologies, MOET, Cloning, transgenic, genomics and accelerated lambing.

Unit III (6 Lectures)

Recent approaches in feeding management, Pasture and grazing management, Phase feeding, Feed resources and feeding techniques under different systems.

Unit IV (6 Lectures)

Recent approaches in housing systems with reference to different agro-climatic zones and rearing systems.

Unit V (6 Lectures)

Prospects of management under stall-fed conditions, management of small ruminates during scarcity periods, Migratory pattern and flock management. Recent approaches in exploiting goat's, milk quality, safety and production aspects of dairy goats. Wool/ fibre production and its quality.

Unit VI (2 Lectures)

Recent approaches in health care management, Parasitic control in present ecological and environmental changes.

VII. Practical (14 Classes)

Critical analysis of various farm practices, Preparation of layout and designs for construction of sheds of various sizes in different agro-climatic zones. Cost analysis of housing. Organization of shearing. Sheep and goat judging – BCS. Farm record analysis. Disease control management. Scorecard and grading of wool. Project report preparation for commercial sheep and goat units.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

The students gain knowledge and experience on different advance management aspects of small ruminants.

X. Suggested Reading

- Devendra C and McLeroy GB. 1983. *Goat and Sheep Production in the Tropics*. Agrodok.
- Gupta JL. 2006. *Sheep Production and Management*. CBS.
- Jansen C and van den Burg K. 2004. *Goat Production in the Tropics*. 4th ed. © Agromisa Foundation, Wageningen.
- Karim SA. 2008. *Small Ruminant Production in India*. Satish Serial Publishing, New Delhi.
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
- Selected articles from journals

I. Course Title : Recent Developments in Swine Production Management

II. Course Code : LPM 703

III. Credit Hours : 1+1

IV. Why this course?

Study of recent developments will facilitate their application for better growth of the swine industry

V. Aim of the course

To impart knowledge on recent advances in the improvement of swine housing, feeding, reproduction and health management.

VI. Theory

Unit I (2 Lectures)

Trends in population and production in India and world, Production systems followed in developed countries.

Unit II (6 Lectures)

Recent approaches in improvement of economic traits, Prenatal and postnatal development, care of newborn, Growth, breeding and reproduction, analysis of mating systems, Farrowing and lactation.

Unit III (3 Lectures)

Strategic management measures in feeding, Phase feeding, Split sex feeding and individual feeding. Automatic feeding and watering techniques, Feed resources and feeding systems.

Unit IV (2 Lectures)

Recent approaches in housing, environmental physiology, summer management, approaches in manure management.

Unit V (2 Lectures)

Strategies to reduce mortality in different classes, common diseases, health management, Biosecurity measures.

VII. Practical (14 Classes)

Critical analysis of various types of managerial practices at farms. Preparation of layout and designs for construction of sties for the backyard and commercial piggeries. Judging and BCS, Farm record analysis. Preparation of Project report for commercial and backyard piggeries. Marketing Analysis

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of the course, the students will gain knowledge on modern aspects swine practices and management including health.

X. Suggested Reading

- Katingi E. 2012. *Raising Pigs – Manuals and Other Useful Resources*. ICARDA and ILRI Publications. https://livestockfish.cgiar.org/2012/06/13/raising-pigs-manuals-and-other-useful-resources/
- Selected articles from journals.

I. Course Title : Livestock and Environment

II. Course Code : LPM 704

III. Credit Hours : 1+0

IV. Why this course?

There is an urgent need for governments and institutions to develop and enact appropriate policies, at the national and international levels, that focus more on and account for livestock–environment interactions.

V. Aim of the course

To impart knowledge related to the application of technologies that improve the efficiency of land use and feed use can mitigate the negative effects of livestock production on biodiversity, ecosystems and global warming. Technologies that increase livestock efficiency include improved breeds, improved grazing-land management, improved herd-health management, etc.,

VI. Theory

Unit I (4 Lectures)

Effect of livestock on the environment- Role of ruminants in global warming, Slaughterhouse waste, Tannery waste, Stray and fallen animal impact. Strategies for mitigation of methane emission from the livestock sector, animal waste management. A life cycle assessment of the environmental impacts of livestock in different production systems.

Unit II (4 Lectures)

Effect of environment on livestock and quality of products: Heat and cold stress, Pollution, Heavy metals, Pesticide residues, etc., Management of micro and macro-environment with respect to animal well-being,

Unit III (4 Lectures)

Concept of Water, Carbon footprints and carbon sequestration of farm animals and products. Thermal load indices, Livestock comfort zones. Carbon trading, mechanisms and opportunities in the livestock sector.

Unit IV (4 Lectures)

Selection of breeds of livestock for hot climate. Recent advances in shelter management practices under the impending climate change scenario. Climate and reproduction. Environment and diseases.

VII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions.

VIII. Learning outcome

By the end of the course, the students gain knowledge about the interaction between livestock and the environment. They also acquire knowledge of the greenhouse effect and mitigation.

IX. Suggested Reading

- Cheeke PR. 1993. *Impacts of Livestock Production on Society, Diet/ health, and the Environment*. Interstate Publishers.
- FAO. 2009. *Livestock in the Balance*, FAO, Rome.
- ICAR. 2014. *Handbook of Animal Husbandry*. ICAR, New Delhi.
- Mudgal VD, Singhal KK and Sharma DD. 2003. *Advances in Dairy Animal Production*, 2nd ed. International Book Distributing Co.
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
- Sejain V, Naqvi SMK, Ezeji T, Lakritz J and Lal R. 2012. *Environmental Stress and Amelioration in Livestock Production*. Springer
- Sirohi SK, Walli TK, Singh B and Singh N. 2013. *Livestock Greenhouse Gas: Emissions and Options For Mitigation*. Satish Serial Publishing, New Delhi.
- Selected articles from journals

I. Course Title : Organic Livestock Production

II. Course Code : LPM 705

III. Credit Hours : 1+0

IV. Why this course?

Organic livestock production offers an effective means of satisfying consumer demand for healthy and safe foods and reducing the environmental pressure of agricultural production. There is a need to know the organic production of livestock products and by-products.

V. Aim of the course

To impart knowledge on key considerations, organic farming standards, certifying agencies, the role of organic livestock farming in environmental protection and biodiversity enhancement and economics of organic livestock products.

VI. Theory

Unit I (2 Lectures)

Historical background and origin, Organic livestock farming vis-a-vis conventional livestock farming, the current status of organic farming in India and world- objectives and importance of organic livestock farming. Opportunities and Problems of organic livestock farming in India.

Unit II (6 Lectures)

Key consideration, selection of animals, housing, feeding, breeding, health care, record keeping, processing and labelling and marketing. Conversion of livestock farm into an organic farm. ITKs used in organic livestock production.

Unit III (4 Lectures)

Organic farming standards in India and the world. IFOAM basic standards, WHO/ FAO Codex Alimentarius, NSOP of India, etc. Role of organic livestock farming in environmental Protection and biodiversity enhancement.

Unit IV (4 Lectures)

Accreditation of inspection and certification agencies. Organic certification mark. Guidelines for organic certification of livestock modalities in the certification of organic products. The economic value of organic livestock products, pricing strategy and marketing of organic products.

VII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions

VIII. Learning outcome

By the end of the course, the student will be acquainted with organic livestock production, economics and marketing of organic products.

IX. Suggested Reading

- Balasubramaniam R, Balakrishnan K and Sivasubramaniam K. 2013. *Principles and Practices of Organic Farming*. Satish Serial Publishing House, New Delhi.
- ICAR. 2014. *Handbook of Animal Husbandry*. ICAR, New Delhi.
- Paajanen T. 2011. *The Complete Guide to Organic Livestock Farming*. Atlantic Publishing Group Inc.
- Katherine M. 2009 *The Organic Dairy Handbook*. Northeast Organic Farming Association.
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.

- Singh M, Sharma DK and Mishra UK. 2011. *Organic Dairy Farming*. Satish Serial Publishing House, New Delhi.
- Selected articles from journals

I. Course Title : Recent Developments in Welfare of Farm Animals

II. Course Code : LPM 706

III. Credit Hours : 1+0

IV. Why this course?

Now there are big movements on ethical animal production all over the World. Hence a doctoral student of LPM has to be prepared on this issue too.

V. Aim of the course

To familiarize students with the concept and practice of ethical livestock production and production from content ended animals - Animal Welfare Management;

VI. Theory

Unit I (2 Lectures)

Ethology: species-specific behaviour, changing with the season, physiological condition of animals, as a guide to animal welfare; not driving animals beyond their natural capacity, for better performance;

Unit II (6 Lectures)

Amelioration of climatic stress and avoidance of unnecessary injury, pain and stress to animals in animal houses, during handling, before and during slaughter, carting bullocks, feeding, milking, shearing, transportation, etc., including deprivance of quality feeds and water; this being a common feature;

Unit III (4 Lectures)

Providing safety, healthcare, feed and water to unproductive animals let off to free roam and injured or orphaned pets, birds and others; monkeys being common – Good management of goshalas and safe shelters for such animals – Conversion of their wastes into VAP to meet part costs of running shelters; Education of the general public, especially children to avoid wanton harm to animals via *Lectures* in schools, TV and radio talks, leaflets, etc.

Unit IV (4 Lectures)

Evaluation of animal welfare measures as an 'instrument' of good animal husbandry, production of quality products and enhanced income to farmers.

VII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

VIII. Learning outcome

By the end of this course, the student will be familiarized with species-specific behaviour, amelioration of climatic stress and evaluation of animal welfare measures.

IX. Suggested Reading

- *Animal Rights and Animal Welfare Publications* 1896-2009. https://www.lib.ncsu.edu/findingaids/mc00440
- Appleby MC, Mench JA, Anna Olsson I and Hughes BO. 2018. *Animal Welfare*. CABI.
- AWBI. Animal Protection Laws, Newsletters, etc. of Animal Welfare Board of India; http://www.awbi.org/section/4/publications/2

- GoI Gazzete. *Order on Animal Welfare* - http://www.moef.nic.in/legis/awbi/awbi18.html
- Phillips C. 2009. *The Welfare of Animals*: *The Silent Majority*. Springer.
- Webster J. 2005. *Animal Welfare: Limping Towards Eden*. Blackwell Publishing.
- Selected articles from journals.

I. Course Title : Entrepreneurship in Livestock Production

II. Course Code : LPM 707

III. Credit Hours : 1+1

IV. Why this course?

Livestock production has huge scope vis a vis income generation. Study of concepts of entrepreneurship will ensure awareness towards the possibilities of taking livestock production as a business unit.

I. Aim of the course

To understand livestock entrepreneurship, concept, incubation centre, PPP perspective in the animal husbandry sector, business communication, inter-personnel skills for establishing an enterprise.

II. Theory

Unit I (2 Lectures)

Understanding livestock entrepreneurship, Concept and characteristics of Entrepreneurship, Role of entrepreneur in relation to enterprise, Functions of the entrepreneur in the economy,

Unit II (4 Lectures)

Process of entrepreneurship development. Barriers in entrepreneurship. The institutional interface in the development of entrepreneurship, incubation centres, startups, PPP Prospective in the animal husbandry sector.

Unit III (6 Lectures)

Essential criteria for the development of entrepreneurship in livestock sector - basic requirements for entrepreneurship initiatives in livestock and allied sectors (i.e. techno-economic feasibility of the enterprises under different conditions, training and management skills, business acumen, business communication, inter-personnel skills for establishing an enterprise, etc.).

Unit IV (4 Lectures)

Entrepreneurial training/ development programmes at the State and National level, Livestock Insurance, Bank and Government support for entrepreneurship, Financial credit and financial management: general principles and practices, analyzing project appraisals and reports, capital, expenditure decisions, reinvestment and payback.

Unit V (2 Lectures)

Preparing projects for bank appraisal, banking requirements, Assessing project profits, Procurement management quality issues, standardisation, grading and packaging.

III. Practical (14 Classes)

Visit incubation centres, extrapolation of existing financial models in livestock entrepreneurship, Approach to the preparation of Entrepreneurial Project on livestock, Bankable project for a dairy enterprise (small/ large dairy unit), Bankable project for a sheep/ goat/ Ram lamb enterprise, Bankable project for a pig-enterprise, Bankable project for a Broiler enterprise (small/ medium/ large unit), Bankable project for a layer-enterprise

IV. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

V. Learning outcome

The student acquires knowledge in entrepreneurship initiatives in livestock and allied sectors, financial management and assessment of project profit.

VI. Suggested Reading

- George RP and Raj Kamal PJ. 2015. *Farm Economics, Entrepreneurship and Marketing*. Satish Serial Publishing, New Delhi.
- Kahan D. 2012. *Entrepreneurship in Farming*. FAO, Rome.
- Zama MMS, Rashid M and Kumar S. 2014. *Handbook of Livestock Entrepreneurship*. Narendra Publishing House.
- *Selected articles from journals.*

I. Course Title : Precision Livestock Farming

II. Course Code : LPM 708

III. Credit Hours : 1+1

IV. Why this course?

Precision Livestock Farming is a combination of developing animal sensing (sensors) tools and decision-making process at the farm level. This information is very much needed for the students in the present technology of the world.

V. Aim of the course

To educate the students with a concept of precision in livestock farming, implementation of the sensor system, automation, use of software and analysis

VI. Theory

Unit I (2 Lectures)

Concepts of Precision Livestock Farming-Scope and limitations. Utilities of Precision tools in Livestock Farming, the present level of usage of precision tools in India

Unit II (6 Lectures)

Implementation of sensor systems and ICTs in animal health, productivity and welfare, Animal identification and tracking- Radio frequency identification (RFID), Livestock identification and traceback system (LITS), etc. Geo-tagging, Virtual fencing, GPS and GIS in the exploration of feeding resources and grasslands.

Unit III (6 Lectures)

Automation in water resource management. Development and evaluation of early warning and disease support systems for animal health and welfare.

Unit IV (2 Lectures)

Use of software's for database creation of the livestock farms, computation and analysis.

VII. Practical (14 Classes)

GPS/ GIS Application in the exploration of breeding tracts of livestock, forage and grassland profiles. Exposure visit to precision livestock farms with automation, use of tools in reproduction and health care, use of different software in farm routines.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of this course, the students will gain knowledge in precision livestock farming.

X. Suggested Reading

- Halachmi I. 2015. *Precision Livestock Farming Applications*. Wageningen Academic Pub.
- Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
- *Selected articles from journals.*

I. Course Title : Recent Developments in Poultry Production Management

II. Course Code : LPM 709

III. Credit Hours : 2+1

IV. Why this course?

The poultry industry is growing at a very fast rate. Students have to remain aware of the recent developments in the sector

V. Aim of the course

To educate the students on recent developments on the management of farms and hatcheries, egg, meat and policy developments in poultry.

VI. Theory

Unit I (8 Lectures)

Planning, organization, executive and management of poultry farms and hatcheries of various sizes - an alternative in poultry production

Unit II (4 Lectures)

Demand, supply, the present status of poultry production in India.

Unit III (10 Lectures)

Problems and new management techniques in poultry for egg and meat in India vis-à-vis in other countries of the world - Automation in poultry houses, management of specific pathogen-free flocks.

Unit IV (10 Lectures)

Poultry development policies and planning for higher production constraints in development and solutions, Ethology in relation to avian welfare in intensive poultry production.

VII. Practical (14 Classes)

Planning and preparation of research and commercial projects on broiler and layer production management.

VIII. Teaching methods

Blackboard, power point presentations, ICT, Group discussions and farm visits

IX. Learning outcome

By the end of this course, the student acquires knowledge in advances of modern poultry farm and hatchery management

X. Suggested Reading

- DAHD. 2015. *Poultry Farm Manual: A Reference Guide for Central and State Poultry Farms*. 2014-15. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India.
- FAO. 2003. Live bird marketing. In: *Egg Marketing - A Guide for the Production and Sale of Eggs*. http://www.fao.org/3/Y4628E/y4628e09.htm#bm9
- Sreenivasaiah PV. 2006. *Scientific Poultry Production: A Unique Encyclopaedia*. International Book Distribution Co.
- *Selected articles from journals.*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Animal Production Sciences
– Livestock Products Technology

Preamble
(Livestock Products Technology)

Salient features of revised courses

- Changed course numbers to bring desired sequence in the courses for better understanding. Revised and updated all courses to ensure practical and latest knowledge covering processing quality control and other aspects of livestock products.
- To give more emphasis on processing, packaging, quality control and marketing of livestock products, separate courses have been developed for processing, packaging and marketing, and quality control (earlier course no. was LPT 602, Now LPT 603, LPT 605, LPT 606). Many latest topics have been included in the revised courses.
- Topics related to poultry meat (earlier course no. LPT 603) are included along with other meat topic in LPT 601, LPT 603, LPT 605 and LPT 606). Separate course has been developed for Fish and Fish Products (LPT 613, optional).
- In abattoir course (LPT 605), contents related to meat plant operations are included as per requirement of industry, so that students get practical knowledge. Course number is changed to LPT 601 to bring desired change in sequence.
- In slaughter house byproducts course (earlier course no. was LPT 606, now LPT 607), all updated/ latest technologies/ processes have been included.
- Courses specifically related to milk, are re-casted. Separate course (LPT 604) is developed on Milk and milk products processing (after deleting processing content from old course - LPT 610). This ensures more emphasis on Market milk and dairy plant operations (LPT 610).
- Updated, revised and changed In-plant training course (LPT 612) to Industrial and Entrepreneurial Training course (LPT 608) and made it as a credit course.
- Advances in Fresh and Processed Meat Products Technology (LPT 702), is divided into two courses (LPT 702 and 703). Topics related to Meat production are also included in LPT 702.
- Contents of these two related courses (LPT 705 and 706, quality control and biotechnological tools) are merged and given in new course LPT 705. Topics are revised, updated and rearranged in other courses.
- Considering the entrepreneurship importance, changing trends of consumer preference for novel animal food products and requirement of the industry, and also to provide practical exposure and training to students, following new courses are proposed:
  1. LPT 706- Ethnic and Organic Meat and Milk Products (1+1)
  2. LPT 707- Industrial and Entrepreneurial Training (0+2)
  3. LPT 708- Current trends in Disposal and Utilization of Waste from Meat and Dairy Industry (1+1)
  4. LPT 709 Advances in Egg and Egg Products Technology (1+1)

Course Title with Credit Load
M.V.Sc. in Livestock Products Technology

Course No.	Course Title	Credits Hours
LPT 601*	Abattoir Practices and Meat Plant Operations	2+1
LPT 602*	Fresh Meat Technology	1+1
LPT 603*	Processing and Preservation of Meat	2+1
LPT 604*	Processing of Milk and Milk Products	1+1
LPT 605*	Packaging and Marketing of Livestock Products	1+1
LPT 606*	Microbiology and Quality Control of Livestock Products	1+1
LPT 607*	Slaughterhouse By-products Technology	1+1
LPT 608	In-Plant Training	0+2
LPT 609	Egg and Egg Products Technology	1+1
LPT 610	Market Milk Processing and Dairy Plant Practices	1+1
LPT 611	Processing and Marketing of Wool	1+1
LPT 612	Biotechnology of Foods of Animal Origin	1+1
LPT 613	Fish and Fish Products Technology	1+1
LPT 691	Seminar	1+0
LPT 699	Research	30

*Core courses

Course Contents
M.V.Sc. in Livestock Products Technology

I. Course Title : Abattoir Practices and Meat Plant Operations

II. Course Code : LPT 601

III. Credit Hours : 2+1

IV. Why this course?

Human Resource Development (Manager, Supervisor, Meat inspector and other Technocrats) for Slaughterhouses and Meat processing plants.

V. Aim of the Course

To impart knowledge about the handling of meat animals, layout and design of abattoir, sanitation and basics of slaughterhouse practices and meat plant operations.

VI. Theory

Unit I (12 Lectures)

Handling and transportation of meat animals including poultry - Pre-slaughter handling and care of food animals – Ante-mortem inspection - Humane slaughter - Principles and methods of stunning - Ritual methods of the slaughter of food animals and poultry - Machinery for slaughter and dressing of food animals - Post-mortem inspection - Handling, disposal and condemnation of unfit materials.

Unit II (11 Lectures)

Abattoir - layout, designing, organization and operation - Maintenance of meat and poultry processing plants - Record keeping - Legislations and regulations for establishment and operation of slaughterhouses and meat processing plants.

Unit III (11 Lectures)

Sanitation of slaughterhouse - Sanitary practices in meat plant and its benefits - Solid and liquid waste management of slaughterhouse - Different methods of effluent treatment and designs of effluent treatment plants - State and Central Pollution Control Board norms.

VII. Practical (17 classes)

Design and outlay of modern abattoir including poultry processing and effluent treatment plants for different capacities - Judging and grading of food animals - Procedure for the slaughter of food animals and poultry - Ante-mortem and post-mortem inspection - Recording of carcass data - carcass yield, meat bone ratio, etc. - Measurement of effluent characteristics - pH, BOD, COD, suspended solids, etc. - Visit slaughterhouse, poultry processing and effluent treatment plants - DPR for the establishment of an abattoir.

VIII. Teaching methods

- Classroom teaching, practical demonstration in Divisional laboratory/ slaughter unit.
- Visit municipal slaughterhouse and meat plants.
- Demonstration of charts, video films and models.

IX. Learning Outcome

Gaining knowledge of abattoir practices and operations to be carried out in meat plants.

X. Suggested Reading

- Collins DS and Huey RJ. 2015. *Gracey's Meat Hygiene*, 11th Ed. John Wiley and Sons Ltd., UK.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences* Vol. I, II and III, 1st ed. Elsevier Academic Press, UK.
- Kerry J, Kerry J and Ledward D. 2005. *Meat Processing- Improving Quality*. Woodhead Publishing Ltd., UK.
- Sahoo J, Sharma DK and Chatli M. 2011. *Practical Handbook on Meat Science and Technology*, 1st ed., Daya Publishing House.
- Swatland HJ. 2004. *Meat Cuts and Muscle Foods*. Nottingham Univ. Press.
- Warriss P. 2010. *Meat Science: An Introductory Text*, 2nd ed. Oxford Press.

I. Course Title : Fresh Meat Technology

II. Course Code : LPT 602

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development for Meat processing Sector

V. Aim of the Course

To impart knowledge about the status of the meat industry, muscle structure and composition, carcass handling, grading and fabrication.

VI. Theory

Unit I (10 Lectures)

History, current development and prospects of meat and poultry industry in India – Skeletal muscle development – pre- and post-natal- Structure and chemistry of muscle including poultry – Muscle Proteins - sarcoplasmic and myofibrillar proteins – Stromal proteins – Types of muscle fibres - Post mortem changes – Rigor mortis - Conversion of Muscle to meat - Pre and post-slaughter factors affecting meat quality – Defects during the conversion of muscle to meat – PSE/ DFD/ Cold Shortening – Off odour development.

Unit II (7 Lectures)

Composition and nutritive value of meat and poultry - Qualities of fresh meat – pH, WHC, colour, odour, juiciness, texture/ tenderness and firmness - Chilling, ageing and conditioning of meat - Electrical stimulation - Carcass evaluation, grading and fabrication- Tenderization of meat.

VII. Practical (17 Classes)

Evaluation/ estimation of physicochemical properties of fresh meat pH, colour, water holding capacity, ERV, shear force value, glycogen, R-value and myoglobin - Proximate analysis of meat - Estimation of drip loss - Determination of sarcomere length, fibre diameter and myofibrillar fragmentation index - Fractionation of sarcoplasmic, myofibrillar and stromal proteins - Carcass evaluation and grading - Meat cutting, retail and wholesale cuts.

VIII. Teaching methods

- Classroom teaching, practical demonstration and analysis in Divisional laboratory/ slaughter unit.
- Visit slaughterhouses, meat plants and retail units
- Use of Audio-visual Capsules.

IX. Learning Outcome

Acquiring knowledge on quality attributes of fresh meat, factors affecting these attributes, composition and nutritive value of meat.

X. Suggested Reading

- Aberle ED, Forest JC, Gerrard DE and Mills E. 2013. *Principles of Meat Science*, 5th ed., Kend All/ Hunt Publishing Company, IOWA.
- Bender A. 1992. *Meat and Meat Products in Human Nutrition in Developing Countries*. FAO, Rome.
- Carlson CW, Greaser ML and Jones KW. 2001. *The Meat We Eat*, 14th ed. Interstate Publishers, INC.
- Jensen WK, Devine C and Dikeman M. 2004. Encyclopaedia of Meat Sciences Vol. I, II and III, 1st ed. Elsevier Academic Press, UK.
- Lawrie RA and Ledward DA. 2006. *Lawrie's Meat Science*, 7th ed. Woodhead Publishing Limited, Cambridge, England.
- Pearson AM. 1994. *Quality Attributes and their Measurement in Meat, Poultry and Fish Products*. Springer, New York.
- Swatland HJ. 2004. *Meat Cuts and Muscle Foods*. Nottingham University Press.

I. Course Title : Processing and Preservation of Meat

II. Course Code : LPT 603

III. Credit Hours : 2+1

IV. Why this course?

Human Resource Development for Meat and Poultry Processing Industry and Entrepreneurship development

V. Aim of the Course

To impart knowledge about processing and preservation of meat including poultry meat, fundamentals of sensory evaluation and techniques for sensory evaluation of meat products.

VI. Theory

Unit I (8 Lectures)

Basic principles of meat preservation – dehydration, chilling, freezing, freeze-drying, thermal processing, direct microbial inhibition, irradiation, use of chemicals and antimicrobials - Curing and smoking - Hurdle technology concept.

Unit II (17 Lectures)

Principles of Meat Processing - Meat and non-meat ingredients and their roles - Additives - Processing techniques - comminution, chopping, blending, marination, massaging, tumbling, etc. - Cooking methods including microwaving – Development of meat products including ham, bacon, tandoori and barbeque - Emulsion formation – factors affecting emulsion formation - Emulsion based meat products - sausages, nuggets and patties - Enrobed, restructured, fermented and intermediate moisture meat products – Ready-to-cook, ready-to-eat and shelf-stable meat products - Canned and retort meat products – Traditional and ethnic meat products - Functional meat products.

Unit III (9 Lectures)

Sensory evaluation – Sensory physiology, types, methods, quality attributes - Factors influencing sensory measurements - Types of sensory panels - Selection of sensory panellists- Sensory evaluation tests- Layout and designing of sensory evaluation laboratory.

VII. Practicals (17 Classes)

Estimation of tyrosine value, nitrite content, TBARS value, peroxide value - Preparation of Meat Products - Minced meat products - Emulsion based meat products – sausages, nuggets and patties - Ham and Bacon - Meat Pickles – Enrobed, restructured, fermented and shelf-stable meat products - Canned/ retorted Meat Products - Traditional and ethnic Meat Products - Kebabs - Sensory evaluation of meat products - Subjective and objective method of sensory evaluation - differential, descriptive, training tests, etc. – Test practices and training in the sensory lab - Determination of emulsion stability - Cooking yield - Texture Profile Analysis.

VIII. Teaching methods

- Classroom teaching, practical performance in Divisional Pilot Processing Plant.
- Visit of Meat and Poultry Processing Unit.
- Demonstration videos

IX. Learning Outcome

Theoretical and practical understanding of meat preservation, processing and sensory evaluation of the meat products.

X. Suggested Reading

- Aberle ED, Forest JC, Gerrard DE and Mills E. 2013. *Principles of Meat Science*, 5th ed. Kendall Hunt Publishing Company, Iowa.
- Amerine MA, Pangborn RM and Roessler EB. 1965. *Principles of Sensory Evaluation of Food*. Academic Press, New York.
- Barbut S. 2005. Poultry Products Technology. CRC Press.
- Carlson CW, Greaser ML and Jones KW. 2001. *The Meat We Eat*, 14th ed. Interstate Publishers, INC.
- Kerry J, Kerry J and Ledward D. 2005. *Meat Processing- Improving Quality*. Woodhead Publishing Ltd., UK.
- Lawless HT and Heymann H. 2010. *Sensory Evaluation of Food - Principles and Practices*, 2nd ed, Springer-Verlag, New York Inc.
- Mountney GJ and Parkhurst CR. 2017. *Poultry Products Technology*, 3rd ed. Food Products Press, New York.
- Pearson AM and Gillett TA. 1996. *Processed Meats*, 3rd ed. Chapman and Hall, Inc, New York.
- Sharma BD, Wani S and Sharma N. 1997. *Sensory Evaluation Manual for Meat and Meat Products*. IVRI Publication.
- Toldrá F. 2010. *Handbook of Meat Processing*. Wiley-Blackwell.

I. Course Title : Processing of Milk and Milk Products

II. Course Code : LPT 604

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for Milk Processing Industry, Cooperatives, etc.

V. Aim of the Course

To impart knowledge about the organization of dairy plants, basic milk operations, cleaning and sanitization of milk processing plants, milk products processing and applications of membrane technologies in dairy industries.

VI. Theory

Unit I (6 Lectures)

Basic concepts of dairy plant organization and operation - collection, chilling, transportation - Heat treatments of Milk - Cleaning and sanitization of Dairy plants - Composition, nutritional, physico-chemical and functional properties of milk - Standards for milk and milk products.

Unit II (7 Lectures)

Manufacture of milk products - Flavoured Milk - Drying of milk and milk products - Evaporated and condensed milk - Milk powders – Butter - Ice cream and other frozen desserts - Manufacture of different fermented milk products - Manufacture of cheddar, mozzarella, cottage and processed cheese - Manufacture of indigenous milk products – paneer, channa, khoa, ghee, dahi and shrikhand - Rheology of milk products - Dairy by-products.

Unit III (4 Lectures)

Membrane filtration technology- principles and concepts - Manufacturing and functional properties of casein - Caseinates- Co-precipitates - Whey protein concentrates (WPC) - Lactose- Dairy whiteners.

VII. Practical (17 Classes)

Platform tests - Determination of fat, SNF, TS, protein, lactose and ash contents of milk - Preparation of butter, ice cream, cheese – cheddar, mozzarella and cottage cheese, khoa, paneer, channa, ghee, dahi, yoghurt, casein, caseinate, co-precipitate, flavoured milk - Determination of degree of browning - Measurement of rheological properties of different milk products - Evaluation of sensory quality of milk and milk products - Visit dairy plants.

VIII. Teaching methods

- Classroom teaching and laboratory practical.
- Visit the milk processing plant.
- Use of Audio-visual Capsules

IX. Learning Outcome

Gaining knowledge of handling and processing of milk and milk products.

X. Suggested Reading

- Aneja RP, Mathur BN, Banerjee AK and Chandan RC. 2002. *Technology of Indian Milk Products*. Dairy India.

- Chandan RC, Kilara A and Shah NP. 2008. *Dairy Processing and Quality Assurance*, 1st ed. Willey–Blackwell.
- Davis JG. 2010. *Milk Testing: A Laboratory Control of Milk*. Agribios.
- MIF. 2005. *Analysis of Milk and its Products: A lab Manual,* 2nd ed. Milk Industries Foundation. Biotech Books, Delhi
- Singh S. 2014. *Dairy Technology,* Vol. 1 and 2. New India Publishing Agency.
- Spreer E. 1993. *Milk and Dairy Products*. Marcel Dekker.
- Varnam AH and Sutherland JP. 1994. *Milk and Milk Products Technology*. Chapman and Hall, UK.
- Walstra P, Wouters JTM and Geurts, TJ. 2006. *Dairy Science and Technology*, 2nd ed. Taylor and Francis Group.
- Web BH, Johnson AH and Alford JA. 1987. *Fundamental of Dairy Chemistry*, 3rd ed. Westport AVI Publ.

I. Course Title : Packaging and Marketing of Livestock Products

II. Course Code : LPT 605

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor, Marketing Executives and other Technocrats) for Packaging Industry and Business Planning.

V. Aim of the Course

To impart knowledge about properties of different packaging material, techniques used in packaging of different livestock products, marketing channels and value chain of processed products.

VI. Theory

Unit I (10 Lectures)

Principles of packaging - objectives and functions - Product characteristics affecting packaging requirements - Packaging materials and their characteristics - Different packaging systems for fresh, cured, dehydrated, freeze-dried and shelf-stable products of milk, meat and chicken - Aseptic packaging of milk - UHT milk - Vacuum packaging – MAP and role of different gases - Retort pouch processing - Active and intelligent/ smart (biosensors) packaging - Edible and biodegradable packaging - Nanotechnology for food packaging - Recycling of packaging materials - Labelling requirements – Barcoding and its importance - Packaging standards and regulations – Economics of different packaging systems.

Unit II (7 Lectures)

Marketing of Livestock Products - Types of markets - Marketing channels of live meat animals and Poultry - Existing systems - constraints and possible solutions - Value Chain of meat, poultry and processed products - strategies and interventions for better profitability – Meat retailing and establishment of retail outlets for meat and poultry - FSSAI, APEDA, EIA, GOI/ WTO regulations for the domestic market, import and export of livestock products.

VII. Practical (17 Classes)

Different packaging materials and their properties - Determination of thickness, bursting strength, piercing strength, water vapour transmission rate, gas transmission rate, headspace gas analysis - Vacuum, shrink, MAP and retort packaging of meat and milk products - Visit milk and meat processing plants - Study of the value chain of livestock products including online marketing.

VIII. Teaching methods

- Classroom teaching, Practical demonstration in the laboratory.
- Visit market and packaging units.
- Demonstration using video films and models.

IX. Learning Outcome

Developing an understanding of packaging and marketing of livestock products.

X. Suggested Reading

- Aberle ED, Forrest JC, Gerrard DE and Mills EW. 2013. *Principles of Meat Science*, 5th ed. Kendall Hunt Publishing Company, Iowa.
- Fuquay JW, Fox PF and McSweeney PLH. 2011. *Encyclopaedia of Dairy Sciences*, 2nd ed. Elsevier Academic Press, UK.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences,* Vol. I, II and III, 1st ed., Elsevier Academic Press, UK.
- Robertson GC. 2012. *Food Packaging- Principles and Practices*, 3rd ed. CRC Press.
- *Selected Articles from Journals.*

I. Course Title : Microbiology and Quality Control of Livestock Products

II. Course Code : LPT 606

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development for Quality Control of Livestock Products

V. Aim of the Course

To develop an understanding about microbial spoilage of different livestock products, quality control and legal standards.

VI. Theory

Unit I (9 Lectures)

Microorganisms associated with spoilage of livestock products - Factors affecting microbial growth - Contamination of livestock products - Microbial spoilage of meat, poultry, eggs, milk and their products - Physical and chemical changes produced by microbes in milk, meat, eggs and their products - Meat and milk-borne infections and intoxications - Control of microbial growth in livestock products - Antimicrobial resistance (AMR).

Unit II (8 Lectures)

Introduction to Good Laboratory Practices (GLP), Good Hygienic practices (GHP) and Good Manufacturing Practices (GMP), Sanitary and Phytosanitary measures (SPS) and Food Safety System Certification (FSSC) - Quality Control – Quality Assurance - principles and practices - Quality Management Systems – Food Safety and Standards Act (FSSAI, 2006 Act) - Codex regulation for food products safety - ISO 9001 - ISO 22000 - HACCP concepts - Risk-based quality assessment - Microbial quality control - FSSAI/ BIS standards for milk, meat and poultry, Chemical residues in livestock products and their effects on the health of the consumer.

VII. Practical (17 Classes)

Basic requirements for setting up of quality control laboratory - Sampling methods for the microbiological examination of different processing plants, products and equipment - Development of HACCP plan for milk and meat processing plants - Microbial evaluation of market samples of milk, meat and egg – Total Viable Count, coliform, etc. - Pathogens of Public Health importance - *E. coli, Salmonella, Staphylococcus aureus, Campylobacter* - Rapid detection methods of food pathogens.

VIII. Teaching methods

- Classroom teaching with laboratory analysis.
- Sampling and survey of market, butchers shop, milk and meat processing plants.
- Visits to units having HACCP and ISO certification.

IX. Learning Outcome

Acquiring knowledge on microbiology, quality control and legal standards for different livestock products.

X. Suggested Reading

- Aberle ED, Forrest JC, Gerrard DE and Mills EW. 2013. *Principles of Meat Science*, 5th ed. Kendall Hunt Publishing Company, Iowa.
- Bell C, Neaves P and Williams AP. 2005. *Food Microbiology and Laboratory Practices*, 1st ed. Blackwell Publishing.
- Collins DS and Huey RJ. 2015. *Gracey's Meat Hygiene*, 11th ed. John Wiley and Sons Ltd., UK.
- Frazier WC and Westhoff DC. 2013. *Food Microbiology*, 5th ed. McGraw Hill Publication.
- Fuquay JW, Fox PF and McSweeney PLH. 2011. *Encyclopaedia of Dairy Sciences*, 2nd ed. Elsevier Academic Press, UK.
- Jay JM, Loessner MJ and Golden DA. 2006. *Modern Food Microbiology*, 7th ed. Springer.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences,* Vol. I, II and III, 1st ed., Elsevier Academic Press, UK.
- Kerry J, Kerry J and Ledward D. 2005. *Meat Processing-Improving Quality*. Woodhead Publishing Ltd., UK.
- Pearson AM and Dutson TR. 1995. *Quality Attributes and their Measurement in Meat, Poultry and Fish Products*. Aspen Publishers, Inc, Maryland, USA.

I. Course Title : Slaughterhouse By-products Technology

II. Course Code : LPT 607

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development for better utilization of animal by-products and pollution control

V. Aim of the Course

To impart knowledge about the utilization and processing of animal by-products.

VI. Theory

Unit I (6 Lectures)

Status and scope of slaughterhouse by-products utilization - Trade practices - Planning, design and layout of by-products plant - Classification of by-products - edible and inedible - Rendering methods and products - Yield and characteristics of rendered fat and meat cum bone meal.

Unit II (6 Lectures)

Utilization of blood, horns and hooves, intestine, bones, feathers, bristles, glandular by-products and ruminal contents - Value-added by-products from slaughterhouse and poultry processing plants - Processing of animal by-products for pet foods - High-value low volume by-products – collagen sheets, scaffolds, bone morphogenic proteins, biopeptides, biodiesel, etc.- Legislation and regulations related to animal by-products.

Unit III (5 Lectures)

Flaying - Classification and factors affecting the quality of hides and skin - Physical and chemical characteristics of hide and skin - Grading and processing of hide and skin for the manufacture of leather - Preparation and quality control of gelatine and glue.

VII. Practical (17 Classes)

Preparation of casing, neatsfoot oil, gelatin and glue - Demonstration of preparation of carcass meal, meat meal, bone meal, blood meal, feather meal, slime meal - Grading of casings - Collection and preservation of glandular by-products - Preparation of pet foods -Visit local by-products processing units - Quality evaluation of rendered animal fat.

VIII. Teaching methods

- Classroom teaching, practical demonstration of different by-products preparation in the Divisional laboratory/ slaughter unit
- Visit of municipal slaughterhouse and tanneries.
- Use of Audio-visual Capsules.

IX. Learning Outcome

Gaining knowledge on proper utilization of slaughterhouse by-products

X. Suggested Reading

- Aberle ED, Forrest JC, Gerrard DE and Mills EW. 2013. *Principles of Meat Science*, 5th ed. Kendall Hunt Publishing Company, Iowa.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences,* Vol. I, II and III, 1st ed., Elsevier Academic Press, UK.
- Mann I. 1962. *Animal By-products: Processing and Utilization*. FAO, Rome. Ockerman HW and Hansen CL. 1999. *Animal By-product Processing and Utilization*. CRC Press.

I. Course Title : In-Plant Training

II. Course Code : LPT 608

III. Credit Hours : 0+2

IV. Why this course?

Development of Entrepreneurial Skill and Human Resources for Meat and Milk Industry

V. Aim of the Course

To impart industrial exposure and develop entrepreneurial skill among postgraduate students.

VI. Practical (*34 sessions/ Hours equivalent to 34 credit hours of practical*)

LPT students shall undergo in-plant training in any one of the specialized area of

Livestock Products Technology in an institute/ industry – private or public sector. After completion of the training, the student will submit a training report. The evaluation will be based on attendance, report submission and viva-voce examination.

VII. Teaching methods

- Deputation to slaughterhouse/ meat/ milk processing plants
- Use of Audio-visual Capsules.

VIII. Learning Outcome

Students after undergoing training will have a good understanding of the functioning of the industry and capable of starting their own enterprises.

IX. Suggested Reading

- Interaction with Industry Persons.
- *Selected articles from Journals.*

I. Course Title : Egg and Egg Products Technology

II. Course Code : LPT 609

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development for Egg Processing Industry/ Plants

V. Aim of the Course

To impart knowledge about the status of egg production, composition, nutritive value, preservation, grading, processing packaging and marketing of eggs and egg products.

VI. Theory

Unit I (9 Lectures)

Status of egg production and processing in India - Structure, composition, nutritive value and functional properties of eggs - Grading, preservation, packaging and marketing of shell eggs - Quality evaluation of shell eggs and factors influencing egg quality - Defects and Spoilage of eggs.

Unit II (8 Lectures)

Layout and design of egg processing Unit - Principles and procedures involved in pasteurization, chilling, freezing, desugarization and drying of egg products - Quality standards of egg products - Packaging of egg products - Designer egg products.

VII. Practical (17 Classes)

Evaluation of physical, chemical, functional and microbial quality of egg and egg products - Preservation of eggs - Preparation of value-added egg products - Visit egg-processing plant.

VIII. Teaching methods

- Classroom teaching, practical demonstration in Divisional laboratory.
- Visit egg processing plant.

IX. Learning Outcome

Gaining knowledge on composition, nutritive value, preservation and marketing of eggs. Quality maintenance and development of designer egg products.

X. Suggested Reading

- Romanoff AL and Romanoff AJ. 1949. *Avian Egg*. John Wiley and Sons.
- Stadelman WL and Cotterill OJ. 2002. *Egg Science and Technology*, 4th ed. CBS.
- *Selected articles from Journals.*

I. Course Title : Market Milk Processing and Dairy Plant Practices

II. Course Code : LPT 610

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for Milk Processing Industry and Dairy Plants.

V. Aim of the course

To impart knowledge about procurement of milk, assessment of milk quality, legislation for quality control, milk processing techniques, the layout of milk processing and dairy effluent plants and preparation of special milk.

VI. Theory

Unit I (5 Lectures)

Organization of procurement and pricing plans of raw milk - Operation of automatic milk collection stations - Reception of milk at Raw Milk Reception Dock (RMRD) - Assessing raw milk quality - Sanitary handling of milk - Milk standards and legislations.

Unit II (6 Lectures)

Unit operations in milk processing plants - Clarification – Bactofugation - Different chilling methods - Standardization - Homogenization (theories, methods and effects) - Heat treatments (thermization, boiling, pasteurization, sterilization (UHT and In-container) - Separation technologies (Microfiltration, Ultrafiltration, reverse osmosis, diafiltration, nanofiltration etc).

Unit III (2 Lectures)

Distribution methods for liquid milk - Consumer pricing - Traceability - Handling of unsold and returned milk- - Adulteration of milk and detection - Residues in milk and preventive steps

Unit IV (4 Lectures)

Fortified, special and functional market milk - A1 and A2 milk Design and layout of dairy plants of different capacities - Dairy by-products - Treatment of Dairy Effluents.

VII. Practical (17 Classes)

Platform tests - Principles of rapid milk analyzers including milko-tester and operation of automatic milk collection stations - Raw milk quality, somatic cell count, bacteriological count - Estimation of homogenization efficiency - Assessment of efficiency of pasteurization, sterilization and boiling- Detection of adulterants.

VIII. Teaching methods

- Classroom teaching and laboratory analysis.
- Visit milk processing plants.

IX. Learning Outcome

Acquaintance with the processing of market milk and other dairy plant practices.

X. Suggested Reading

- FAO. 2013. *Milk and Dairy Products in Human Nutrition*. FAO, Rome.
- Fuquay JW, Fox PF and McSweeney PLH. 2011. *Encyclopaedia of Dairy Sciences*, 2nd ed. Elsevier Academic Press, UK.
- Walstra P, Wouters JTM and Geurts, TJ. 2006. *Dairy Science and Technology*, 2nd ed., Taylor and Francis Group.

I. Course Title : Processing and Marketing of Wool

II. Course Code : LPT 611

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for Wool Processing Industry

V. Aim of the Course

To impart knowledge about the growth and structure of wool and fibres and their use. Grading, processing, marketing and specifications of wool and speciality fibres.

VI. Theory

Unit I (10 Lectures)

Status and prospects of wool industry - Wool types and their uses - Growth and molecular structure of wool fibre - physical and chemical properties of wool - Grading of wool, Characteristics of speciality hair fibres and their uses- factors influencing the quality of wool and speciality hair fibres - principles and steps involved in the processing of wool and speciality hair fibres, Impurities in wool and their removal, Defects in wool.

Unit II (7 Lectures)

Physical, chemical and mechanical testing of wool - by-products of wool industry - Trade and Marketing of wool, specification and regulation for quality control - Characteristics of natural and synthetic fibres

VII. Practical (17 Classes)

Physical, chemical and mechanical testing of wool and speciality hair fibres - Characterization of wool - grading of wool - Identification of natural and synthetic fibres - Visit the wool processing industry and acquaintance with various steps in the processing of wool and speciality hair fibres.

VIII. Teaching methods

- Classroom teaching and laboratory analysis.
- Visit wool processing units.

IX. Learning Outcome

Gaining knowledge on the quality and processing of wool.

X. Suggested Reading

- Bergen WV. 1963. *Wool Hand Book*, Vols. I and II. Interscience.
- Houck MM. 2009. *Identification of Textile Fibres*. Woodhead Publishing Limited, Cambridge, England.

- Johnson NAG and Russell IM. 2009. *Advances in Wool Technology*. Woodhead Publishing Limited, Cambridge, England.

I. Course Title : Biotechnology of Foods of Animal Origin

II. Course Code : LPT 612

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development for meat and milk processing Industry with understanding of the latest biological techniques

V. Aim of the Course

To impart knowledge about new biotechnological techniques and tools for improving livestock productivity, quality control and food value.

VI. Theory

Unit I (10 Lectures)

Role of Biotechnology in improving productivity and quality of Meat, Milk and their products - Application of biotechnological tools in food preservation and packaging - Transgenic meat animal production - techniques - Genes influencing meat quality traits – Production of meat and milk with the desired composition - Application of enzymes in dairy and meat industry - Genetically modified enzymes - Biotechnologically produced food flavours and colours for animal products.

Unit II (7 Lectures)

Starter cultures in Meat and milk - Pre and probiotics, and their supplementation in animal origin foods - Biopreservation- Bacteriocin - Fermentation technology - Upstream and Downstream processing - Biosensors - Antimicrobial Peptides - Meat Species Identification- Molecular tools.

VII. Practical (17 Classes)

Introduction of basic biotechnological techniques such as western blotting, enzyme isolation and identification, DNA extraction, amplification, different types of PCR, Acquaintance with RT-PCR, Multiplex PCR, gene identification and characterization - Biotechnological techniques for meat species identification and meat quality - Electrophoresis, Chromatography for fatty acids- Operation of Fermenters.

VIII. Teaching methods

- Classroom teaching.
- Use of Audio-visual capsules.

IX. Learning Outcome

Gaining knowledge on utilization of biotechnology as a tool to improve production, shelf life and nutritive value of livestock products.

X. Suggested Reading

- Kerry J, Kerry J and Ledward D. 2005. *Meat Processing - Improving Quality*. Woodhead Publishing Ltd., UK.
- Kowale BN, Kulkarni VV and Keshava Rao V. 2008. *Methods in Meat Science*. Jaypee Brothers Medical Publishers, New Delhi.
- Sahoo J, Sharma DK and Chatli MK. 2011. *Practical Handbook on Meat Science and Technology*, Daya Publishing House, New Delhi.

- Toldra F. (Ed). 2008. *Meat Biotechnology*, Springer Science, New York
- Webb BH, Johnson AH and Alford JA. 2005 *Fundamentals of Dairy Chemistry*, 2nd ed. CBS Publishers and Distributors Pvt. Ltd.
- Selected articles from Journals.

I. Course Title : Fish and Fish Products Technology

II. Course Code : LPT 613

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for Fish Processing Industry

V. Aim of the Course

To impart knowledge about fish resources, structure and composition of fish muscles, preservation and processing of fish, marketing of fish products, deterioration of quality and legislations for quality control.

VI. Theory

Unit I (9 Lectures)

Fishery resources, marine and freshwater fishes- Transportation and hygienic handling of fish - Fish Muscle structure, composition and nutritive value - Processing of fish - gutting, filleting, beheading, peeling, deveining, etc. - Preservation - chilling, freezing, etc. - Principles and procedure of canning, curing, smoking, dehydration - Surimi and other Fish based products.

Unit II (8 Lectures)

Quality control- identification of freshness of fish - Chemical and Microbial spoilage of fish, labelling and marketing of fish and fish products, utilization of fish processing waste. National and international regulations, standards, quality control and marketing of fish and fish products.

VII. Practical (17 Classes)

Visit fish processing plant - Grading of live fish for freshness - Filleting and other techniques for the processing of fish - Proximate Composition of Fish - Physico-chemical and Microbial evaluation of fish quality - Preparation of Value added fish products.

VIII. Teaching methods

- Classroom teaching.
- Practical demonstration in the laboratory.

IX. Learning Outcome

Acquiring knowledge on the structure of fish muscle, preservation, processing and quality control of fish and fish products.

X. Suggested Reading

- Pearson AM. 1994. *Quality Attributes and their Measurement in Meat, Poultry and Fish Products*. Springer, New York.
- Suzuki T. 1981. *Fish and Krill: Protein Processing Technology*. Applied Science Publ.
- *Selected articles from Journals.*

Course Title with Credit Load
Ph.D. in Livestock Products Technology

Course No.	Course Title	Credits
LPT 701*	Modern Abattoir Practices and Animal By-Products Technology	1+1
LPT 702*	Advances in Meat Production and Fresh Meat Technology	1+1
LPT 703*	Developments in Processed Meat Technology	1+1
LPT 704*	Current Trends in Processing of Milk And Milk Products	1+1
LPT 705	Biotechnological Techniques and Quality Control of Livestock Products	1+1
LPT 706	Ethnic and Organic Meat and Milk Products	1+1
LPT 707	Industrial and Entrepreneurial Training	0+2
LPT 708	Current Trends in Disposal and Utilization of Waste From Meat and Dairy Industry	1+1
LPT 709	Advances in Egg and Egg Products Technology	1+1
LPT 791	Seminar I	1+0
LPT 792	Seminar II	1+0
LPT 799	Research	75

*Core courses

Course Contents
Ph.D. in Livestock Products Technology

I. Course Title : Modern Abattoir Practices and Animal By-Products Technology

II. Course Code : LPT 701

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for Slaughterhouses, Tanneries and other by-products industries.

V. Aim of the Course

To impart knowledge about advances in abattoir practices and animal by-products utilization.

VI. Theory

Unit I (5 Lectures)

Current scenario of slaughterhouses and processing plants in India - Establishment and operation of a modern abattoir - Basic machinery and tools of slaughterhouse - Automation/ Robotics in meat and by-product processing – Latest developments in the evaluation of carcass quality – Chilling and freezing of carcass - Maintenance of cold storages.

Unit II (8 Lectures)

Latest machinery and tools used in by-products processing plant - New technologies for utilization of animal by-products as food, feed, pharmaceuticals and other miscellaneous products - Leather chemistry and processing technology - Latest Techniques in handling, preservation, tannery procedure, manufacture and testing of leather - Value addition in leather processing - Developments in gelatin, glue and natural casings production - Characterization, processing, yield and quality control of rendered fat and meat cum bone meal.

Unit III (4 Lectures)

Organization, layout and operation of dry and wet rendering plants. Latest trends in the disposal of slaughterhouse effluents and control of environmental pollution. Designs and function of effluent treatment plants.

VII. Practical (17 Classes)

Plan and outlay of various components of a modern abattoir. Designs of ETP. Estimation of TS (suspended and dissolved) BOD and COD from abattoir effluents. Ante-mortem inspection of food animals, methods of stunning, stunning instruments. Slaughter and dressing of food animals. Electrical stimulation of carcasses. Post mortem inspection of carcasses of food animals - Visit municipal slaughterhouse, by-product processing plant, Effluent treatment plant and tanneries.

VIII. Teaching methods

- Classroom teaching, practical demonstration in laboratory/ slaughter unit.
- Visit municipal slaughterhouse and tanneries.
- Demonstration through charts, video films and models.

IX. Learning Outcome

Understanding of latest techniques employed in abattoir practices and slaughterhouse by-products utilization.

X. Suggested Reading

- Biswas A and Kondaiah N. 2014. *Meat Science and Technology*, 1st ed. Jaya Publishing House.
- Collins DS and Huey RJ. 2015. *Gracey's Meat Hygiene*, 11th ed. John Wiley and Sons Ltd., UK.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences*, Vol. I, II and III, 1st ed. Elsevier Academic Press, UK.
- Kerry J, Kerry J and Ledward D. 2005. *Meat Processing- Improving Quality*. Woodhead Publishing Ltd., UK.
- Swatland HJ. 2004. *Meat Cuts and Muscle Foods*. Nottingham University Press.
- Warriss P. 2010. *Meat Science: An Introductory Text*, 2nd ed. Oxford Press.
- *Selected articles from Journals.*

I. Course Title : Advances in Meat Production and Fresh Meat Technology

II. Course Code : LPT 702

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for Meat Industry

V. Aim of the Course

To impart knowledge about the latest trends in meat production, the ultrastructure of muscle fibres, strategies for improving meat production and traceability of meat products.

VI. Theory

Unit I (7 Lectures)

Current status of meat production trends in India - Government policies - economics and viability – Traceability in the meat industry – Strategies for augmenting meat production - Salvaging male buffalo calf - Non-conventional meat resources.

Unit II (10 Lectures)

Pre- and Post-natal development of Muscle fibres - Genetic, nutritional and physiological aspects of muscle development - Ultrastructure of skeletal muscle - Modern tools for fibre typing of muscle - Chemical and biochemical aspects of rigor mortis and fresh meat quality – Odour, colour, water holding capacity - Texture profile - Artificial tenderization - Myofibrillar, sarcoplasmic and connective tissue proteins - Cytoskeletal proteins - Lipid profile - Meat in human nutrition - Meat and health issues.

VII. Practical (17 Classes)

Economics of establishing commercial meat animal production Unit - Extraction of sarcoplasmic and myofibrillar proteins and their fractionation - Estimation of Collagen content of Meat - Histochemistry of muscle tissues - Muscle fibre typing - Meat tenderization techniques.

VIII. Teaching methods

- Classroom teaching, practical demonstration in laboratory/ slaughter unit
- Visit municipal slaughterhouse and meat plants
- Use of Audio-visual capsules.

IX. Learning Outcome

Knowledge of latest trends in meat production and fresh meat technology.

X. Suggested Reading

- Aberle ED, Forest JC, Gerrard DE and Mills E. 2013. *Principles of Meat Science*, 5th ed. Kendall Hunt Publishing Company, Iowa.
- Carlson CW, Greaser ML and Jones KW. 2001. *The Meat We Eat*, 14th ed. Interstate Publishers, Inc.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences*, Vol. I, II and III, 1st ed. Elsevier Academic Press, UK.
- Lawrie RA and Ledward DA. 2006. *Lawrie's Meat Science*, 7th ed. Woodhead Publishing Limited, Cambridge, England.
- Pearson AM and Dutson TR. 1997. *Advances in Meat Research. Healthy Production and Processing of Meat, Poultry and Fish Products,* Vol. 11. Springer.
- Swatland HJ. 2004. *Meat Cuts and Muscle Foods*. Nottingham Univ. Press.
- *Selected articles from Journals.*

I. Course Title : Developments in Processed Meat Technology

II. Course Code : LPT 703

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for Meat Processing Industry

V. Aim of the Course

To impart knowledge about the advances in the technology for processing of meat and development of value-added meat products.

VI. Theory

Unit I (5 Lectures)

Current trends in meat processing techniques - Functional properties of the tissue component in meat processing - Approaches for new product development - Latest equipment used for processing of meat products - Indigenous and heritage meat products - Curing and smoking - purpose, composition and methods of smoking - Liquid smoke - Processing of Ham, bacon, sausages, patties, meatloaves and tandoori chicken- Novel meat products - Non-thermal processing - Irradiation techniques - Canning/ retorting.

Unit II (8 Lectures)

Marination, massaging, tumbling and flaking techniques - Restructured/ reformed, intermediate moisture, fermented, enrobed, shelf-stable and dried meat products - Meat analogues and substitutes - Thermal processing of meat- Enzymatic and non-enzymatic browning reactions - Protein changes in processed meat products - Lipid changes - Protein and lipid interaction - Protein and carbohydrate interaction - Bioactive peptides.

Unit III (4 Lectures)

Functional and designer meat products - Role of omega-3 fatty acids in animal foods - Role of n-3 in PUFA enriched and CLA enriched meat and eggs - Packaging of meat and meat products - smart, active, intelligent packaging - Developments in sensory evaluation of meat products.

VII. Practical (17 Classes)

Evaluation of textural characteristics of meat products – Estimation of emulsifying capacity, emulsion stability- Estimation of Nitrosamines and PAHs - Preparation of emulsion-based, restructured, enrobed, cured and smoked, dried, fermented, intermediate moisture, ready to eat, and shelf-stable meat products-objective and subjective evaluation of meat products.

VIII. Teaching methods

- Classroom teaching, practical performance in Divisional Pilot Processing Plant.
- Visit Meat Processing Unit.
- Demonstration by videos.

IX. Learning Outcome

Acquaintance with the knowledge of the latest techniques used in meat processing and packaging and development of functional meat products.

X. Suggested Reading

- Aberle ED, Forest JC, Gerrard DE and Mills E. 2013. *Principles of Meat Science,* 5th ed. Kendall Hunt Publishing Company, Iowa.
- Barbut S. 2005. *Poultry Products Technology*. CRC Press.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences*, Vol. I, II and III, 1st ed. Elsevier Academic Press, UK.
- Kerry J, Kerry J and Ledward D. 2005. *Meat Processing- Improving Quality*. Woodhead Publishing Ltd., UK.
- Pearson AM and Gillett TA. 1996. *Processed Meats*, 3rd ed. Chapman and Hall, Inc, New York.
- Toldrá F. 2010. *Handbook of Meat Processing*. Wiley-Blackwell.
- *Selected articles from Journals.*

I. Course Title	:	**Current Trends in Processing of Milk And Milk Products**
II. Course Code	:	**LPT 704**
III. Credit Hours	:	**1+1**

IV. Why this course?

Human resource development (Manager, Supervisor and other Technocrats) for the milk processing industry

V. Aim of the Course

To impart knowledge about current trends in the processing of milk and milk products and their effect on physico-chemical and nutritional quality of milk, the scope of mechanization in the production of indigenous milk products and advances in the utilization of dairy by-products.

VI. Theory

Unit I (8 Lectures)

Principles and practices of production of quality raw milk - Advances in methods of chilling of milk - Thermal processing of milk – Principles and methods - types of UHT processing plants - Advances in the packaging of milk and milk products - Rheology of milk products - Preservatives, antioxidants, antibiotics and different toxic residues in milk - Advances in bacteriological and physico-chemical analysis of milk and milk product – Different legal and voluntary standards for milk and milk products - A1 and A2 milk and their significance.

Unit II (4 Lectures)

Bacteriological, physical, chemical and nutritional effects of processing on milk - New concepts in milk processing – radiation, microwave processing and conduction heating of milk – By-products from the dairy industry and their utilization.

Unit III (5 Lectures)

Innovative mechanization in the manufacture of Indigenous dairy products - Advances in the utilization of dairy by-products - preservation of milk products - Application of immobilized enzymes in dairy products – Latest trends in cleaning and sanitation of dairy plant

VII. Practical (17 Classes)

Quality evaluation of milk and milk products - Preparation of novel and indigenous milk products and their economics of production, quality and sensory evaluation - Use of Starter cultures - Maintenance of cultures - Demonstration of membrane processing technology - Preparation of DPR for Dairy plants of different capacities.

VIII. Teaching methods

- Classroom teaching and laboratory analysis.
- Visit the milk processing plant.
- Use of Audio-visual Capsules.

IX. Learning Outcome

Gaining knowledge of advances in the processing of milk and milk products.

X. Suggested Reading

- Fuquay JW, Fox PF and McSweeney PLH. 2011. *Encyclopaedia of Dairy Sciences*, 2nd ed. Elsevier Academic Press, UK.
- Herrington BL. 2000. *Milk and Milk Processing*. Green World Publishers.
- Walstra P, Wouters JTM and Geurts, TJ. 2006. *Dairy Science and Technology*, 2nd ed. Taylor and Francis Group.
- *Selected articles from Journals.*

I. Course Title : Biotechnological Techniques and Quality Control of Livestock Products

II. Course Code : LPT 705

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor and other Technocrats) for production of high-quality livestock products and their quality assurance.

V. Aim of the Course

To impart knowledge about advances in the application of biotechnological techniques for improving the production and quality of livestock products. To familiarize with the agencies responsible for maintaining the quality of livestock products, quality standards and legislations

VI. Theory

Unit I (10 Lectures)

Biotechnological tools for microbial testing of food - Industrial cell culture – Bioreactor types and design – Upstream and downstream processing - Bacterial food additives and supplements - Characteristics and application of microbial starters in milk and meat fermentation - Biotechnology in production of designer livestock products - Bio-production of flavours and colour and their application in dairy products - Enzyme applications in dairy technology. - Utilization of nanotechnology in livestock products - Biotechnology for food safety - Cultured meat - Biotechnology in meat species identification.

Unit II (7 Lectures)

Importance of quality control for livestock products - Concept and application of HACCP - BIS, FSSAI and AGMARK standards - GMP and total quality management in the processing of livestock products - ISO-9000, ISO-14000 and ISO-22000 - Codex regulations of food product safety.

VII. Practical (17 Classes)

Demonstration of the latest biotechnological techniques including DNA and protein-based techniques. Operation of bioreactors - Gene identification and characterization. Visit Milk/ Meat processing plants for an understanding of HACCP and other quality management systems.

VIII. Teaching methods

- Laboratory analysis.
- Visit of ISO and HACCP certified food processing plant.
- Use of Audio-visual Capsules.

IX. Learning Outcome

Gaining knowledge on the application of biotechnology for augmenting production and quality assurance.

X. Suggested Reading

- Fuquay JW, Fox PF and McSweeney PLH. 2011. *Encyclopaedia of Dairy Sciences*, 2nd ed. Elsevier Academic Press, UK.
- Jensen WK, Devine C and Dikeman M. 2004. *Encyclopaedia of Meat Sciences*, Vol. I, II and III, 1st ed. Elsevier Academic Press, UK.
- Kerry J, Kerry J and Ledward D. 2005. *Meat Processing-Improving Quality*. Woodhead Publishing Ltd., UK.
- *Selected articles from Journals.*

I. Course Title : Ethnic and Organic Meat and Milk Products

II. Course Code : LPT 706

III. Credit Hours : 1+1

IV. Why this course?

Improving the production, processing and marketing of ethnic and organic meat and milk and their products.

V. Aim of the Course

To impart knowledge about the production of ethnic and organic meat and milk products.

VI. Theory

Unit I (9 Lectures)

Historical developments, present scenario and prospects of ethnic meat and milk products in various parts of India - Ethnic meat products - haleem, biryani, chettinad recipe, pork vindaloo, Kebab, Goan sausages, Kashmiri wazwan and meat products of North Eastern Region (NER) - Ethnic milk products – churpi, kalari, kunda, etc. - Constraints in promoting ethnic meat products - Approaches for development and commercialization of ethnic meat products - Fermented and non-fermented ethnic milk and meat foods – Impact of Globalization and role of WTO in promoting ethnic meat and milk products from India.

Unit II (5 Lectures)

Entrepreneurship Development for Ethnic meat and milk Products – Formulation, composition, quality, safety and shelf life of ethnic meat and milk products of India - Geographical indicators for recognition of ethnic meat and milk products.

Unit III (3 Lectures)

Organic meat and milk products - introduction, registration, certification, marketing and scope.

VII. Practical (17 Classes)

Preparation of ethnic meat products - haleem, biryani, chettinad recipe, pork vindaloo, Kebab, Goan sausages, Kashmiri wazwan and meat products of NER/ local region, Preparation of Ethnic milk products – churpi, kalari, Kunda, etc. - Composition, physico-chemical and microbial quality of ethnic milk and meat products - Packaging and marketing of ethnic milk and meat products.

VIII. Teaching methods

- Classroom teaching, practical demonstration in the laboratory
- Through the study of reports published by Govt. agencies time to time

IX. Learning Outcome

To acquaint with the knowledge for the production of ethnic and organic meat and milk products.

X. Suggested Reading

- Books on Indian Food.
- *Selected articles from Journals*

I. Course Title : Industrial and Entrepreneurial Training

II. Course Code : LPT 707

III. Credit Hours : 0+2

IV. Why this course?

Human Resource Development for catering to livestock products and related industry.

V. Aim of the Course

To prepare students to venture into various start-ups for self-reliant enterprises.

VI. Practical (34 Classes)

Preparation of basic feasibility report including raw material availability, marketing potential, economic viability and regulatory requirements for different livestock products related industry. Entrepreneurial training in an industrial establishment related to livestock products (17 sessions/ Hours equivalent to 17 credit hours of practical).Preparation of Detailed project reports (DPR) for the establishment of livestock products enterprises, viz. slaughterhouses, milk and meat processing plants, effluent treatment and byproducts utilization plants, etc..

VII. Teaching methods

- Visiting processing units
- Web surfing

VIII. Learning Outcome

Students envisioned having adequate knowledge and skills for setting up livestock products enterprises.

IX. Suggested Reading

- *Selected articles from Journals.* Through Interaction with Industry personnel.

I. Course Title : Current Trends in Disposal and Utilization of Waste From Meat and Dairy Industry

II. Course Code : LPT 708

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development (Manager, Supervisor, Meat inspector and other Technocrats) for better utilization of animal wastes and effluent treatments.

V. Aim of the Course

To impart knowledge about disposal and handling of wastes from the meat and dairy industry, Agencies involved and their norms for pollution control from meat and dairy industries.

VI. Theory

Unit I (8 Lectures)

Terminologies used in solid and liquid waste management systems - Public health significance - Classification, composition, functional elements and sources of solid waste from Meat and Dairy Processing plants and their management - Aerobic and anaerobic systems of liquid waste management.

Unit II (9 Lectures)

Waste handling, separation, storage, processing and utilization of Solid waste - Common solid waste disposal methods like rendering, composting, deep burial and incineration - Scope for zero waste management - Properties of dried sludge and its utilisation as manure - Economical aspects of waste treatment and disposal - Utilization of meat and dairy processing wastes - Application of nanotechnology in waste management - State and Central Pollution Control Board norms.

VII. Practical (17 Classes)

Visit Sewage and Effluent Treatment Plants - Estimation of pH, dissolved oxygen, TSS, BOD and COD - Estimation of micronutrients in treated effluents - Design and schematic layout of various solid and liquid waste treatment plants.

VIII. Teaching methods

- Classroom teaching
- Visit Sewage Treatment Plant

IX. Learning Outcome

Gaining knowledge on advances in the utilization of wastes from the meat and dairy industry.

X. Suggested Reading

- *Selected articles from Journals.* Through Interaction with personnel of Municipal Corporation and Pollution Control Board.

I. Course Title : Advances in Egg and Egg Products Technology

II. Course Code : LPT 709

III. Credit Hours : 1+1

IV. Why this course?

Human Resource Development for Egg Processing Industry and Egg Processing Plants

V. Aim of the Course

To impart knowledge about the status of egg production, composition, nutritive value, preservation, grading, processing packaging and marketing of eggs and egg products.

VI. Theory

Unit I (5 Lectures)

Advanced preservation techniques for egg and egg products - Maintenance of quality of eggs - Microbiology of egg - Spoilage of eggs and its prevention.

Unit II (8 Lectures)

Preparation of fast foods and role of egg in fast foods chains - Egg breaking and processing plants - lay-out and organization Preservation methods viz pasteurization, desugarization, freezing, dehydration, etc. – process and methods - Quality estimation of egg and egg products - Designer egg and egg products.

Unit III (4 Lectures)

Specifications, Standards and marketing of egg and egg products - Quality control of egg products.

VII. Practical (17 Classes)

Evaluation of physical, chemical and functional quality of egg and egg products - Detection of egg rots - Evaluation of microbiological quality of egg and egg products - Preservation techniques of eggs - Preparation of convenient, dehydrated and value-added egg products -Visit a modern egg processing plant

VIII. Teaching methods

- Classroom teaching, practical demonstration in the laboratory.
- Visit the egg processing plant.

IX. Learning Outcome

Gaining knowledge on composition, nutritive value, preservation and marketing of eggs. Quality maintenance and development of designer egg products.

X. Suggested Reading

- Romanoff AL and Romanoff AJ. 1949. *Avian Egg*. John Wiley and Sons.
- Stadelman WL and Cotterill OJ. 2002. *Egg Science and Technology*, 4th ed. CBS.
- *Selected articles from Journals.*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 3

Animal Production Sciences
– Poultry Science

Preamble
(Poultry Science)

Poultry industry in India has made a remarkable growth ever since its inception and is presently emerging as a sunrise sector with a growth rate of 8.51 and 7.52 percent in egg and broiler production respectively (BAHS, 2019) as against 2.5 percent for agricultural crops. Within the poultry sector, broiler and layer segment constitutes about 65.3 and 34.7 percent with the monthly turnover of 400 million chicks and 8400 million eggs, respectively (ICRA, 2020). In poultry farming activities around one million farmers are engaged with 85 percent of them having less than 2 ha of land or the landless. With the annual poultry production of 851.8 million, poultry in India has emerged as the most dynamic and diversified subsector with third largest egg producing and fourth largest broiler producing country in the world with an estimated production of 103.3 billion eggs and 4.1 million metric tons (MMT) of broiler meat (BAHS, 2019).

Indian poultry industry has witnessed a radical and robust transformation from backyard poultry farming in villages to environmental controlled house coupled with high end automation. Industry is continuously updating with the evolvement and enrichment of newer technologies for achieving maximum efficiency in poultry at production and post-harvest levels. These developments demand the requirement of poultry veterinarians experts and managers for optimized production practices. In order to keep pace in the race of advancing poultry farming technology, a realistic update at academic level in poultry science is highly mandatory and demands of the hour. Hence, an academic curriculum of poultry science involving the industrial visits, automation in poultry farms, market research skills and winning bankable project reports for poultry startups can shape and equip poultry veterinarians so as to cater the needs of the poultry industry. The current designed syllabus provides the students regarding working knowledge in farms, decision making and troubleshooting analytical skills at different stages of poultry production.

Recently, waste disposal from poultry farms is emerged as an alarming issue for which knowledge on efficient wealth from waste technological intervention is required to pave a way for Go Green Poultry and the current syllabus has been designed to include the course on this emerging and much needed requirement to train veterinary post graduates to tackle this problem. Since waste recycling is very important to address environmental concerns and also to rduce use of energy sources used in disposal of waste. Hence, the course on waste recycling has also been designed so as to teach newer and innovative techniques of waste recycling for production of useful end products with concept of waste to wealth.

As changing environmental scenario is also posing problems in disease incidence and survivability of pathogens leading to constant threat of emerging and re-emerging diseases in poultry, the contents has been designed in such a way to impart knowledge on the sensitive and precise aspects of disease detection and also the segment has been incorporated to gain an knowledge on disease preventive measure including designing vaccination programme. Since biosecurity measures remains the cheap and effective means of disease preventive measures and it becomes essential to teach the basic concept of disease prevention so the poultry industry is helped with trained veterinarians with knowledge and skills in prevention of disease incidence.

The syllabus has also been designed in such a way so that the students can get practical exposure with farm/ lab/ field visits to the advanced environmentally controlled houses, feed manufacturing units, processing plants, advanced disease diagnostic labs on–filed poultry farms so that they can learn the practices being followed in these units so that they can think and plan to get more knowledge in the problems faced in the field conditions and can think of devising mechanisms to solve the problems.

Emphasis has been given to include the courses on commercial poultry nutrition. As nutrition in poultry production remains important segment and constitutes around 60-70% costs of production. Hence, emphasis has been laid to teach more basic aspects related to commercial aspects so that the cost of production can be minimized with knowledge in estimating the precise nutrient requirements in different poultry species, commercial uses of feed ingredients and use of non-conventional feed ingredients in poultry. Further practical emphasis has also been given to standardize the seasonal changes in feeding practices, use of advanced analytical techniques for estimating the feed nutrient contest and also to learn other feeding practices for better poultry production and profitability.

Since diversified poultry species like quails, duck, guinea fowl, geese, ostrich and emu which are also important poultry species and these contribute to the economy of our country. In some segment of the country the diversified poultry species remains important for poor farmers due to geographical conditions of those regions. So it becomes imperative to train the veterinarians on all aspects of these species for optimum production and profitability. As breeding, feeding, health requirement are different chickens and thus, the contents of newly added course have been focused on different aspects related breeding, feeding, housing and health care management.

Emphasis has also been given on new scientific techniques, value-addition, post-harvest management, methods of organic poultry production, formulation of bankable projects with minimal expenditure in poultry production and also on utilizing the by-products from poultry processing and waste Overall the course has been designed in such a way so as to focus to enhance skills for tackling emerging problems in this sector, increase employment and also focus has been given to cope up the post-covid-19 challenges. The newly designed syllabus will greatly enhance the capacity of the veterinarians in the areas of emerging nature and will meet new education policy requirement

Summary of changes in syllabus

	Old courses	New course **title**	Changes
M.V.Sc. courses			
1.	**PSC-603:** Commercial layer production 2+1 **PSC-604:** Commercial broiler production 2+1	**PSC-603**: Commercial layer and broiler management [2+1]	Two courses (PSC-603 and PSC-604) merged
2.	**PSC-605:** Breeder stock, flock health and hatchery management	**PSC-605**: Poultry health and biosecurity	Health aspect delinked from old PSC-605 and title modified
3.	**PSC-607**: Poultry products technology and marketing	**PSC-607**: Poultry products technology	Title changed
4.		PSC-**610**: Commercial poultry nutrition	New course added
5.		**PSC-611**: Poultry welfare and waste management	New course added
Ph.D. courses			
1.	**PSC-703**: Developments in poultry products technology	**PSC-703:** Developments in poultry processing and products technology	Title modified
2.	**PSC-704**: Emerging diseases of poultry and flock health	**PSC-704**: Emerging and re-emerging diseases of poultry and health management	Title modified
3.	**PSC-705**: Advanced poultry breeding methods	**PSC-705**: Applied poultry breeding	Title merged
4.		**PSC-707** Diversified poultry production	New course added

Course Title with Credit Load
M.V.Sc. in Poultry Science

Course Code	Course Title	Credit Hours
PSC 601*	Poultry Breeding and Genetics	2+1
PSC 602*	Poultry Nutrition and Feeding	2+1
PSC 603*	Commercial Layer and Broiler Management	2+1
PSC 604*	Breeder Stock and Hatchery Management	2+1
PSC 605	Poultry Health and Biosecurity	2+1
PSC 606	Management of Other Avian Species	3+1
PSC 607*	Poultry Products Technology	2+1
PSC 608	Poultry Economics, Project Formulation and Marketing	2+1
PSC 609*	Physiology of Poultry Production	1+1
PSC 610	Commercial Poultry Nutrition	1+1
PSC 611	Poultry Welfare and Waste Management	2+0
PSC 691	Seminar	1+0
PSC 699	Research	30

*Core courses

Course Contents
M.V.Sc. in Poultry Science

I. Course Title : Poultry Breeding and Genetics
II. Course Code : PSC 601
III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on different systems of breeding, selection methods, design and implementation of the breeding programme in developing egg-type and meat-type birds. Modern tools in poultry breeding.

V. Theory

Unit I (12 Lectures)

Genetic classification of Poultry – Origin and breed characteristics of poultry-Mendel's laws of inheritance related to poultry - Qualitative and Quantitative traits in Poultry breeding – Additive and Non-additive – Dominance, Incomplete dominance, Epistasis and complementary gene actions – Lethals and mutations in poultry – Sex-linked, Sex limited and Sex influenced traits – Economic traits – Partitioning of variance - Heritability – Quantitative inheritance – Phenotype, Genotype and environment interactions.

Unit II (10 Lectures)

Systems of Breeding – Systems of Mating – Selection methods – Breeding programme for developing egg-type, meat type and rural poultry strains - Developing hybrids - Breeding and management of other species of Poultry- Formation and Management of inbred pure lines, grandparent and parent stock - Industrial breeding.

Unit III (12 Lectures)

Artificial insemination in chicken –Autosexing–Random Sample Test - Use of molecular genetics in poultry breeding-Quantitative trait loci and marker-assisted selection- Conservation of poultry genetic resources.

VI. Practical (17 Classes)

Breeds of poultry – Estimation of qualitative and quantitative traits in poultry – Exercises on individual and family selection – Constructing multi-traits selection index and Osborne index-Estimating heritability – Breeding program for developing commercial hybrid layers, broilers and Japanese quail– Breeding programmes for rural poultry - Semen collection, evaluation, dilution and insemination in chicken and turkey – Breeding records –Use of computers to maintain breeding records and for selection– Estimation of effective population size, rate of inbreeding, response to selection and genetic and phenotypic responses.

VII. Teaching methods

- Classroom teaching with laboratory support and farm visits
- Use of computers for quantitative genetic analysis

VIII. Learning outcome

Gaining knowledge on poultry breeding and genetics

IX. Suggested Reading

- Crawford RD. 1990. *Poultry Breeding and Genetics*. Elsevier.
- Falconer DS. 1997. *Introduction to Quantitative Genetics*. Benjamin Cummings.
- Hutt FB. 1949. *Genetics of the Fowl*. McGraw-Hill
- Muir WM and Aggrey SE. 2003. *Poultry Genetics, Breeding and Biotechnology*. CABI.
- Singh RP and Kumar J. 1994. *Biometrical Methods in Poultry Breeding*. Kalyani Publications

I. Course Title : Poultry Nutrition and Feeding

II. Course Code : PSC 602

III. Credit Hours : 2+1

IV. Aim of the course

Teaching about nutrients and their functions, nutrient requirements of poultry and factors influencing the same. Imparting knowledge of different types of feeds and feeding methods.

V. Theory

Unit I (8 Lectures)

Digestive system, digestion, metabolism and absorption of nutrients in poultry – Factors influencing the feed consumption in birds – Macro and micro-nutrients – Protein and amino acids - Nutrient requirements for various species of poultry – Factors influencing the nutrient requirements - Partitioning of energy - Calorie: protein ratio – Nutrient interrelationships.

Unit II (12 Lectures)

Feed ingredients composition - Feed storage techniques - Milling and quality control-Processing of feed – Types and forms of feeds and feeding methods - Commonly occurring antinutrients and toxicants in poultry feed ingredients – Mycotoxins and their prevention – Feeding chicks, growers, layers, broilers and breeders – Principles of computing feed – Balanced feeds - Least cost feed formulation and programming – Feeding in different seasons and stress conditions - Nutritional and metabolic disorders in poultry.

Unit III (8 Lectures)

Systems of feeding – restricted, forced, controlled and phase feeding -Use of Additives and Non-additives- enzymes, probiotics, prebiotics, antibiotics, herbs and other performance enhancers – Utilization of non-conventional feedstuff - Feeding of ducks, turkeys, Japanese quails and Guinea fowls.

Unit IV (6 Lectures)

Organic, functional, designer and SPF feed production - Production of feeds free from drug residue, pesticide residue and toxins – Regulations for Import and Export of feed and feed supplements.

VI. Practical (17 Classes)

Physical and sensory evaluation of feed ingredients- sampling techniques for ingredients and compounded feed-Estimation of proximate principles of feed and feed ingredients – Computing various poultry feed formulae based on commonly available feed ingredients – Computer applications in feed formulations - Estimation of Aflatoxin, Calcium, Phosphorus, Sand, Silica and Salt – Mash, pellet and crumble feed preparation – Feeding procedures. Visit to feed mills –Hands-on training in feed analytical lab.

VII. Teaching methods

- Classroom teaching with laboratory support and feed mill visits
- Use of computers in feed formulations

VIII. Learning outcome

Gaining knowledge on poultry nutrition and feeding

IX. Suggested Reading

- Bell DD and Weaver WD JR. 2002. *Commercial Chicken Meat and Egg Production*, 5th ed. Kluwer Academic Publishers.
- ICAR. 2013. *Nutrient Requirements of Poultry*. ICAR Publication.
- Leeson S and Summers JD. 2001. *Scott's Nutrition of the Chicken*. University Books.
- Leeson S and Summers JD. 2008. *Commercial Poultry Nutrition*, 3rd ed. University Books.
- Singh RA and Panda B. 1992. *Poultry Nutrition*. Kalyani Publishers.

I. Course Title : Commercial Layer and Broiler Management

II. Course Code : PSC 603

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on different systems of rearing and management of commercial layer and broilers for maximum egg and meat production

V. Theory

Unit I (10 Lectures)

Development of Poultry Industry in India and the World – Systems of layer and broiler farming – Location and layout of the farm – Systems, types and design of houses – Poultry farm equipment - Automation in poultry houses and its maintenance - Environmentally controlled houses and their management -Deep litter and cage system of management- Litter materials -All in All out and Multiple batch systems of rearing layers and broilers –Brooding management - Lighting programme for egg-type and meat-type birds- Water quality standards, watering and water sanitation - Biosecurity and health management – Production indices for broilers and layers – Integration in broiler and layer production.

Unit II (12 Lectures)

Cages and modified cages for egg-type birds – Feeding management in layers - Medication and vaccination schedules and procedure for layers –Brooder, grower, pre-layer, layer and cockerel management – Management of layers during peak egg production and maintaining the persistency in production – Strategies to prolong the egg production beyond 72 weeks of age - Factors causing uneven growth and low egg production - Monitoring egg production curve - Culling of unproductive birds – Record keeping –Management during different seasons – Induced moulting.

Unit III (10 Lectures)

Management of broilers during different seasons -Mash, crumble and pellet feeding of Broilers – Weekly growth rate, feed conversion and livability in broilers- Sex separate feeding – Feeding broilers for optimum growth rate and feed efficiency – Broiler farm records - Broiler farm routine, medication and vaccination schedule – Transport of broilers - Regulations and specifications for the production of export quality broilers.

VI. Practical (17 Classes)

Layer farm layout– Design of different chick, grower and layer houses, their specifications – Selection and culling of layers, debeaking, dubbing, deworming, delicing, vaccination and other farm routines and operations – Farm sanitation, disinfection and waste disposal – Visit commercial layer farms including environmental controlled houses – Record keeping – Calculating Hen day egg production, Hen housed egg production and other economic traits – Calculating the cost of production of eggs and meat and economics–Location and layout for a broiler farm – Broiler house design – Visit to commercial broiler farms including environmental controlled houses – Broiler brooding, Medication, vaccination, transportation and farm routines - Record keeping - Calculating the cost of production of broilers – Feeding of broilers at different ages – Working-out feed efficiency.

VII. Teaching methods

- Classroom teaching with farm visits
- Using different housing models
- Using Audio-visual capsules
- Demonstration of different management practices at farms

VIII. Learning outcome

Gaining knowledge of commercial broiler and layer production

IX. Suggested Reading

- Bell DD and Weaver WD, Jr. 2002. *Commercial Chicken Meat and Egg Production*, 5th ed. Kluwer Academic Publishers.
- Narahari D. 1997. *Commercial Broiler Production*. Emkay Publishers.
- Rajini RA. 2012. *Simply Poultry Science*. Alpha Publishers.
- Sapcota D, Narahari D and Mahanta JD. 2017. *Avian Poultry Production*, 2nd rev ed. New India Publishing Agency.
- Scanes CG, Brant G and Ensminger ME. 2003. *Poultry Science*, 4th ed. Prentice-Hall.
- Sreenivasaiah PV. 2015. *Textbook of Poultry Science*. Write and Print Publications.

I. Course Title : Breeder Stock and Hatchery Management

II. Course Code : PSC 604

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about care and management of breeders and hatchery operations.

V. Theory

Unit I (9 Lectures)

Different types of commercial breeder flocks –Special care of breeder chicks – Breeder male and female management – Feeding the breeder flocks: Separate sex feeding, feed restriction in broiler breeders. Management for improving fertility and hatchability, Management of parent and grandparent farms - Management of pure lines – Artificial Insemination - Care and management of Hatching eggs.

Unit II (4 Lectures)

Vaccination of layer and broiler parents - Nutrient supplementation – Seasonal management of breeders – Lighting management in breeder farms - Flock testing and culling.

Unit III (12 Lectures)

Natural and Artificial incubation –Stages of embryonic development -Incubation principles – Location of hatchery – Layout and design of hatchery - hatchery equipment– Hatchery management - Ventilation and temperature control –Pre-incubation storage, Fumigation and sanitation – Hatchery operations, routine and schedule – Egg candling -Packaging and transportation of hatching eggs and chicks, hatchery troubleshooting- Factors affecting fertility and hatchability - Biosecurity and hatchery waste disposal – Control of vertically transmissible and hatchery borne diseases – Special incubator management during hot summer – Hatch analysis.

Unit IV (9 Lectures)

SPF egg production - Import and export regulations – Maintaining Salmonella and Mycoplasma free breeding flock –Application of HACCP and Good Management Practices (GMP) in hatchery management for better chick quality.

VI. Practical (17 Classes)

Layout and blueprints for breeder farm and hatchery –Incubator management – Candling - Hatchery sanitation, fumigation procedures and hatchery hygiene – Pedigree hatching – Hatchery waste disposal and recycling – Calculating the cost of production of hatching eggs and day-old-chicks, management of bangers– Attending breeder farm routines and operation – Flock testing and culling of reactors – Analyzing hatchability results – Use of computers in hatchery operations - Economics of setting up of layer and broiler hatchery. Vaccinating day-old chicks and concept of in-ovo vaccination, visit to commercial breeder farm and hatchery.

VII. Teaching methods

- Classroom teaching with breeder farm and hatchery visits
- Using Audio-visual capsules

VIII. Learning outcome

Gaining knowledge of breeder flock and hatchery management

IX. Suggested Reading

- Bell DD and Weaver WD, Jr. 2002. *Commercial Chicken Meat and Egg Production*, 5th ed. Kluwer Academic Publishers.
- Leeson S and Summers JD. 2009. *Broiler Breeder Production*. Context Products.
- Sreenivasaiah PV. 2006. *Scientific Poultry Production: A Unique Encyclopaedia*. International Book Distributing Co.
- Taylor LW. 2003. *Fertility and Hatchability of Chicken and Turkey*. John Wiley and Sons.

I. Course Title : Poultry Health and Biosecurity

II. Course Code : PSC 605

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about common diseases and disorders of poultry, diagnosis, vaccination, prevention, control and treatment. Biosecurity measures in the control of common poultry diseases.

V. Theory

Unit I (7 Lectures)

Common bacterial diseases: *Salmonella*, *Pasteurella*, *E.coli,* Fowl typhoid, Mycoplasma, Infectious *Coryza*, *Gallibacterium*, *Clostridium*

Unit II (9 Lectures)

Common Viral diseases: Newcastle, Infectious bronchitis, Infectious laryngeotracheitis, Marek's, Fowl pox, Infectious Bursal disease, Egg drop syndrome-76, Avian Encephalomyelitis, Avian influenza, Duck viral hepatitis, Chicken Infectious Anaemia, etc.

Unit III (8 Lectures)

Common Fungal, parasitic and metabolic diseases: Aspergillosis, Mycotoxicosis, Fatty liver haemorrhagic syndrome(FLHS), Gout, Ascites, leg weakness - Coccidiosis, Ecto- and endo-parasitic infestation of poultry, etc.

Unit IV (5 Lectures)

Diagnosis, vaccination, prevention, treatment and control of various poultry diseases.

Unit V (5 Lectures)

Principles of biosecurity - Locational, structural and operational biosecurity in Poultry farms – Water sanitation and control of water-borne diseases – Quarantine of poultry - Farm sanitation and disinfection procedures.

VI. Practical (17 Classes)

Ante-mortem and Post-mortem examination of birds – Sample collection – Despatch of samples – Processing of samples and detection of pathogens/ etiological agents -Different sanitizers and disinfectants available and their uses. Care and contraindication of using different products. Personal hygiene and isolation – Different vaccines and routes of administration – Methods of medication – Water quality analysis, Field visit to poultry diagnostic lab.

VII. Teaching methods

- Classroom teaching with laboratory diagnosis
- Post-mortem examination
- Using Audio-visual capsules

VIII. Learning outcome

Gaining knowledge on poultry health and bio-security

IX. Suggested Reading

- Gordon RF and Jordan FTW. 1982. *Poultry Diseases*. ELBS
- Pattison M, McMullin P, Bradbury JM and Alexander D. 2008. *Poultry Diseases*, 6th ed. Elsevier.

- Saif YM. 2008. *Diseases of Poultry*. Blackwell Publishing House.
- Thyagarajan D. 2011. *Diseases of Poultry*, Satish Serial Publishing House.
- Vegad JL. 2015. *Poultry Diseases Farmers. A Guide for Farmers and Poultry Professionals*. International Book Distributing Co.

I. Course Title : Management of Other Avian Species

II. Course Code : PSC 606

III. Credit Hours : 3+1

IV. Aim of the course

Care and management of different breeds, varieties of poultry other than chicken, methods of rearing and common diseases affecting them and their control measures.

V. Theory

Unit I (15 Lectures)

Breeds and varieties of Turkey, Duck, Goose, Guinea fowl, Japanese quail, Emu and Ostrich – Incubation periods and incubation procedure for different species – Production standards - Housing, cage and equipment for other avian species under different systems of rearing.

Unit II (15 Lectures)

Management and rearing of Turkey, duck, goose, Guinea fowl, Japanese quail, emu and ostrich- Feeding standards and feeding, watering and rearing systems and procedure for different species of poultry - Breeding programmes for egg and meat production in different species.

Unit III (10 Lectures)

Different types of pet birds - Management and rearing of pet birds of regional importance (Pigeon, budgerigar, parakeets, love birds, macaws, doves, parrots, etc.) – Housing for pet birds, their habitat, feeding and breeding under captivity.

Unit IV (8 Lectures)

Common diseases affecting other avian species and their control – Regulations for import and export of different species of poultry – Prevention of exotic diseases through the import of live birds.

Unit V (3 Lectures)

Concept and definition of organic poultry – status, certification and guidelines for organic poultry production – Government policies on organic poultry farming.

VI. Practical (17 Classes)

Layout and design of housing and cages for other species of poultry. Visit commercial Japanese quail, turkey and duck farms. Incubation and care of hatching eggs and young ones – Rearing practices followed by duck, quails and turkey farmers under field conditions - Sexing of pet birds – Preparing project reports for different species and calculating the cost of production – Feeding pet birds and their chicks.

VII. Teaching methods

- Classroom teaching with farm visits
- Visit pet bird farms
- Using Audio-visual capsules

VIII. Learning outcome

Gaining knowledge on rearing different poultry species other than chicken

IX. Suggested Reading

- Cherry P and Morris T. 2011. *Domestic Duck Production: Science and Practice*. CABI
- CPDO. *Duck – Management Guide*. Central Poultry Development Organization Publication (online resource)
- CPDO. *Turkey – Management Guide*. Central Poultry Development Organization Publication (online resource)
- Mayer J and Donnelly TM. 2012. *Clinical Veterinary Advisor: Birds and Exotic Pets*. Elsevier.
- Pathak N. 2013. *Poultry and Ratite Nutrition*. Narendra Publishing House.
- Sapcota D, Narahari D and Mahanta JD. 2017. *Avian Poultry Production*, 2nd rev ed. New India Publishing Agency.
- Scanes CG, Brant G and Ensminger ME. 2003. Poultry Science, 4th ed. Prentice-Hall.

I. Course Title : Poultry Products Technology

II. Course Code : PSC 607

III. Credit Hours : 2+1

IV. Why this course?

V. Aim of the course

Composition and nutritive value of eggs and chicken meat, grading and preservation methods of eggs and meat, functional and value-added poultry products.

VI. Theory

Unit I (15 Lectures)

Physical and chemical composition and nutritive value of eggs and meat – Grading of eggs and meat by different standards - Egg quality deterioration - Factors affecting egg quality – Handling, processing, packaging materials, packaging, transport and marketing of eggs.

Unit II (8 Lectures)

Quality control of poultry meat – Preservation of egg and meat-Functional and value-added egg and meat products – Further processing of eggs and meat – Various egg and meat fast foods.

Unit III (11 Lectures)

Sanitary and phytosanitary measures to ensure food safety – Pre and Post oviposition value addition to the eggs and Post-processing value addition to the meat for export–Microbial safety of poultry products – Import and export of poultry products – Further processing of poultry for export – Implementation of GMP and HACCP procedures for food safety – Codex regulations for poultry products safety – Traceability and branding of poultry products.

VII. Practical (17 Classes)

Measuring internal and external egg qualities – Measurement of meat quality - Preservation of table eggs, grading of eggs – Processing of chicken – Further processing of poultry – Preservation of poultry meat – Preparation of various eggs and poultry meat products and fast foods – Preservation, packaging and transport – Quality control of value-added poultry products – Measures of microbial safety of poultry products for export, visit to poultry processing plant.

VIII. Teaching methods

- Classroom teaching with laboratory analysis
- Visit egg and meat processing plants
- Using Audio-visual capsules

IX. Learning outcome

Gaining knowledge of poultry products technology

X. Suggested Reading

- Biswas A and Kondaiah N. 2014. *Meat Science and Technology*. Jaya Publishing House.
- Mead G. 2004. *Poultry Meat Processing and Quality*. Elsevier
- Mountney GJ and Parkhairst CR. 1995. *Poultry Products Technology*, 3rd ed. AVI Publ.
- Romanoff AL and Romanoff AJ. 1949. *The Avian Egg*. CAB international
- Sim JS and Nakai S. 1994. *Egg Use and Processing Technologies: New Developments*. CAB International.
- Stadelman WJ and Cotterill OJ. 1995. *Egg Science and Technology*, 4th ed. CRC Press.

I. Course Title : Poultry Economics, Project Formulation and Marketing

II. Course Code : PSC 608

III. Credit Hours : 2+1

IV. Aim of the course

To study about measures of performance efficiency in poultry farms and its allied sector, components of project reports and preparation of viable projects related to poultry Industry.

V. Theory

Unit I (10 Lectures)

Glossary of terms used in poultry economics and projects – Measures of performance efficiency in the broiler, layer, breeder and other poultry species, hatcheries and other poultry-related operations – Production standards and goals for layer, broiler and breeders.

Unit II (12 Lectures)

Planning poultry enterprise – Minimum viable units - Bank norms for poultry projects – Poultry insurance– Methods to improve the production efficiency and reduce the production cost - Components of project reports and preparing projects and return on investment.

Unit III (12 Lectures)

Integration in Poultry production and marketing – Marketing channels for eggs and meat - Cost of production of the egg, broiler, hatching egg, day-old chick and compounded feed –New regulations on cage rearing of layers. Traceability and branding of poultry products. Export norms for poultry products.

VI. Practical (17 Classes)

Preparing different poultry projects for bank finance – Calculating the cost of production of various products under various systems-case study – Preparation of Balance sheet, break-even points, Cost: Benefit ratio and other farm economic indices- Preparation of feasibility and viability reports.

VII. Teaching methods

- Classroom teaching with calculations
- Using Audio-visual capsules

IX. Learning outcome

Gaining knowledge of poultry marketing and project preparations.

X. Suggested Reading

- Bell DD and Weaver WD, Jr. 2002. *Commercial Chicken Meat and Egg Production*, 5th ed. Kluwer Academic Publishers.
- Narahari D and Asha Rajini R. 2005. *Poultry Economics and Projects*. Pixie Publication India (P) Ltd.

I. Course Title : Physiology of Poultry Production

II. Course Code : PSC 609

III. Credit Hours : 1+1

IV. Why this course?

V. Aim of the course

To study the basic principles of physiology of poultry production in relation to egg production, incubation, stress and role of environment.

VI. Theory

Unit I (7 Lectures)

Skeletal system of poultry – Comb pattern and plumage - Physiology of poultry digestive system- Digestion, metabolism and absorption of feed and water – Role of enzymes – Poultry circulatory system – Respiratory system – Physiology of growth.

Unit II (7 Lectures)

Poultry nervous system and its function – Excretory system – Male and female reproductive system - Semen production-semen characteristics- Semen extenders – Egg formation- Egg laying pattern-photo periodic responses – Role of endocrine glands and their functions - Neuroendocrine control of egg production - Ovulation and Oviposition – Clutch and Pause.

Unit III (3 Lectures)

Thermoregulatory mechanism – Stress due to adverse environmental factors – Acid-base balance

VII. Practical (17 Classes)

Demonstration of various systems of birds – the structure of feather - Identification of endocrine glands and demonstration of hormones estimation in poultry production and reproduction - Haematology of poultry species - SGOT, SGPT, free fatty acids - Morphology of Poultry spermatozoa. Demonstration of artificial insemination in poultry.

VIII. Teaching methods

- Classroom teaching with laboratory techniques
- Using Audio-visual capsules

IX. Learning outcome

Gaining knowledge on the physiology of poultry production

X. Suggested Reading

- Etches RJ. 1995. *Reproduction in Poultry*. CAB International.
- Scanes CG. 2014. *Sturkie's Avian Physiology*. Elsevier.

I. Course Title : Commercial Poultry Nutrition

II. Course Code : PSC 610

III. Credit Hours : 1+1

V. Aim of the course

To impart knowledge on advanced poultry nutrition with respect to commercial egg and meat production

VI. Theory

Unit I (7 Lectures)

Breed specific nutrient requirements. Factors influencing the digestibility of nutrients – Reasons to assist the birds for digestion – Gut health management.

Unit II (4 Lectures)

Commercial use of feed ingredients by the industry – their drawbacks - Use of different feed additives and supplements: Enzymes, prebiotics, probiotics, postbiotics, phytobiotics, nucleotides, acidifiers, emulsifiers, and essential oils, etc. – Trace minerals: organic, inorganic and nanoparticles – Pre-digested proteins.

Unit III (6 Lectures)

Unconventional feed ingredients: Merits and demerits – Measures to counteract the demerits – Responsible use of them for reducing the cost of production – Least cost feed formulation – Phase feeding for layers and broilers – Juvenile nutrition.

VII. Practical (17 Classes)

Analytical methods for quick estimation of proximate principles and other nutrients – Use of latest technologies like NIR – Force-feeding, Challenge feeding – Factors preventing the birds from optimum feeding: Particle size, feed milling technologies, etc.– Seasonal variations in feeding practices, in-ovo feeding, visit to commercial poultry nutrition lab and feed mill.

VIII. Teaching methods/ activities

- Classroom teaching with laboratory support and feed mill visits
- Use of computers in feed formulations

IX. Learning outcome

Gaining knowledge on advances in poultry nutrition

X. Suggested Reading

- ICAR. 2013. *Nutrient Requirements of Poultry*. ICAR Publication.
- Leeson S and Summers JD. 2001. *Scott's Nutrition of the Chicken*. University Books.
- Leeson S and Summers JD. 2008. *Commercial Poultry Nutrition*, 3rd ed. University Books.
- Singh RA and Panda B. 1992. *Poultry Nutrition*. Kalyani Publishers.

I. Course Title : Poultry Welfare and Waste Management

II. Course Code : PSC 611

III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge on the concept of poultry welfare and safe disposal of wastes generated from poultry farms

V. Theory

Unit I (14 Lectures)

Concept of poultry welfare – Different freedoms to the birds – Present housing systems with relation to the welfare – Welfare and productivity – Feed restriction – Economics - Welfare cages – Welfare in relation to country's requirement. Precautions and requirements before, during and after transport of birds from one place and another, thermal imaging, assessment of welfare in poultry

Unit II (20 Lectures)

Waste generated from poultry farms and hatcheries – Male chicks disposal - Hazards of waste for humans and environment – Spread of diseases – Fly problems – Leaching of toxic substances in groundwater – Emission of gases – Dust and smell problem – Disposal of carcasses – Means to mitigate the hazardous effects of wastes – Composting of manure and dead birds - Generation of biogas, electricity, rendering plant products for feeding other species – Wastewater recycling – Usage of slurry – Preparation of bio-fuel pellets, methods of recycling poultry feathers.

VI. Teaching methods

- Classroom teaching
- Visit various waste disposal units

VII. Learning outcome

Gaining knowledge on the welfare of poultry and methods for safe disposal of poultry wastes

VIII. Suggested Reading

- Collins E (Ed.). 1999. *Poultry Waste Management Handbook*. NARES Series 132. Natural Resources.
- DAHD. 2015. *Poultry Farm Manual*. Department of Animal Husbandry, Dairy and Fisheries, GOI.
- Mench JA. 2017. *Advances in Poultry Welfare*. Woodhead Publishing
- Overcash MR, Humenik FJ and Miner RJ. 1983. *Livestock Waste Management*. CRS Press.

Course Title with Credit Load
Ph.D. in Poultry Science

Course Code	Course Title	Credits Hours
PSC 701*	Applied Poultry Nutrition	2+1
PSC 702*	Recent Trends in Commercial Poultry Production	2+1
PSC 703	Developments in Poultry Processing and Products Technology	2+1
PSC 704	Emerging Diseases of Poultry and Health Management	2+1
PSC 705	Applied Poultry Breeding	1+1
PSC 706	Poultry Economics, Marketing and Integration	2+1
PSC 707	Diversified Poultry Production	2+1
PSC 791	Seminar I	1+0
PSC 792	Seminar II	1+0
PSC 799	Research	75

*Core courses

Course Contents
Ph.D. in Poultry Science

I. Course Title : Applied Poultry Nutrition

II. Course Code : PSC 701

III. Credit Hours : 2+1

IV. Aim of the course

Teaching about nutrients and their functions, nutrient requirements of poultry and factors influencing the same. Different methods and forms of feeds and feeding of poultry.

V. Theory

Unit I (10 Lectures)

Developments in the nutrient requirement for egg and meat-type chicken - Concepts in various poultry feeding procedures and methods for optimal production - Factors influencing the nutrient requirements, feed intake and feed efficiency in poultry - Nutritional deficiencies - Protein and energy utilization – Digestibility of nutrients – Ileal digestibility of amino acids - Vitamins, minerals and their interactions in poultry rations.

Unit II (10 Lectures)

In ovo - juvenile nutrition for optimal growth rate and feed efficiency – Care in grower and pre-layer feeding - Nutrition and feeding of layers/ breeders during peak egg production - Nutritional requirements for higher egg production, broiler meat production, fertility and hatchability and other special purposes.

Unit III (10 Lectures)

Feeding of broilers for uniform growth and feed efficiency – Feeding to enhance egg quality and nutrients – Nutritive and non- nutritive feed additives in feed production – organic, functional and designer feed. Advances in feed milling technology – Specialty feed production to produce microbial safe foods, SPF eggs and organic foods.

Unit IV (4 Lectures)

HACCP implementation in feed quality control – Production of feed free from antibiotics, mycotoxins and pesticide residues.

VI. Practical

Computation of specific and functional feeds – Estimation of available carbohydrate/ Metabolizable energy, Aflatoxin, anti-nutritional factors and other toxins in the feed. Evaluation of various feeds for its quality – Field methods of feed quality control including feed microscopy – Estimation of carotenes, cholesterol and peroxides. Quality control of functional poultry feeds – Maintaining the feed quality from production to consumption.

VIII. Teaching methods

- Classroom teaching with laboratory support and feed mill visits
- Use of computers in feed formulations

IX. Learning outcome

Gaining advanced knowledge in poultry nutrition.

X. Suggested Reading

- Bell DD and Weaver WD, Jr. 2002. *Commercial Chicken Meat and Egg Production*, 5th ed. Kluwer Academic Publishers.
- ICAR. 2013. *Nutrient Requirements of Poultry*. ICAR Publication.
- Leeson S and Summers JD. 2001. *Scott's Nutrition of the Chicken*. University Books.
- Leeson S and Summers JD. 2008. *Commercial Poultry Nutrition*, 3rd ed. University Books.Nutrient
- Singh RA and Panda B. 1992. *Poultry Production*. Kalyani Publishers.
- *Selected articles from journals.*

I. Course Title : Recent Trends in Commercial Poultry Production

II. Course Code : PSC 702

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on different systems of poultry rearing, care and management of commercial layers/ broilers for optimal egg and meat production.

V. Theory

Unit I (7 Lectures)

Global trends in poultry production - Advances in broiler production in India – concepts in egg production – Latest concepts in breeder management – advances in hatchery operations for higher hatchability and chick quality – Use of artificial intelligence in poultry production.

Unit II (8 Lectures)

Optimal microclimatic condition in poultry houses and cages for higher production – Management of poultry in environmentally controlled houses – Management of poultry under adverse climatic conditions – advances in the management of other species of poultry - Behavioural patterns of poultry in different growing systems.

Unit III (7 Lectures)

Advanced management techniques for egg and meat production - advances in lighting management, feeding management, litter management and manure management.

Unit IV (5 Lectures)

Factors influencing egg production in different species of poultry – Factors influencing growth rate and egg production - Automation in poultry production.

Unit V (7 Lectures)

Regulations for cage-free egg production and organic chicken production – Functional feeds for functional foods – Production of HACCP and GMP certified table eggs, meat, chicks, hatching eggs and other value-added products for export. Advances in Biosecurity, welfare and waste management - Role of integration in poultry production.

VI. Practical (17 Classes)

Performance study in the commercial layer, broiler, Japanese quail, duck, turkey and other species of poultry farms by Interpretation of the farm records - Management routines of different species of poultry - calculating the cost of production – Estimation of microclimatic conditions and comparing the productive traits– Modern poultry house and cage design for optimal efficiency and cost reduction.

VII. Teaching methods

- Classroom teaching with farm visits
- Use of Audio-visual capsules

VIII. Learning outcome

Gaining knowledge of advanced commercial poultry production practices

IX. Suggested Reading

- Bell DD and Weaver WD, Jr. 2002. *Commercial Chicken Meat and Egg Production*, 5th ed. Kluwer Academic Publishers.
- Sreenivasaiah PV. 2006. *Scientific Poultry Production: A Unique Encyclopaedia*. International Book Distributing Co.
- Online sources of equipment manufacturers
- *Selected articles from journals.*

I. Course Title : Developments in Poultry Processing and Products Technology

II. Course Code : PSC 703

III. Credit Hours : 2+1

IV. Aim of the course

Composition and nutritive value of eggs and chicken meat, grading, packaging and preservation methods of eggs and meat, functional and value-added poultry products, marketing of eggs and poultry meat.

V. Theory

Unit I (9 Lectures)

Global trends in egg and poultry processing -Indian scenario of poultry processing industry - Nutrients and Non-nutrient components in regular and value-added poultry products – various measures of egg and meat quality control – advances in value addition to poultry products.

Unit II (12 Lectures)

Concepts in poultry meat and egg preservation – Newer concepts in meat tenderization, canning, dehydration, curing, irradiation, etc. - Modified atmosphere packaging and other packaging techniques – Other processed products - Room temperature preservation of poultry fast foods by multi hurdle technology – Further processing to produce ready to eat products.

Unit III (5 Lectures)

Egg powder production - Egg desugarization - pasteurization – Functional properties of eggs – Industrial uses of eggs – Marketing trends in poultry meat and eggs.

Unit IV (8 Lectures)

Improving the product quality to meet Codex and European standards – Standards for the egg, meat and their products -Production of immunoglobulins, lecithin, lysozyme, sialic acid and other pharmaceutical products from eggs – Sanitary and phytosanitary measures for food safety.

VII. Practical (17 Classes)

Preparation of value-added products suitable for preservation at room temperature– Further processing – Barbecuing and Tandoori preparation – preparation of local specific poultry meat and egg products – Meatballs, meat patties, etc. - Quality estimation of egg, meat and their products - Preservation of meat and eggs - Measuring the microbial quality of poultry foods.

VIII. Teaching methods

- Classroom teaching with laboratory analysis
- Preparation of value-added meat and egg products
- Use of Audio-visual capsules

IX. Learning outcome

Gaining knowledge of advanced poultry products and processing technology.

X. Suggested Reading

- Biswas A and Kondaiah N. 2014. *Meat Science and Technology*. Jaya Publishing House.
- Mead G. 2004. *Poultry Meat Processing and Quality*. Elsevier.
- Mountney GJ and Parkhairst CR. 1995. *Poultry Products Technology*, 3rd ed. AVI Publ.
- Owens CM. 2010. *Poultry Meat Processing*. CRC Press.
- Stadelman WJ and Cotteril OJ. 1995. *Egg Science and Technology*, 4th ed. CRC Press.
- *Selected articles from journals.*

I. Course Title : Emerging and Reemerging Diseases of Poultry and Health Management

II. Course Code : PSC 704

III. Credit Hours : 2+1

IV. Aim of the course

To study about common diseases and disorders of poultry, their diagnosis, vaccination, prevention and treatment, emphasis on control of emerging poultry diseases of zoonotic importance, disease diagnostic techniques.

V. Theory

Unit I (6 Lectures)

Concepts of disease prevention in poultry – Emerging and re-emerging avian diseases -Factors influencing immunosuppression/ immunity – Enhancing immunity in poultry.

Unit II (10 Lectures)

Water sanitation, hatchery sanitation procedures - Control of vertically transmissible diseases, hatchery borne diseases – non-infectious, metabolic and parasitic diseases in poultry and their control –Mycotoxins and their control.

Unit III (12 Lectures)

Stress alleviation – prevention and control of bacterial and viral diseases in poultry – Biosecurity measures – Control measures of problematic re-emerging diseases of poultry like Ranikhet, Avian influenza, Marek’s disease, Infectious bursal disease, Infectious Bronchitis, Infectious laryngotracheitis, etc.

Unit IV (6 Lectures)

Flock management for Specific pathogen-free egg production – Maintaining the

HACCP standards in poultry farms – developments in the EXIM policies for flock health – Concept of compartmentalization and zoning as per terrestrial code., geographical information system in disease control.

VI. Practical (17 Classes)

Studying the Immune status of birds – Egg inoculation techniques in laboratory diagnosis – differential diagnosis of various poultry diseases by post-mortem, and laboratory techniques – Molecular diagnosis of diseases - Antibiotic sensitivity test – Designing Vaccination schedule for different poultry species – Disinfection and sanitation - Ectoparasite control, medication procedures.

VII. Teaching methods

- Classroom teaching with laboratory techniques
- Post-mortem examination and sample collection
- Use of Audio-visual capsules

VIII. Learning outcome

Gaining knowledge of the emerging disease of poultry and health management.

IX. Suggested Reading

- Davison F, Kaspers B and Schat KA. 2008. *Avian Immunology*. Elsevier
- Pattison M, McMullin P, Bradbury JM and Alexander D. 2008. *Poultry Diseases*, 6th ed. Elsevier.
- Thyagarajan D. 2011. *Diseases of Poultry*. Satish Serial Publishing House.
- Vegad JL. 2015. *Poultry Diseases Farmers. A Guide for Farmers and Poultry Professionals*. International Book Distributing Co.
- *Selected articles from journals.*

I. Course Title : Applied Poultry Breeding

II. Course Code : PSC 705

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge about different systems of breeding, selection methods and implementation of the breeding programme in developing egg and meat type hybrids. Modern tools in poultry breeding.

V. Theory

Unit I (7 Lectures)

Gene and genotypic frequency - Sex-linked, limited and influenced traits-Auto sexing- Qualitative and quantitative traits and its inheritance in poultry- methods of selection – family selection – selection for multi characteristics and construction of selection indices –Reciprocal recurrent selection – Recurrent selection, Marker assisted selection – Random bred control populations - Selection limit - Osborne's index – construction of selection index for multiple traits - Use of molecular genetics in poultry breeding.

Unit II (5 Lectures)

Exploitation of additive and non-additive gene action for commercial poultry production - Heterosis – Exploitation of hybrid vigour for commercial production of layers and broilers - Formation of synthetic lines – Development of strains in poultry - Comparative efficiency of different selection methods in poultry.

Unit III (5 Lectures)

Modern methods in commercial layer and broiler breeding, performance testing – Pure line-breeding – Inbreeding and hybridization - Diallele mating. Pedigree hatching. Genotype × Environment interaction.

VI. Practical (17 Classes)

Construction of selection index – Analysis of breeding data collected from breeding records – Estimation of qualitative and quantitative inheritance - Estimation of variance, heritability and standard error of heritability by different methods – Repeatability - analysis of heritability for different traits – Estimation of inbreeding coefficient – Artificial insemination in poultry.

VII. Teaching methods

- Classroom teaching with breeding farm visits
- Utilizing computer for quantitative genetic analysis
- Use of Audio-visual capsules

VIII. Learning outcome

Gaining knowledge on applied poultry breeding methods

IX. Suggested Reading

- Crawford RD. 1990. *Poultry Breeding and Genetics*. Elsevier.
- Muir WM and Aggrey SE. 2003. *Poultry Genetics, Breeding and Biotechnology*. CAB International.
- Singh R and Kumar J. 1994. *Biometrical Methods in Poultry Breeding*. Kalyani Publishers.
- *Selected articles from journals.*

I. Course Title : Poultry Economics, Marketing and Integration

II. Course Code : PSC 706

III. Credit Hours : 2+1

IV. Aim of the course

To study about measures of performance efficiency in poultry farms and its allied sectors, hatcheries and developing poultry projects.

V. Theory

Unit I (11 Lectures)

Present practices and future trends in the production of egg and meat – Present trends in consumption – Demand and supply - Seasonal variations in production and consumption. Marketing channels- procedures of marketing for eggs and meat - Market intelligence -Advertising and branding of poultry products.

Unit II (14 Lectures)

Various poultry enterprises – choice of production size of business – input and output analysis – calculating cost of various inputs – calculating cost of production – Break-even point analysis - Price determination – Role of NECC, BroMark and other marketing agencies - Least demand and supply indices of performance – Performance targets and achievements - marketing and business management - market managerial skills and human resource development - cost and financial management.

Unit III (9 Lectures)

Future trends in broiler and egg production – Factors influencing the profit margin in poultry enterprises – Role of integration in Poultry business – Different types of integration.

VI. Practical (17 Classes)

Study of marketing channels of egg and meat, calculating the cost of production of eggs, meat, day-old chick and feed – Calculating marketing costs - Preparing other related poultry projects. Use of social media in popularizing poultry and poultry products – Study of successful business models in the poultry sector.

VII. Teaching methods

- Classroom teaching and interaction with the poultry industry
- Use of Audio-visual capsules

VIII. Learning outcome

Gaining knowledge of market intelligence and marketing techniques

IX. Suggested Reading

- Narahari D and Asha Rajini R. 2005. *Poultry Economics and Projects*. PIXIE Publications India (P) Ltd.
- Vashisht K. 2006. *Practical Approach to Marketing Management*. Atlantic.
- Online sources of NABARD website4. *Selected articles from journals*.

I. Course Title : Diversified Poultry Production

II. Course Code : PSC 707

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on care and management of different breeds, varieties of poultry other than chicken, methods of rearing and common diseases affecting them and their control measures.

V. Theory

Unit I (9 Lectures)

Commercial hybrid strains of ducks for egg and meat production – Feeding and management – Housing – Specific diseases of ducks, prevention and their control – Slaughter and processing of ducks – Economics of production of ducks, indigenous duck production system including polythene duck pond.

Unit II (8 Lectures)

Varieties of Japanese quail for meat and egg production – Cage and deep litter system of rearing of quails – Feeding and management – Housing – Emerging diseases affecting Japanese quail – Nutritive value of Japanese quail meat and egg - Economics of production of Japanese quail.

Unit III (9 Lectures)

Varieties/ breeds of Turkey, Guinea fowl, Geese, Emu and Ostriches – System of rearing – Feeding and management – Housing – Emerging diseases and their prevention – Nutritive value of Turkey, Geese and Guinea fowl – By-products of Geese, Emu and Ostriches.

Unit IV (8 Lectures)

Scope and constraints in the marketing of diversified poultry products – Rearing and management of common pet birds and other birds of regional importance – Common diseases affecting pet birds and their prevention and treatment - Economics of production of different pet birds.

Learning outcome

Gaining advanced knowledge of diversified poultry production

VI. Practical (17 Classes)

Layout and design of housing for other species of poultry. Visit commercial Japanese quail, turkey and duck farms. Incubation and care of hatching eggs and young ones – Rearing practices followed for duck, quails and turkey farmers under field conditions – Designing of aviaries for pet birds - Different types of feed prepared for pet birds – Vaccination and medication for diversified poultry species - Preparing project reports for different species and calculating the cost of production.

VII. Teaching methods

- Classroom teaching and visit to other avian species farms
- Use of Audio-visual capsules

VIII. Suggested Reading

- Cherry P and Morris T. 2011. *Domestic Duck Production: Science and Practice*. CAB International.
- CPDO. *Duck – Management Guide*. Central Poultry Development Organization Publication (online resource)
- CPDO. *Turkey – Management Guide*. Central Poultry Development Organization Publication (online resource)
- Pathak N. 2013. *Poultry and Ratite Nutrition*. Narendra Publishing House.
- Thiyagarajan D. 2012. *Scientific Turkey Farming*. SSPH, New Delhi.

ANNEXURE I

List of BSMA Committee Members for Animal Production Sciences

Name, designation and address	Position	Specialization
1. **Dr S.P. Tiwari** Dean College of Veterinary Sciences Chhattisgarh Kamdhenu University, Durg-491 001	Chairman	Animal Nutrition
2. **Dr A.K. Pattanaik** Principal Scientist Division of Animal Nutrition ICAR-Indian Veterinary Research Institute Izatnagar-243 122	Convener	Animal Nutrition
3. **Dr A.K. Ghosh** Professor Department of Animal Genetics and Breeding GB Pant University of Agriculture and Technology Pantnagar-263 145	Member	Animal Genetics and Breeding
4. **Dr S.M. Deb** Principal Scientist Division of Animal Genetics and Breeding ICAR-National Dairy Research Institute Karnal-132 001	Member	Animal Genetics and Breeding
5. **Dr M. Mahender** Associate Dean College of Dairy Technology (PVNRTVU) Kamareddy 503 111	Member	Livestock Production and Management
6. **Dr (Mrs) Sanjita Sharma** Head Department of Livestock Production and Management, and Dean, Post Graduate Institute of Veterinary Education and Research (RAJUVAS) Jaipur-302 031	Member	Livestock Production and Management
7. **Dr K. Kondal Reddy** Registrar (Retd.) PV Narsimha Rao Telangana Veterinary University Hyderabad-500 030	Member	Livestock Products Technology

Name, designation and address	Position	Specialization
8. **Dr S.K. Mendiratta** Head Division of Livestock Products Technology ICAR-Indian Veterinary Research Institute Izatnagar-243 122	Member	Livestock Products Technology
9. **Dr A.S. Yadav** Principal Scientist Division of Post-Harvest Technology ICAR-Central Avian Research Institute Izatnagar-243 122	Member	Poultry Science
10. **Dr P.K. Shukla** Registrar PDDU Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan (DUVASU) Mathura-281 001	Member	Poultry Science

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Restructured and Revised Syllabi of Post-graduate Programmes

- Dairy Science and Technology
- Agricultural Engineering & Technology
- Food Sciences Technology

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त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the

syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language.*
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing.*
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition.* S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

   (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

   (b) An application is made by the student concerned duly supported by the Advisory Committee;

   (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

   (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 4

Dairy Science and Technology

- Dairy Technology
- Dairy Engineering
- Dairy Chemistry
- Dairy Microbiology

Contents

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Preamble

The contents of the master's and doctoral courses were critically examined for introducing new dimension to the curriculum in light of the advances made in the scientific knowledge in thefour major disciplines of Dairy Processing and allied disciplines during the last ten years. In Dairy Technology discipline, two new courses at Master's Levelhavebeen added.The course on Production and Applications of Dairy Ingredients covers the principles of conventional and novel approaches for separation, concentration and fractionation of milk components and the second course on Advances in Cheese Technology primarily focuses on the new developments in rennet and acid coagulated cheeses. For doctoral level program in this discipline, Advances in Carbohydrate Technology has been added as a new course. Two other courses namely Advances in Food Processing and Non-Conventional Processes for Dairy and Food Industry have been significantly modified while minor changes have been incorporated in the contents and titles of the other courses. In Dairy Microbiology discipline, two old courses 'Methods in Microbiology' and 'Feed and Rumen Microbiology' have been removed and three new courses 'Microbiology of Fluid Milk and Dairy Products'; 'Microbiology of Cheese and Fermented Dairy Foods' and 'Research Techniques' have been introduced in Masters' Degree Programme to make the students abreast with the emerging trends and scope of microbiology of milk and milk products along with the conventional and innovative analytical instrumentationsrelevant during the research work.In doctoral programme, the course 'Microbiology of Food-borne Pathogens' has been replaced with two new courses 'Advances in Food Safety of Dairy Products' and 'Advances in Probiotics and Functional Foods' to address the recent development in rapid changing fields of food safety and functional foods. In Dairy Engineering discipline, five new courses for Master level program, viz. Industrial Automation and Robotics, Unit Operations, Engineering Properties of Dairy and Food Products, Mechanization in Manufacturing of Indigenous Dairy Products and Energy Management and Auditing in Dairy and Food Plants and two new courses for doctoral program, viz. Advances in Food Process Engineering and Package Permeability and Shelf-Life Modelling have been added in the course curriculum. The idea for inclusion of these courses was conceived based on the feedback from the students working in the industry and educational institutions. In addition to their relevance to the dairy operations, thesenew courses would cover a wide spectrum of application of engineering principles and would be particularly helpful to the students in comprehensive understanding of the subject and in several competitive examinations which require sound basic engineering knowledge. In Dairy Chemistry discipline, although no new course has been introduced; significant changes in the course content were made in the existing courses. The course on Physico-chemical Aspects of Milk Constituents has been modified to better understand the physico-chemical properties of milk constituents in light of the emergence of new analytical techniques, along with the addition of topics related to their recent application in food processing, storage and quality assurance. The courseon Chemistry of Food Constituents has been restructured in such a way that different constituents both major and minor are covered with their specific properties for better applications in the food processing. Additionally, the credit load and the nomenclature of many other courses have been suitably revised for their better understanding and applications.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Technology

Course Title with Credit Load
M.Tech. in Dairy Technology

Course Code	Course Title	Credit Hours
	Major Courses	
DT-511*	Advances in Dairy Processing	3+1
DT-512	Advances in Food Processing	3+1
DT-513*	Rheology of Dairy and Food Products	2+1
DT-514	Biotechnology for Dairy Applications	2+1
DT-515	Advances in Traditional Indian Dairy Products	2+1
DT-516	Non-conventional Processes for Dairy and Food Industry	2+1
DT-521*	Membrane Processing for Dairy Applications	2+1
DT-522*	Advances in Dairy and Food Packaging	2+1
DT-523	Technology of Food Emulsions, Foams and Gels	2+1
DT-524	Functional Foods and Nutraceuticals	3+1
DT-525	Production and Applications of Dairy Ingredients	2+1
DT-526	Advances in Cheese Technology	2+1
DT-591	Master’s Seminar	1+0
DT-599	Master’s Research	0+30

Course Contents
M. Tech. in Dairy Technology

I. Course Title : Advances in Dairy Processing

II. Course Code : DT 511

III. Credit Hours : 3+1

IV. Why this course?

The basic principles of dairy processing have been understood at undergraduate level. Any dairy plant has to be abreast with the latest developments taking place in the arena of dairy processing, dairy product preservation, quality assurance and public health safety, automation, mechanization, etc. Knowledge of such aspects will help in controlling milk solids losses, aid in process optimization and help in catering to quality dairy products to the consumers.

V. Aim of the course

To provide in-depth knowledge about the various unit operations and basic concepts in dairy processing

VI. Theory

Unit I

Use of bio-protective factors for preservation of raw milk: effects on physico-chemical, micro-bial and nutritional properties of milk and milk products; Present status of preservation of raw milk.

Unit II

Methods of determining lethality of thermal processing; UHT processed milk products, their properties and prospects, types of UHT plants, aseptic fillers, heat stability and deposit formation aspects, effect on milk quality; techno-economic considerations; Nutritional aspects of UHT treated milk vis-à-vis retort sterilized/ HTST treated milk.

Unit III

Principles and equipment for bactofugation and bactotherm processes; Partial homogenization and its application in dairy industry, Low pressure homogenization; Microfluidization of milk: Principle, equipment, effects and applications.

Unit IV

Concentration processes and their impact on quality of finished products; Dehydration: advances in drying of milk and milk products; Freeze dehydration: physico-chemical changes and in-dustrial developments; Glass Transition Temperature and its relevance to dried milks.

Unit V

Water activity; Sorption behaviour of foods, energy of binding water, control of water activity of different milk products in relation to their chemical, microbiologi-cal and textural properties; Hurdle technology and its application in development of shelf-stable and intermediate-moisture foods; Use of carbonation in extending the shelf life of dairy products.

Unit VI

Current trends in cleaning and sanitization of dairy equipment; Automation, Ultrasonic techniques in cleaning; Bio-films; Bio-detergents, innovations in sanitizers - chemical, radiation; Mechanism of fouling and soil removal; Assessing the effectiveness of cleaning and sanitization of dairy equipment, Water conservation methods.

VII. Practical

- Measurement of thiocyanate in milk system
- LP system for extending the keeping quality of raw milk
- Determination of HCT-pH profile of milk
- Determination of water activity and sorption isotherms of milk products
- Determination of WPNI of milk powders
- Functional properties of milk powders
- Determination of HMF content in dried milks
- Freeze drying of milk and milk products
- Homogenization efficiency
- Cleaning and sanitization efficiency of dairy equipment
- Visit to a UHT Processing plant.

VIII. Teaching Methods/Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work and Group Discussion
- Visit to various dairy plants

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge to ensure delivery of safe and quality product from the dairy plant to the consumers
- To process the milk and dairy products in such a manner that losses of milk solids are minimal
- Be able to suggest to the dairy plant personnel, the latest type of tools that can be harnessed to produce quality products, without impairing the nutritive value of milk
- To suggest the dairy industry personnel regarding the formulation of detergent and/or acid and sanitizers which would help in efficient cleaning and sanitization of dairy equipment?

X. Suggested Reading

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- Scherjon Dairy Equipment Holland: Dairy processing equipment-https://scherjon.eu/
- National Dairy Council-https:/nationaldairycouncil.org/
- Alfa Laval – Dairy Processing-https://alfalaval.in/industries/food-dairy-and-beverage/dairy-processing/

I. Course Title : Advances in Food Processing

II. Course Code : DT 512

III. Credit Hours : 3+1

IV. Why this course?

The basic principles of food processing, including dairy processing has been understood at undergraduate level. Any food plant has to be abreast with the latest developments taking place in the sphere of food processing, food product preservation, quality assurance and public health safety, automation, mechanization, etc. Information on composite foods may give an idea about foods formed using amalgamation of dairy foods with other food materials and ingredients. Knowledge of such aspects will help in developing value-added food products, cater to functional (health promoting) foods, adopting non-thermal processing methods to obtain food products having freshness and preserved nutrients and colour, etc.

V. Aim of the course

To provide in-depth understanding of advances in theoretical and practical aspects of food processing keeping in mind the nutritive value of product and its perishability

VI. Theory

Unit I

Status of food processing industry in India and abroad; Prospects and constraints in development of Indian food industry.

Unit II

Development in Post-harvest management of Fruits and Vegetables (Controlled and Modified Atmospheric Storage, Designing aspects of CAS/MAS, Components of CAS/MAS), hypobaric storage, harvesting indices for fruits and vegetables.

Unit III

Newer methods of drying of foods (Super-heated steam drying, Freeze drying, infra-red drying and microwave drying; Osmodrying process), Concepts of UHT and retort sterilization of food products, packaging materials for thermally processed foods.

Unit IV

Basic principles involved in fermentation, Technological aspects of pickled vegetables like sauerkraut, cucumbers, Technology of wine, beer and distilled alcoholic beverages, defects in alcoholic beverages.

Unit V

Advances in milling of rice (solvent extractive milling) and Turbo milling of wheat. Emerging concepts in cereal processing including gluten free products, Low calories bakery products, Technologies for breakfast cereals, Utilization and importance of dairy ingredients in bakery products.

Unit VI

Definition, classification and technologies of fabricated and formulated foods and their nutritional aspects. Imitation dairy products and dairy analogues; meat analogues. Principle of extrusion processing, design and working of extruder, classification, application in food and dairy processing. Food additives, including stabilizers, emulsifiers, antioxidants, preservatives, etc. for formulated foods. Fortification of staples.

Unit VII

Non-thermal processing technologies for food: Principles, Effect on food constituents and Salient application in food sector/industry.

Unit VIII

Enzymes in food processing; newer concepts in food processing including organic foods; Processing of organic raw material; Genetically modified foods; Space foods, Nutrigenomics, metabolomics and other Omics concepts in food processing.

VII. Practical

- Experiments on MAS of fruits and vegetables
- Application of microwave for blanching and drying of foods
- Osmoair drying of fruits and vegetables

- Retort processing of food products
- Application of milk ingredients in caramel, egg-less cake, mayonnaise
- Enzymatic extraction and clarification of fruit juices
- Preparation of soymilk and tofu, Manufacture of sauerkraut/ fermented vegetables
- Preparation of protein isolates
- Application of extrusion processing for breakfast cereal and meat analogue manufacture
- Application of hydrocolloids in stabilization of proteins in acidified beverages
- Manufacture of low calorie and gluten-free cereal products.

VIII. Teaching Methods/Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work and Group Discussion
- Visit to various food plants

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the latest post-harvest management of fresh produce with limited shelf life
- To have an idea about the processing methods that do not diminish the quality attributes of food being processed
- To know about the recent packaging methodologies that can enhance the shelf life of fresh as well as processed produce/food.
- To have any idea about the enzymes that can be used as processing aids.

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- *Welcome to APEDA*-https//*apeda.gov.in/*
- *Food safety and quality: Chemical risks and JECFA-FAO-https//fao.org/food/food-safety-quality/scientific-advice/jecfa/en/*
- HACCP and GHP: Standards in Food Industry: (EUFIC)-https://eufic.org/en/food-safety/article/food-industry-standards-focus-on-haccp

I. Course Title : Rheology of Dairy and Food Products

II. Course Code : DT 513

III. Credit Hours : 2+1

IV. Why this course?

The mouth feel of processed food product is one of the parameters for the acceptance of foods. The sensory textural quality of food is closely related to the rheology of that pertinent food product. Any technological treatment meted out to dairy/food product leads to change in its rheological characteristics. Such treatment can be specifically practiced to improve the textural quality of food product. Rheology can be used as a quality control tool to monitor the quality of food product being processed or manufactured.

V. Aim of the course

To explain the basics of food rheology, and to familiarize the students with rheological instruments and their use in relation to dairy and food products

VI. Theory

Unit I

Introduction to rheology of foods: Definition of texture, rheology and psychophysics – their structural basis; Physical considerations in study of foods; Salient definitions of stress tensor and different kinds of stresses.

Unit II

Rheological classification of Fluid Foods: Shear-rate dependence and time dependence of the flow-curve; Non-Newtonian fluids; Mechanisms and relevant models for non-Newtonian flow; Effect of temperature on rheology; Compositional factors affecting flow behaviour; Viscosity of food dispersions: dilute and semi-dilute systems, concentration effects.

Unit III

Viscometers; Types (Co-axial cylinders, Spindle or Impeller type, Cone-plate, Capillary, Falling sphere, Vibratory, Extrusion, and Orifice), comparative assessment, merits and limitations; Rheometer: principles and operational features.

Unit IV

Rheological characterization of semi-solid and solid foods; Mechanical models for viscoelastic foods (Maxwell, Kelvin, Burgers and generalized models) and their application; Dynamic measurement of viscoelasticity.

Unit V

Large Deformations and failure in foods: Definitions of fracture, rupture and other related phenomena; Texture Profile Analysis; Instrumental measurements: Empirical and fundamental methods; Rheometers and Texture Analyzers; Measurement of extensional viscosity; Acoustic measurements on crunchy foods.

Unit VI

Rheological and textural properties of selected dairy products; Measurement modes and techniques; Effect of processing and additives (stabilizers and emulsifiers) on food product rheology; Relationship between instrumental and sensory data; Microstructure of dairy products; Tribology and its applications.

VII. Practical

- Study of different types of viscometers.
- Flow behaviour of fluid dairy products.
- Thixotropy in ice-cream mix.
- Force-deformation study in selected dairy products using Texture Analyzer.
- Effect of test conditions on the texture profile parameters of dairy products.
- Stress relaxation studies in solid foods.
- Use of Cone Pen-etrometer and FIRA-NIRD extruder for measurement of butter texture.
- Assessment of pasting profile of starch/flours using viscoanalysers.
- Oscillatory measurements using Rheometer.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Classify food products based on their rheological characteristics
– Understand the relationship between instrumental rheology and sensory perception of food
– To recommend use of textural analysis of dairy and food product for its quality control aspect
– To recommend specific type of instrument for textural analysis of specific type of food (fluid or solid)

IX. Suggested Reading

- Ahmed J, Ptaszek P and Basu S. (Eds.). 2016. *Advances in Food Rheology and its Applications*. Amsterdam: Woodhead Publishing.
- Barnes HA, Hutton JF and Walters K. 1989. *An introduction to rheology*. Elsevier Pub.
- Bourne M 2002. *Food texture and viscosity: Concept and Measurement*. London: Elsevier Pub.
- Irgens F. 2014. *Rheology and Non-Newtonian Fluids*. New York: Springer International Publishing.
- Malkin AY and Isayev AI. 2017. *Rheology: Concepts, methods, and applications*. Toronto: ChemTec Publishing.
- Mezger TG. 2006. *The Rheology Handbook: For Users of Rotational and Oscillatory Rheometers*. Hannover: Vincentz Network GmbH and Co KG.
- Mohsenin NN. 1970. Physical properties of plant and animal materials. Vol. 1. Structure, physical characteristics and mechanical properties. New York: Gordon and Breach Science Publishers.
- Norton IT, Spyropoulos F and Cox P. (Eds.). 2010. *Practical Food Rheology: An Interpretive Approach*. John Wiley and Sons.

- Rao MA. 2013. *Rheology of fluid, semisolid and solid foods: Principles and applications*. New York: Springer Science and Business Media.
- Sherman P. 1979. *Food texture and rheology*. London: Academic press.

Websites

- Texture in Food Production – Food Technology Corporation- https://www.foodtechcorp.com/texture-food-production
- Universal testing/Tensile testing machine: SCHIMADZU- https//shimadzu.com/an/test/universal/index.html
- Texture Analysis System and Software – Food Online- https://foodonline.com/doc/texture-analysis-system-and-software-0001

I. Course Title : Biotechnology for Dairy Applications

II. Course Code : DT-514

III. Credit Hours : 2+1

IV. Why this course?

Biotechnology is a tool for the value addition to dairy foods. Genetic techniques have been employed to manipulate bacteria that have significance to the dairy industry. Biotechnological means can be used to regulate the production of flavour enhancing metabolites and to develop starter cultures that are resistant to bacteriophage and bacteriocins. Genetic engineering will be able to deliver dairy foods that can be tolerated by lactose intolerant persons or for persons who are allergic to milk proteins too.

V. Aim of the course

To project the importance of biotechnology in dairy processing and imparts knowledge on all aspects of dairy process biotechnology in production and preservation of dairy products employing the principles of biotechnology.

VI. Theory

Unit I

Introduction to process biotechnology; Principles of recombinant DNA technique; Development and impact of biotechnology on dairy and food industry.

Unit II

Microbial rennet and recombinant chymosin - characteristics and applications in cheese making; exogenous free and microencapsulated enzymes. Immobilized enzymes - their application in continuous coagulation of milk in cheese making; Enzyme modified cheeses (EMC) - their utilization in various food formulations.

Unit III

Technological requirements of modified micro-organisms for applications in cheese, Probiotic and fermented milk products; physiologically active bio-peptides/ nutraceuticals.

Unit IV

Protein hydrolysates - production, physico-chemical, therapeutic properties and application in food formulations; Enzymatic hydrolysis of lactose for preparation of whey and UF-permeate beverages; Continuous lactose hydrolysis of whey.

Unit V

Microbial polysaccharides - their properties and applications in foods; Production of alcoholic beverages; Bio-sweeteners - Types, properties and their applications in dairy and food industry.

Unit VI

Bio-preservatives - characteristics and their applications in enhancing the shelf life of dairy and food products.

VII. Practical

- Effect of exogenous enzymes on hydrolysis of protein and fat in culture containing milk sys-tems
- Factors affecting the coagulation of milk by microbial and vegetable rennets
- Manu-facture and evaluation of probiotic cheese and fermented milks
- Preparation of Enzyme Modified Cheese
- Determination of glycolysis, proteolysis and lipolysis in cheese and fermented milks
- Enzymatic process for manufacture of low lactose milk/whey products
- Preparation of casein hydrolysates
- Visit to a bio-processing unit.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To have any idea about the enzymes that can be used as processing aids.
– Have knowledge on the latest biotechnological approaches to add value to the dairy product
– Ability to produce protein hydrolysates
– Application of biotechnology for bio-preservation of dairy foods

IX. Suggested Reading

- Aluko RE. (Ed.). 2012. *Functional Foods and Nutraceuticals*. Springer.
- Bhat R, Alias AK and Paliyath G. 2012. *Progress in Food Preservation*. John Wiley and Sons Ltd. (Print ISBN: 9780470655856. Online ISBN: 9781119962045) DOI: 10.1002/9781119962045.
- Coffey AG, Daly C and Fitzgerald G. 1994. The impact of biotechnology on the dairy industry. Biotechnology Advances, 12(4): 625-633. Elsevier Pub. doi.org/10.1016/0734-9750(94)90003-5

I. Course Title : Advances in Traditional Indian Dairy Products

II. Course Code : DT 515

III. Credit Hours : 2+1

IV. Why this course?

Traditional Indian dairy products (TIDP) especially the sweetmeats have its own significance in Indian diet and have tremendous export potential. The application of strict hygiene in manufacture of such TIDPs is the need of the day and its technology up gradation (especially mechanization and automation) from research level to industry level needs to be harnessed. Even there is an urgent need to have knowledge about the 'Techno-economic aspects for establishing commercial units for traditional dairy products'. Enhancement in the shelf life of TIDPs has been still a challenging task in the dairy industry.

V. Aim of the course

To project the present status, modernization and globalization of production of traditional Indian dairy products with a focus on process innovation, shelf life, quality and functionality enhancement.

VI. Theory

Unit I

Global prospects and export potential of traditional Indian dairy products.

Unit II

Differences in quality of traditional dairy products from cow, buffalo, goat, camel, and sheep milks; Process innovations in commercial production of heat-desiccated, coagulated and fermented traditional dairy products; Mechanized production of traditional milk based sweets; Automation for manufacture of ghee, *paneer*, *dahi*, *lassi*and traditional sweetmeats.

Unit III

Composite traditional milk products; Application of membrane technology and microwave processing for industrial production of traditional Indian dairy products.

Unit IV

Technologies for region specific traditional Indian dairy products and their value addition, their application as a vehicle for delivering functional ingredients; Manufacture of dietetic traditional dairy products.

Unit V

Techno-economic aspects for establishing commercial units for traditional products.

Unit VI

Convenience traditional dairy products; Food safety issues; Shelf life extension of food using newer techniques; Novel packaging and preservatives.

VII. Practical

- Production of reduced calorie, composite and functional traditional Indian dairy products.
- Microwave heating of traditional Indigenous milk delicacies for shelf life extension.
- Membrane technology for improving the quality of traditional Indigenous products made from cow and buffalo milk.
- Preparation of feasibility report for establishing commercial units for traditional dairy products.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Have an idea about the global prosper and export potential of TIDPs.
– Be an entrepreneur in delivering mechanized production of certain TIDPs including automation, wherever feasible.
– Be able to recommend the methods to enhance the shelf life of perishable TIDPs and recommend the type of packaging technology to be used for safety and shelf life extension.

IX. Suggested Reading

- Aneja RP, Mathur BN, Chandan RC and Banerjee AK. 2002. *Technology of Indian dairy products*. A Dairy India Publication.

- Goyal MR, Kumar A and Gupta AK. 2018. *Novel Dairy Processing Technologies: Techniques, Management, and Energy Conservation*. CRC Press.
- Puniya AK. 2015. *Fermented Milk and Dairy Products;* CRC Press/Taylor and Francis (ISBN 9781466577978)
- Shrott C and O'Brien. 2003. *Handbook of Functional Dairy Products*. CRC Press
- *TetraPak Dairy Processing Handbook*. 2015. www.dairypeocessinghandbook.com.

Websites

- Indian Dairy Product Market–Indian Council of Food and Agriculture– https//icfa.org.in/assets/doc/reports/Indian_Dairy_Product_Market.pdf
- Mechanized production of Indian Dairy Products–AMEFT– https//download.ameft.com/MechanisedProduction.pdf
- Indian Dairy Industry–Aavin – https//aavinmilk.com/dairyprofile.html
- Present Status of Traditional Dairy Products–Technische–TIB– https://www.tib.eu/en/search/id/./Present-Status-of-Traditional-Dairy-Products/

I. Course Title : Non-Conventional Processes for Dairy and Food Industry

II. Course Code : DT 516

III. Credit Hours : 2+1

IV. Why this course?

Unravelling the truths based on the knowledge of 'science and technology' has paved the way for development of several non-conventional technologies. These when used judiciously can have advantage in minimizing the changes in the colour, nutritive value and textural quality of dairy and food products. Certain non-conventional processes may be used as adjunct to the conventional processing technology to reap the benefits from use of such synergistic effects.

V. Aim of the course

To develop an understanding of the basic principles underlying the novel/non-conventional food processing techniques, equipment required, features and actual and potential applications

VI. Theory

Unit I

Irradiation: sources and properties of ionizing radiation; Mechanism of interaction with microorganisms and food components; Chemi-cal effects; Industrial irradiation systems, benefits and limitations; UV pasteurization of milk; Safety aspects in radiation processing; National and international regulations in relation to radiation processing; Cold plasma processing.

Unit II

High frequency heating (Microwave and Radio frequency processing): Principles, merits and demerits; Design and working of processing units; Applications in dairy and food processing; Microwavable packaging; Safety aspects.

Unit III

Infra-red (IR) heating and Ohmic heating: Principle, equipment and applications.

Unit IV

Ultrasonic treatment of food: Mechanism of ultrasound induced cell damage, generation of ultrasound, design of power ultrasonic system, types of ultrasonic reactors, application of power ultrasound in food processing, effects on food constituents, ultrasound in amalgamation with other food processing operations – thermo-sonication, manosonication, thermo-manosonication, advantages and future prospects.

Unit V

High hydrostatic pressure (HHP) processing: Principle of microbial inactivation, barotolerance of microorganisms, effect on food constitu-ents; equipment; dairy and food applications; Merits and demerits of HHP.

Unit VI

Pulsed electric field processing; Description/ mechanism and factors affecting microbial inactivation; effects on food com-ponents; Present status and future scope for food applications.

Unit VII

Super-critical Fluid Extraction; Principle, instrumentation and applications.

VII. Practical

- Market survey of food products processed using non-conventional technologies
- Pasteurization and concentration of milk using ohmic heating
- Degassing of fluids using ultrasound
- Determination of power output and temperature profile of a microwave oven
- Effect of chemical composition on heating behaviour of milk and milk products
- Microwave pasteurization of milk
- Effect of shape and size of container on microwave heating
- Preparation of 'instant' products in a microwave oven
- Visit to a commercial food processing facility.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To recommend use of feasible non-conventional technology for processing and shelf life extension of food
– Application of non-conventional processing technology as adjunct processing for accomplishing hurdle technology for dairy and food products
– To visualize the difference in the physico-chemical properties and microbial changes in dairy/food product when adopting traditional vs. non-conventional technology

IX. Suggested Reading

- Chen D, Sharma SK and Mudhoo A. 2012. *Handbook on applications of ultrasound-sonochemistry for sustainability*. Boca Raton: Taylor and Francis Group, LLC, 273-739.
- Delgado A, Kulisiewicz L, Rauh C and Wiersche A. 2012. *Novel thermal and non-thermal technologies for fluid foods*. New York: Academic Press.
- Monika Willert-Porada. 2001. Advances in Microwave and Radio Frequency Processing. Report from the 8th International Conference on 'Microwave and high frequency heating' held in Bayreuth, Germany, 2001.
- Nanda V and Sharma S. 2017. *Novel food processing technologies*. New India Publishing Agency, New Delhi, India.
- Raso J and Heinz V. 2006. *Pulsed electric fields technology for the food industry fundamentals and applications*. Springer Science + Business Media, LLC, USA.

- Zhang HQ, Barbosa-Canovas GV, Balasubramaniam VM, Dunne CP, Farkas DF and Yuan JT. (Eds.). 2011. *Non-thermal processing technologies for food* (Vol. 45). John Wiley and Sons.

Websites

- Microwave-assisted green extraction technology for sustainable food processing-https://intechopen.com/books/emerging-microwave-technologies-in-industrial-agricultural-medical-and-food-processing/microwave-assisted-green-extraction-technology-for-sustainable-food-processing
- Ultrasound in the food industry– https://hielscher.com/food_01.htm; Microwave assisted extraction (MAE)-https://slideshare.net/Nabiilah/microwave-assisted-extraction

I. Course Title : Membrane Processing for Dairy Applications

II. Course Code : DT 521

III. Credit Hours : 2+1

IV. Why this course?

Amongst non-thermal processes for dairy applications, membrane processing is one of the significant illustrations. Membrane processing has helped the dairy industry, not only to obtain dairy ingredients with high protein and low lactose content, but even to recover the important whey proteins from the by-product – whey. Salient application of use of membrane processed milk concentrate is in cheese making and in concentrated and dried milk manufacture.

V. Aim of the course

To elucidate the basics of membrane technology and its applications in dairy processing

VI. Theory

Unit I

Membrane techniques; Classification and characteristics of filtration pro-cesses; types of commercially available membranes; membrane hardware, design of membrane plants, modelling of ultrafiltration (UF) processes, mass transfer model, resistance model; Membrane fouling-problems and mitigation strategies; Cleaning and sanitization of different types of membranes.

Unit II

Factors affecting permeate flux during ultrafiltration and reverse osmo-sis of milk and sweet/sour whey, energy requirements for membrane processing of milk and whey.

Unit III

Applications of ultrafiltration (UF), reverse osmosis, nanofiltration and microfiltration in the dairy industry: food and pharmaceutical grade lactose, low lactose milk powder, dairy whiteners, WPC, WPI, MPC, MPI, Native micellar casein powder, etc. Preparation, properties and uses of Milk Protein Concentrate (MPC) and Milk Protein Isolate (MPI); Manufacture of some cheeses and fermented milk products and impact of membrane processing on quality of such products. Use of membrane processing techniques for separating prophylactic biological from milk.

Unit IV

Demineralization: principles, processes, equipment and applications.

Unit V

Functional properties of whey proteins (WPC and WPI), micellar casein and UF milk retentate and their modifications.

VII. Practical

- Factors affecting permeate flux during membrane processing (type of feed, temperature, transmembrane pressure, etc.)
- Effect of microfiltration of skim milk and whey on fat content and microbial count
- Preparation of WPC, WPI, MPC, native micellar casein, etc.
- Evaluating the functional properties of milk proteins.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To recommend use of membrane processed milk in manufacture of selected dairy products
- Application of specific membrane processes for milk/whey to prepare certain prophylactic biological
- To recommend the suitable cleaning and sanitization agents to take care of cleaning and sanitization of specific type of membrane used in membrane processing of milk.

IX. Suggested Reading

- Baker RW. (Ed.) 2012. *Membrane Technology and Applications*, 3rd Edn,Wiley Publishers.
- Cooper A.R. (Ed.) 2013. *Ultrafiltration Membranes and Applications* (Vol. 13). Springer Science and Business Media.
- Field RW, Bekassy-Molnar E, Lipnizki F and Vatai G. 2017. *Engineering Aspects of Membrane Separation and Application in Food Processing*. CRC Press.
- Fuquay JW, Fox PF and Mc Sweeney PL. 2011. *Encyclopedia of Dairy Sciences*. Academic Press.
- Hu K and Dickson J. (Eds.). 2015. *Membrane Processing for Dairy Ingredient Separation*. John Wiley and Sons.
- Mohanty K and Purkait M. 2011. *Membrane Technologies and Applications*. CRC Press, Taylor and Francis Group.
- Tamime AY. (Ed.). 2013. *Membrane processing: Dairy and beverage applications*. Wiley-Blackwell Publishers, pp. 1-370.

Websites

- Membrane technology in Dairy Industry – Slideshare-https://slideshare.net/./membrane-technology-in-dairy-industry
- Specialty and Dairy – Products – Toray Membrane-https://toraywater.com/products/specialty/index.html
- Membrane filtration in the dairy industry GEA-https://gea.com/en/binaries/gea-membrane-filtration-brochure-for-dairy-industry_tcm11-17109.pdf

I. Course Title : Advances in Dairy and Food Packaging

II. Course Code : DT 522

III. Credit Hours : 2+1

IV. Why this course?

Packaging of food though carried out towards the end of product manufacture has a great role to play in conserving the processed food in its original state – including freshness of fresh food. Packaging plays a crucial role in acceptance of the food product by the consumer and the extensibility of the shelf life of the food being packaged, especially using advanced techniques such as MAP, active packaging, etc.

V. Aim of the course

To impart basic and advanced knowledge of dairy and food packaging

VI. Theory

Unit I

Trends in packaging industry; designing framework for packaging; Testing of packaging materials.

Unit II

Adhesives; Graphics; Coding (Barcode and Quick Response code), and labeling used in food packaging.

Unit III

Protective packaging of foods; Effect of light, oxygen and moisture on packaged food.

Unit IV

Packaging of dairy products, convenience foods, fresh produce and fruits and vegetable products, Packaging of fats and oils, spices, meat, poultry, fish and other sea foods.

Unit V

Modified atmosphere packaging, Shrink and stretch packaging; Self-heating and self-cooling cans.

Unit VI

Retort pouch technology, microwavable, biodegradable, and edible packages; Principles and applications of Active Packaging, Smart and Intelligent Packaging, Antimicrobial packaging.

Unit VII

Industrial packaging: unitizing, palletizing, containerizing, distribution systems for packaged foods.

Unit VIII

Safety aspects of packaging materials; sources of toxic materials and migration of toxins into food materials, packaging and flavour interaction.

VII. Practical

- Testing of packaging materials for qual-ity assurance: thickness, GSM, grease resistance, bursting strength, tearing resistance, WVTR, puncture resistance
- Estimation and prediction of shelf life of packaged foods
- Development of edible, biodegradable and antimicrobial films
- MAP of perishable foods
- Effect of edible coatings on respiration behaviour of fruits and vegetables
- Application of oxygen scavengers in packaged foods.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To recommend the type of package suitable for specific type of dairy or other food products

- To employ intelligent packaging techniques in food packaging to warn the public in case of impeding health hazard
- Recommending SOPs to the food industry personnel to avoid migration of toxic substances from the package into the food system

IX. Suggested Reading

- Coles R, McDowell D and Kirwan MJ. 2003. *Food Packaging Technology*. Oxford: Oxford Blackwell. Frank, A., Paine, H., and Paine,Y. (1983). *A Handbook of Food Packaging*. Glasgow: Leonard Hill.
- Gordon LR. 2013. *Food Packaging: Principles and Practic*e, 3rd Edn., Florida, USA: CRC Press, Taylor and Francis Group.
- Han JH. 2005. *Innovations in Food Packaging*. Elsevier Science and Technology Books.
- Parry RT. 1993. *Principles and Applications of Modified Atmosphere Packaging of Foods*. Dordrecht: Springer Science+Business Media.
- Piergiovanni L and Limbo S. 2015. Food Packaging Materials. In: *Chemistry of Foods*, Springer Publishers.
- Raija A. 2006. *Novel Food Packaging*. England: Woodland Publishing Co.
- Robertson GL. (Ed.). 2012. *Food Packaging: Principles and Practice*. 3rd Edn.,Florida, US: CRC Press.
- Robertson GL. 2010. *Food Packaging and Shelf Life: A Practical Guide*. Boca Raton: CRC Press.
- Yam KL. 2009. *The Wiley Encyclopedia of Packaging Technology*, 3rd Edn., USA: John Wiley and Sons, Inc.

Websites

- Indian Institute of Packaging-https//iip-in.com/
- The Regulation of Food Packaging-https://www.packaginglaw.com/special-focus/regulation-food-packaging
- Packaging Industry Servies-www.nsf.org/services/by-industry/food-safety-quality/packaging

I. Course Title : Technology of Food Emulsions, Foams and Gels

II. Course Code : DT 523

III. Credit Hours : 2+1

IV. Why this course?

In order to improve the viscosity or rheological characteristics of food systems, certain food additives such as stabilizers, emulsifier and even foaming agents play a significant role. The chances of probability of defect in certain food products can be circumvented through use of such food additives. Emulsifiers play a great role in maintaining emulsion of two or multiple phases in the food system till its consumption. Foaming agents are of significance in ice cream, whipping cream, meringue, certain baked goods, etc.

V. Aim of the course

To impart basic knowledge regarding food dispersion systems, their formation, behaviour, and factors affecting their stability.

VI. Theory

Unit I

Food dispersions, their characteristics and factors affecting food dispersions.

Unit II

Food emulsions; Emulsifiers and their functions in foods; HLB concept for food emulsifiers; Emulsion formation and stability; Surfactants.

Unit III

Dairy based foams and their applications, structure of foams; Egg foams and uses; Foam formation and stability.

Unit IV

Theory of gel formation; Carbohydrate and protein based gels. Gelled milk products. Advances in food gels (organogel, hydrogel and nanogel).

Unit V

Structure of dairy based emulsions, foams and gels; blend of stabilizers and emulsifiers; Effect of stabilizers and/or emulsifiers on functional properties of dairy foods; Aerosols and propelling agents in foamed dairy products.

Unit VI

Techniques for evaluating the structure of food emulsions, foams and gels

VII. Practical

- Determination of emulsifying efficiency and emulsion stability
- Examination of foaming capacity and foam stability
- Gel formation and gel properties
- Preparation of hydrogels and organogels
- Preparation of single and double emulsions.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To be able to recommend specific type of food additive from amongst stabilizers and emulsifiers for stability of the food system
- Be able to recommend solution to the food processor to improve upon the textural quality of food products through use of food additives like stabilizers and/or emulsifiers
- To make the food processors understand how the type of emulsion in question in the food product has a bearing on the functional property of that specific food product

IX. Suggested Reading

- Rajah KK. (Ed.). 2014. Emulsifiers and stabilisers. Chapter 7.Young, N.W.G. *Fats in food technology*.UK: John Wiley and Sons Ltd. (ISBN: 9781405195423).
- Valdez B. (Ed.) 2012. Milani J and Maleki G. Hydrocolloids in food industry. Chapter in Book. *Food industrial processes – Methods and equipment*. InTech Europe, Rijeka, Croatia, pp. 1-418 (www.InTechopen.com)
- Whitehurst RJ. (Ed.). 2004. *Emulsifiers in food technology*. 1st Edn. Wiley-Blackwell Publisher, pp. 1-264. (ISBN-13 978-1405118026).

X. Websites

- Stabilizers – Specialty food ingredients – Federation of European Specialty Food Ingredients Industry-https://specialtyfoodingredients.eu/ingredients-and-benefits/group/stabilizers
- Emulsifier Solutions – Corbion- https://corbion.com/base/DownloadHelper/DownloadFile/8386

I. Course Title : Functional Foods and Nutraceuticals
II. Course Code : DT 524
III. Credit Hours : 3+1

IV. Why this course?

Ingestion of food possessing nutraceuticals can sustain and maintain human health – free from diseases. Today's consumers are aware about the health promoting foods and if the industry launches functional foods, there are takers for such foods. Several herbs and spices are known to contain components that have nutraceutical value. Ayurveda system is built on such naturally available materials. However, consumer does want to seek food that can sustain their health and nutritional requirement – not to rely on medicines. Fermented probiotic foods are the latest prominent functional foods.

V. Aim of the course

To impart knowledge about functional ingredients and nutraceuticals and their utilization in developing physiologically beneficial health foods, functional foods and speciality foods

VI. Theory

Unit I

Classes of functional foods and their status.

Unit II

Functional ingredients; Classification; Dietary and therapeutic significance.

Unit III

Food fortification; Significance and techniques of fortifying foods with functional ingredients.

Unit IV

Infant nutrition; Dietary formulations, special needs, additives; Geriatric Foods: Design considerations, ingredients, special needs; Sports foods: Significance, strategies and design considerations.

Unit V

Reduced calorie foods: Significance, strategies, additives (fat replacers, bulking agents, non-nutritive sweeteners).

Unit VI

Low sodium and low lactose foods: Nutritional and health significance.

Unit VII

Herbs; Classification; Therapeutic potential, applications; Phytochemicals; Classes; Physiological role; Applications; Bioactive ingredients from animal and marine sources.

Unit VIII

Probiotic, prebiotic and synbiotic foods: Concept and applications.

VII. Practical

- Determination of soluble and insoluble fibre
- Determination of antioxidant activity of functional ingredient/food

- Determination *of in vitro* bioavailability of nutrients
- b-galactosidase activity for low-lactose dairy products
- Prebiotic potential of selected plant/milk components
- Probiotic potential of selected microorganisms
- Preparation of functional foods

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:
- Be able to identify food in which fortification with necessary nutrients are required
- Be able to evolve Geriatric foods and food for infants based on their requirement and physiological functions
- To make food available to the consumers amalgamated with functional ingredients such as herbs, phytochemicals, etc.

IX. Selected Reading

- Earle M, Earle R and Anderson A. (Eds.). 2001. Food product development.1st Edn., Woodhead Publishing, pp. 1-392 (eBook ISBN: 9781855736399).
- Francesco C. (Ed.). 2017. Advances in dairy products. John Wiley and Sons Ltd. pp. 1-448. Chapter 4.2 - Consumer insight in the process of new dairy products development(ISBN: 9781118906460).
- Kanekanian A. (Ed.). 2014. Milk and dairy products as functional foods. John Wiley and Sons, Ltd., UK: West Sussex, pp. 1-373.
- Leong TSH, Manickam S, Martin GJ, Li W and Ashokkumar M. 2018. Ultrasonic Production of Nano-emulsions for Bioactive Delivery in Drug and Food Applications. Springer.
- Saarela M. (Ed.). 2007. Functional dairy products (2007) Vol. 2, Series in Food Science, Technology and Nutrition, Woodhead Pub., pp. 521-539.
- Shortt C and O'Brien J. (Eds.). 2003. Handbook of functional dairy products – Functional foods and Nutraceuticals, 1st Edn. Boca Raton, FL: CRC Press, pp. 1-312.

Websites

- Foods for Specified Health Uses (FOSHU)-https://mhlw.go.jp/english/topics/foodsafety/fhc/02.html
- A New Definition for Functional Food by FFC-https//functionalfoodscenter.net/files/111174880.pdf
- Food-info.net: Functional Foods-https//food-info.net/uk/ff/intro.htm

I. Course Title : Production and Applications of Dairy Ingredients

II. Course Code : DT 525

III. Credit Hours : 2+1

IV. Why this course?

Milk is a source of several components, which may contribute to nutrients, nutraceuticals, flavour, colour, texture to the food products in which they may be incorporated. Nowadays, we have perfected technologies to separate the dairy components having specified function for use in dairy as well as food products. The by-products such as whey and buttermilk can be salvaged through separation of components, which are of significance to the dairy and food industries alike.

V. Aim of the course

The aim of this course is to give comprehensive information of various milk components used as ingredients in food processing with regard to their separation, properties and applications.

VI. Theory

Unit I

An overview of dairy ingredients for food processing; Composition, nutritive value and health attributes of dairy ingredients; Important quality indices; National and international regulatory standards.

Unit II

Principles of conventional and novel approaches for separation, concentration and fractionation of milk components(Ig, lf, b-Lg): centrifugal separation, concentration, drying, membrane processing, enzyme-assisted separation, supercritical fluid extraction, electric field assisted membrane technique, etc.

Unit III

Chemical, physical and functional characteristics of concentrated and dried dairy ingredients (SMP, WMP, lactose, whey powder, WPC, WPI, MPC, casein and caseinates, cream powder, butter powder, cheese powder, yogurt powder, buttermilk powder, etc.).Miscellaneous dairy ingredients, viz. dairy permeates, hydrolysates, coprecipitates andlactoferrin.

Unit V

Interactions of dairy ingredients with other food components and its effect on product quality.

Unit V

Applications of dairy ingredients in food industry: bakery and confectionery; Infant, adult and sports nutrition; Processed meat products; spreads; functional Foods; edible films and coatings.

VII. Practical

- Manufacture of whey powder, caseinates, whey protein/milk protein concentrates, lactose, sweet cream butter milk powder, cream powder, yogurt powder and cheese powder.
- Determination of functional and nutraceutical properties of dried dairy ingredients.
- Manufacture of enzyme-modified dairy ingredients
- Production of eggless cakes using WPC
- Production of processed meat products incorporating caseinates
- Visit to a dairy ingredients manufacturing industry.

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Be able to separate the various important components from milk/dairy byproduct having significance in dairy and food industries
- Be able to recommend the required type of specialized dairy ingredient for use in formulated and composite foods
- To be able to erect a dairy factory producing specialized dairy ingredients with immense value addition

IX. Suggested Reading

- Chandan RC and Kilara A. 2011. *Dairy Ingredients for Food Processing*. Iowa, USA: Blackwell Publishing Ltd.
- Corredig M. 2009. *Dairy Derived Ingredients: Food and Nutraceutical Uses*. Cambridge, UK: Woodhead Publishing Ltd.

- Fox PF. 1985. *Developments in Dairy Chemistry*. Vol.3.Lactose and minor constituents, New York: Elsevier Applied Science.
- Fox PF. 1989. *Developments in Dairy Chemistry*. Vol.4. Functional milk proteins, New York: Elsevier Applied Science.
- McSweeney PLH and Fox PF. 2013. *Advanced Dairy Chemistry*. Vol.1A: Proteins: Basic aspects. 4th Edn. Springer Publication.
- McSweeney PLH and O'Mahony JA. 2016. *Advanced Dairy Chemistry*. Vol.1B: Proteins: Applied Aspects. Springer Science + Business Media.

I. Course Title : Advances in Cheese Technology

II. Course Code : DT 526

III. Credit Hours : 2+1

IV. Why this course?

There is an array of cheese varieties; use of different starter cultures can lead to the development of specific cheese variety too. However, the technological principles involved in Cheddar cheese making are common to several varieties of cheeses with some modifications. Cheese is getting popularized in India, especially the Pizza cheese variety that is preferentially used as a topping on pizza pie. The functional properties of cheese dictate its end use functionality in food system. Basically, some cheese varieties can be produced by two methods – starter culture and direct acidification. Wheyless cheese making from ultra-filtrated milk concentrate is one unique possibility. There has been trend to produce cheeses having low-fat and low salt for the health conscious consumers.

V. Aim of the course

To impart advanced knowledge on milk coagulants, theory of milk coagulation, the technology, biochemistry and microbiology of cheese.

VI. Theory

Unit I

Rennet coagulation: Measurement of milk clotting activity and gelation properties, Catalytic mechanism and milk-clotting properties of rennet and rennet substitutes. Advances in renneting of milk; recombinant rennet.

Unit II

Acid coagulated milk gels: formation, rheology, structural properties, etc.

Unit III

Advances in cheese starters; genetics of Lactic Acid Bacteria (LAB); Exo Polysaccharide (EPS) starters; Genetic engineering of LAB.

Unit IV

Biochemistry of cheese ripening: Metabolism of residual lactose and lactate, protein hydrolysis, lipid hydrolysis, amino acid catabolism; Development of cheese flavour, and body and texture; Cheese microstructure. Accelerated cheese ripening.

Unit V

Mold-ripened cheeses; Starter cultures, technology, ripening process (Blue, Roquefort, Camembert, etc.)

Unit VI

Low fat and low-sodium cheeses: challenges, strategies and advances; Membrane technology in cheese; Cheese as an ingredient in food systems.

Unit VII

Technology of non-bovine cheese: popular varieties, challenges, strategies; Technology of cheeses prepared by coagulation other than rennet and acid (Ricotta, Brown whey cheese, etc.); Advances in cheese packaging; Automation in cheese making; Cheese analogues.

VII. Practical

- Instrumental determination of rennet coagulation time
- Rheology of acid-coagulated milk gels
- Fermentation dynamics of common cheese starters
- Evaluation of cheese ripening behaviour
- Manufacture of mold ripened-, low sodium-, low fat-cheeses
- Manufacture of Goat and Ewemilk cheeses
- Manufacture of Ricotta cheese
- Microstructure of cheese

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Be able to manufacture various varieties of cheeses
- Try to employ various non-thermal pre-treatment to milk to obtain value added cheese
- Be able to develop low-calorie and low-salt cheeses
- Recommend the cheese makers for appropriate mechanization

IX. Suggested Readings

- Jana AH and Thakar PN. 1996. Recombined milk cheeses – A review. *Australian Journal of Dairy Technology*, **51**(1), 33-43.
- Jana AH and Tagalpallewar GP. 2017. Functional properties of Mozzarella cheese for its end use application – A Review. *Journal of Food Science and Technology,* **54**(12), 3766-3778.
- Johnson ME, Kapoor R, McMahon DJ, McCoy DR and Narasimmon RG. 2009. Reduction of sodium and fat levels in natural and processed cheeses: Scientific and technological aspects. *Comprehensive Reviews in Food Science and Food Safety*, **8**(3), 252-268.
- Lucey JA and Singh H. 1997. Formation and physical properties of acid milk gels: a review. *Food Research International*, **30**(7), 529-542.
- Mc Sweeney PLH. 2004. Biochemistry of cheese ripening. *International Journal of Dairy Technology*, **57**(2 3), 127-144.
- Mc Sweeney PLH, Fox PF, Cotter PD and Everett DW. (Eds.) 2017. *Cheese: Chemistry, physics and microbiolo*gy, 4th Edn, Vol. 1, Academic Press.

Websites

- Cheeses and related cheese products – Proposal to permit the use of ultra-filtered milk-https://federalregister.gov/documents/2005/10/19/05-20874/cheeses-and-related-cheese-products-proposal-to-permit-the-use-of-ultrafiltered-milk
- Go cheese to add new products in its portfolioBW Businessworld-http://businessworld.in/article/GO-Cheese-To-Add-New-Products-In-Its-Portfolio/10-07-2018-154382
- American Cheese Society: Serving the Cheese Industry-https://cheesesociety.org/
- Cheese: Dairy Processing Handbook-https://dairyprocessinghandbook.com/chapter/cheese

Course Title with Credit Load
Ph.D. in Dairy Technology

Course Code	Course Title	Credit Hours
DT 611	Advances in Lipid Technology	3 (3+0)
DT 612**	Advances in Protein Technology	3 (3+0)
DT 621**	Product Monitoring and Process Control	3 (3+0)
DT 622	R and D Management in Dairy Industry	3 (3+0)
DT 623	Advances in Carbohydrates Technology	3 (3+0)
DT 691	Doctoral Seminar-I	1 (1+0)
DT 692	Doctoral Seminar-II	1 (1+0)
DT 699	Doctoral Research	75 (0+75)

Minor Courses

The courses will be selected from the allied disciplines of Dairy Engineering, Dairy Chemistry and Dairy Microbiology to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered inagricultural statistics, computer applications and IT, and other related relevant disciplinesto meet the minimum credit requirements.

Common Courses

1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1
5.	Agricultural Research, Research Ethics and Rural Development Programmes	1

*Core courses for Master's programme; **Core courses for Doctoral programme

Course Contents
Ph.D. in Dairy Technology

I. Course Title : Advances in Lipid Technology

II. Course Code : DT 611

III. Credit Hours : 3+0

IV. Why this course?

Fats have multifarious effect on human beings. These are source of saturated fats, unsaturated fats, sterols (including cholesterol), phospholipids, etc. The essential fatty acids have a significant role in human health. There are however, some relations between certain type of fats (i.e. cholesterol, certain saturated fats and trans-fats) and cardiovascular disease in humans. There are several technological means to modify fat such as inter-esterification, fractionation of fat, hydrogenation, bleaching, refining, etc. Repeated frying of fat can lead to formation of toxic substances, unfit for consumption. Consumers have started accepting the modified fats for health reasons.

V. Aim of the course

To study the physico-chemical and nutritional characteristics of fats and oils, their processing and application in food products.

VI. Theory

Unit I

Current trends in the fats and oil industry in India and abroad: Sources and classification of commercial edible fats and oils from animal, vegetable and marine origin; Non-conventional fats/oils for edible purpose – rice bran oil, microbial lipids, etc.

Unit II

Structural aspects of fats and oils in relation to their processing, properties and utilization; Polymorphism and polytypism, crystallization kinetics.

Unit III

PUFA, MUFA, CLA, Medium Chain Triglycerides (MCTs), Omega fatty acids, Trans-fatty acids: Nutritional and technological interventions; Phytosterols and their significance.

Unit IV

Advances in extraction and refining of oils and fats; Application of membrane techniques in oil refining.

Unit V

Physical, chemical and enzymatic modification approaches to tailor-made fats. Cholesterol reducing treatments; structured lipids; Fat replacers; Isolation of emulsifiers.

Unit VI

Applications of fats and oils: Margarine and low-fat table spreads; Bakery and confectionery fats; Coatings; Shortenings; Salad dressings; Technology of cooking oils, salad oils and oil based dressings.

Unit VI

Frying process and systems; Changes in fats and oils during frying; Snack foods - Processing sys-tems; Modified fats and oils for use in bakery and confectionery products, shortenings and spreads; Cocoa butter substitutes.

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– Able to recommend the type of fat suitable for given application (i.e. for frying).
– Prepare modified fats with reduced cholesterol, reduced long chain saturated fats, etc.
– Make the food processor understand the principle of polymorphic transformation of fat for texture development in fatty food system.
– Can modify the fat to suit physiological needs of the people.

VIII. Suggested Reading

- Garti, N.andSato, K. (Eds.). 2001.Hartel, R.W., and Kaylegian, K.E. Chapter 11. Advances in milk fat fractionation – Technology and applications. In: *Crystallization processes in fats and lipid systems*, 1st Edn,Boca Raton: Taylor and Francis Group (eBook ISBN 9781482270884).
- Hartel, R. W., and Kaylegian, K. E. 2001. Advances in milk fat fractionation – Technology and applications. In: *Crystallization Processes in Fats and Lipid Systems*. Garti, N., and Sato, K. (Eds.), Chapter 11, Taylor and Francis Group.
- Rajah, K.K. (Ed.). 2014. *Fats in food technology*. John Wiley and Sons Ltd., UK(**ISBN:** 9781405195423)
- Tamime, A.Y. (Ed.). 2009. *Dairy fats and related products*. Oxford, UK: Blackwell Publishing Ltd., pp. 1-315.

Websites

- **AOCS Lipid Library**-http://lipidlibrary.aocs.org/human-nutrition/trans-fat-replacements-in-foods-(pg2)
- **Fats and Cholesterol - USDA**-https://nal.usda.gov/fnic/fats-and-cholesterol
- **Fats and Fatty Acids in Human Nutrition**-http://fao.org/3/a-i1953e.pdf
- **Dietary Guidelines Advisory Committee**-http://www.usda.gov/cnpp/Pubs/DG2000/Full%20Report.pdf

I. Course Code : DT 612

II. Course Title : Advances in Protein Technology

III. Credit Hours : 3+0

IV. Why this course?

Protein is an essential major nutrient in the diets. Essential amino acids play an important role. Cheaper sources of protein are being constantly unearthed possibly from several sources, viz. plants, animals, microbes and mushrooms. Protein malnutrition, especially in children is being tackled today. Use of membrane processing (especially ultrafiltration) and food texturization technologies has led to the development of newer type of high protein food ingredients and products. The state of protein – un-denatured and denatured can play a role in functionality of resultant food as well as in digestion of the nutrient. Protein hydrolysates have their own application even in pharmaceuticals.

V. Aim of the course

To study the characteristics of food proteins and to familiarize the students with their nutritional role, implications in processing and their interactions in food systems

VI. Theory

Unit I

Characteristics, functional properties and applications of proteins from plant, animal, microbial and non-conventional sources.

Unit II

Denaturation of proteins: effect of processing parameters on denaturation; effect of denatur-ation on the physico-chemical and biological properties of proteins in food systems.

Unit III

Structure-functional relationship of food proteins; Protein interactions with food constituents and their significance: protein-protein interactions. Protein--lipid interactions, protein-polysaccharide interactions, protein-ion interactions.

Unit IV

Nutritional aspects of dietary proteins: Protein nutrition and digestion; protein quality evaluation methods; effect of processing on nu-tritive value of proteins.

Unit V

Food protein concentrates and isolates: types, production, characterization and applications Protein hydrolysates: production and processing; de-bittering; bioactive peptides: classification, production and properties.

Unit VI

Texturization of proteins; Selection of ingredients and processes; Microstructure of texturized foods, Protein based fat substitutes; Protein engineering; Protein genetic polymorphism.

VII Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Tackle the problem of protein malnutrition.
- Adopt some recent technological means to produce high protein food ingredients such as WPC, WPI, MPC, Micellar casein powder, etc.
- Modify the native protein (i.e. protein hydrolysate) to have specific applications in composite food products

IX. Suggested Reading

- Boland M, Singh H and Thompson A. (Eds.). 2014. *Milk proteins: From expression to food*. Academic Press.
- Consultation FE. 2011. Dietary protein quality evaluation in human nutrition. *FAO Food Nutrition Papers*, 92, 1-66.
- Damodaran S. 1997. *Food proteins and their applications*. CRC Press.

- Fox Patrick F and McSweeney PLH. (Eds.) 2013. *Advanced Dairy Chemistry: Volume 1: Proteins, Parts A&B*, New York: SpringerScience+Business Media.
- Hayes M. 2018. *Food Proteins and Bioactive Peptides: New and Novel Sources*, Characterisation Strategies and Applications. *Foods*, **7**(3):E38. (doi: 10.3390/foods7030038).
- Hettiarachchy NS, Sato K, Marshall MR and Kannan A. (Eds.). 2012. *Food proteins and peptides: Chemistry, functionality, interactions and commercialization*. CRC Press.
- Maskan M and Altan A. 2016. *Advances in Food Extrusion Technology*. CRC press.
- Phillips GO and Williams PA. (Eds.). 2011. *Handbook of Food Proteins*. Elsevier Pub.
- Sims S. (Ed.). 2019. Protein Hydrolysates: Uses, Properties and Health Effects. Nova Publishers.
- Yada RY. (Ed.). 2017. *Proteins in Food Processing*. Woodhead Publishing.

Websites

- Protein energy malnutrition-FAO-http://fao.org/DOCREP/W0073e/w0073e05.htm
- Dietary Protein EU Science Hub European Commission-https://ec.europa.eu/jrc/en/health-knowledge-gateway/promotion-prevention/nutrition/protein
- High and Low Biological Value Protein Foods: (EUFIC)-https://www.eufic.org/en/whats-in-food/article/the-basics-proteins

I. Course Title : Product Monitoring and Process Control

II. Course Code : DT 621

III. Credit Hours : 3+0

IV. Why this course?

Whatever food products are processed at the food plant needs to be monitored for product quality and safety. Recent developments in advanced control techniques have opened up novel possibilities for food process control. Food processes have been particularly difficult to automate and control owing to non-uniformity and variability in raw-materials, and lack of sensors for real-time monitoring of key process variables and quality attributes. Model-based control, distributed control systems together with field communication protocols, and other computer-aided advanced control strategies have proven themselves in selected food processing applications. The benefits of advanced control techniques include reduced costs, increased quality and improved food safety.

V. Aim of the course

To develop the understanding of the concept of monitoring and optimization of food quality/characteristics and familiarize the students with the techniques involved.

VI. Theory

Unit I

The concept of Product-Process Monitoring in dairy and food industries; Definition of ‘quality’, optimization paradigm, quality-prediction model based on quality kinetics and process state equations, simulation modelling; Process/Product Optimization: optimization procedures – search methods, Response surface, differentiation and programming methods; neural networks, optimization software.

Unit II

Process Control: objectives, control loop, loop elements and their functions; Modes of process control; Control techniques; Control equipment.

Unit III

Real-time instrumentation: sensors, their classification based on proximity, working principle, examples of applications in process control; Requirements of on-line sensors; Biosensors – construction, types, working principles, applications, merits and limitations; Time-temperature indicators – partial-history and full-history indicators; Commercial devices; Applications and limitations; E-Nose and E-Tongue – Simulation of natural organs, components and their functions, applications.

Unit IV

Flavour analysis: flavour bioassays – Gas Chromatography-Olfactometry techniques; Isolation, separation and detection/identification of flavour compounds – GC-MS, LC-MS, NMR, FTIR; Analysis of chiral compounds.

Unit V

Formation of flavour compounds in milk and milk products during heat processing (including UHT processing, caramelization and extrusion cooking), fermentation and ripening (cultured products and cheese flavour, with special reference to bitterness) and storage (Maillard browning); Aroma losses/retention during the drying process (in rela-tion to milk powder, cheese powder and dry cultured products); Industrial processes for extraction of desirable and undesirable volatile components from fresh and/or stored products by supercritical fluid (SCF) technique.

Unit VI

Monitoring of food structure: Application of analytical techniques (Differential Thermal Analysis, Differential Scanning Calorimetry, X-ray crystallography, circular dichroismspectroscopy, dynamic light scattering, laser diffraction, image analysis and Nuclear Magnetic Resonance) to monitor the effect of processing and storage on structure of foods.

Unit VII

Emerging spectroscopic techniques in assessment of foods: Raman Spectroscopy and Electron Spin Spectroscopy – working principles and applications; Monitoring of irradiated foods, detection of lipid auto-oxidation, etc.; Microwave and NIR absorption/reflection methods for Compositional analyses; Automated milk analysers; Proximate principles in cheese and milk powder.

Unit VIII

Colour Characterization: colour and appearance (gloss and translucence) monitoring through visual colorimeter, tri-stimulus colorimeters and reflectance spectrophotometer, CIE, Hunter-Lab, Munsel and other systems of three-dimensional expression of colour; Colour-based sorting of foods; Computer vision – principles, applications and benefits.

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Prepare a protocol for specific food industry in which all critical processes are to be monitored
- Avoid chances of occurrence of structure defect in food product through monitoring of the food structure using latest methodologies (i.e. DSC, NMR, etc.)
- Improve and stabilize the color of the food system through color characterization methods

– Elucidate the development of flavor for flavor rich foods (i.e. cheese, Enzyme modified cheese, fermented dairy products, etc.)

VIII. Suggested Reading

- Acree TE and Teranishi R. 1993. *Flavour Science: Sensible Principles and Techniques*. Washington: Amer. Chem. Soc.
- Bartlett PN, Elliott JM and Gardner JW. 1997. Electronic noses and their application in the food industry. *Food Technology*, **51**(12), 44-48.
- Kress-Rogers E and Brimelow CJB. (Eds.). 2001. *Instrumentation and Sensors for the Food Industry*. CRC Press, Woodhead Pub. Ltd.
- Nollet LML. (Ed.) 2020. *Mass Spectrometry Imaging in Food Analysis*, CRC Press.
- Pomeranz Y. (Ed.). 2013. *Food analysis: Theory and Practice*. Springer Science and Business Media.
- Schaertel BJ and Firstenberg-Eden R. 1988. Biosensors in the food industry: present and future. *Journal of Food Protection*, **51**(10), 811-820.

IX. Websites

- Quality Management Tools-Including TQM, Six Sigma, Cost of Quality and EFQM-https://cgma.org/resources/tools/essential-tools/quality-management-tools.html
- Process Control Solutions: Berthhold Technologies-https://berthold.com/en/pc/home?gclid=EAIaIQobChMIl-uQ4—K4gIVQyUrCh0P_gqvEAMYASAAEgJfcPD_BwE
- Laboratory Quality Management System – World Health Organization-https://who.int/ihr/publications/lqms_en.pdf
- Real Time Process Monitoring in Food and Beverage Manufacturing-https://manufacturing.net/article/2016/02/real-time-process-monitoring-food-and-beverage-manufacturing

I. Course Title : R&D Management in Dairy Industry

II. Course Code : DT 622

III. Credit Hours : 3+0

IV. Why this course?

Several dairy industries have separate R and D cell to carry out product innovation or to bring in more returns to the organization. Managing the R&D in a planned manner helps to deliver the goods to reap its benefit. Once patenting procedure is known, those research findings of extreme utility in dairy industry can be filed for patenting. The researches that have far reaching impact value should be taken for transfer of technologies within the limited time frame.

V. Aim of the course

To provide in-depth knowledge to students about selection and management of research projects and in patenting and transfer of technology processes.

VI. Theory

Unit I

Global scenario of R&D efforts in dairy processing; Determinants of Consumer Preferences; Competitive positioning and value chain configuration in global market.

Unit II

Management of human resources in dairy Industry: Structure and design of Research and Development organization; Analysis of organization behaviour – Transactional analysis; Personnel management – Typology analysis, individual and the organization, team building, human behaviour at work, motivation.

Unit III

Skill requirements of an R and D manager; New product development: strategies, models and life cycle analysis.Food innovation dynamics; innovation opportunities; innovations in traditional and functional foods; consumer driven food innovation; implementation of latest technology and assessment.

Unit IV

Management of R&D functions: Criterion for selection of R&D projects; Technology development process, Techniques for monitoring R and D functions.

Unit V

Patenting Laws; Indian Patenting Act/International Protocols for technology transfer; Transfer of technology from Lab to Plant, ISO 9001, ISO 14001, ISO 22000, ISO 50001, OHSAS; Laboratory Quality Management System- ISO 17025, Retailer Standards -BRC Food and BRC/IoP Standards, International Food Standard (IFS), SQF 1000 and SQF 2000, Global GAP and India GAP., Six-Sigma concept.

Unit VI

Project proposal writing for research funding, Development of feasibility and technical report for dairy plant establishment, Report writing of projects and its evaluation

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:
- Identify whether the researches carried out are suitable for patenting
- Help in selecting proper R and D projects for the benefit of the industry as well as for the consumers
- Can write Project proposals to bring in Research funding from external agencies for mutual benefit

VIII. Suggested Reading

- Basu CR. 2017. *Business Organization and Management*. Tata-McGraw Hill Publication.
- Early R, Early M and Anderson A. 2009. *Food Product Development*. Woodhead Publishing Ltd.
- Robbins SP, Judhe, TA and Vorha N. 2013. *Organization Behaviour*. 15th Edn, Pearson Education Publishing Inc.
- Tetra Pak Dairy Processing Handbook. 2015. www.dairyprocessinghandbook.com.

Websites

- World Intellectual Property Organization-https//wipo.int
- IPR and Patents CEN CENELEC-https://cencenelec.eu/ipr/Pages/default.aspx
- ISO-International Standardization for Organization-https://iso.org/home.html
- ISO-45001 Occupational Health and Safety-https://iso.org/iso-45001-occupational-health-and-safety.html

I. Course Title : Advances in Carbohydrate Technology

II. Course Code : DT 623

III. Credit Hours : 3+0

IV. Why this course?

Besides proteins and fats, carbohydratesareother important nutrients. The flavour, colour and structure of food product also depend on the type and amount of carbohydrates present and their reactivity with other constituents during processing. Modified starches have been the recent addition to the list of stabilizers available for the food industry. Lactose – the carbohydrate of milk origin has a special role to play in dairy and food industry. Modifications of carbohydrates such as inversion, enzymic hydrolysis, maillard reaction can lead to value-addition in some food products.

V. Aim of the course

To study the physico-chemical and nutritional characteristics of carbohydrates, and their applications in food processing and health

VI. Theory

Unit I

Introduction to Carbohydrates: Classification, Sources of carbohydrates, Structure of major groups, Non-conventional sources of carbohydrates.

Unit II

Characterization and functional properties of Carbohydrates; Various classes of sweeteners; Production technologies for Corn Syrup Solids (CSS), High fructose corn syrup (HFCS); Maltodextrins; Phenomenon of retrogradation of starch and interventions in foods and methods to control it.

Unit III

Milk Carbohydrates: Manufacturing technologies and their functional, nutritional and technological properties; Lactose hydrolysed dairy products.

Unit IV

Nutritional and therapeutic aspects of carbohydrates: Role in dental caries, obesity, cardiovascular diseases (CVD), colon health, diabetes; resistant starches, Prebiotics, Non-digestible carbohydrates (NDC) and their health benefits.

Unit V

Modified starches: Technologies for starch modification; Properties, applications, safety and toxicity. Carbohydrate based edible packaging films.

Unit VI

Hydrocolloids: Classification, structures, functional properties, and applications.

Unit VII

Cyclodextrins; Carbohydrates as fat replacers/fat substitutes; microencapsulating agents; Techniques for production of protein-polysaccharide conjugates and their applications.

VII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Unravel the unconventional sources of carbohydrate for human nutrition
- To produce dairy foods free of allergenicity i.e. lactose-free for lactose intolerant persons
- Able to ameliorate defects in food product through knowledge about interaction of carbohydrates with other constituents in food during processing and/or storage
- To recommend reducing calorie in food (formulate dietetic food) through use of carbohydrate source to mimic properties of fat

VIII. Suggested Reading

- Eliasson AC. 2006. *Carbohydrates in Food*, 2nd Edn, CRC Press, Taylor and Francis group.
- Biliaderis CG and Izydorczyk MS. 2007. *Functional Food Carbohydrates.* CRC Press, Taylor and Francis group.
- Mc Sweeney PLH and Fox PF. 2009. *Advanced Dairy Chemistry*. Volume 3, Lactose, water, salts and minor constituents. USA: Springer Science and Business Media.
- Paques M and Lindner C. (Eds.). 2019. Lactose: Evolutionary Role, Health Effects, and Applications. Academic press.
- Steve W Cui. 2005. *Food Carbohydrates: Chemistry, Physical Properties and Applications.* CRC Press, Taylor and Francis group.

Websites

- Effect of Food Processing on Dietary Carbohydrates-http://fao.org/3/W8079E/w8079e0j.htm
- Carbohydrates: Uses, health benefits, and risks – Medical News Today-https://www.medicalnewstoday.com/articles/161547.php

Potential Areas for Research

1. Active, intelligent and biodegradable packaging
2. Application of non-thermal processes for value-added dairy products
3. Bioactives from plant/plant bio-waste for human nutrition
4. By-products from agri-food industry: Recovery, utilization and revalorization
5. Composite dairy foods
6. Dairy based analogues
7. Dairy derived ingredients and their applications
8. Green technologies for dairy and food products
9. Health foods for conferring physiological benefits
10. Innovations in fermented dairy and food products
11. Nanotechnology in dairy and food applications
12. Non-bovine milk and milk products
13. Novel extruded food based on dairy and cereal/legume based solids.
14. Novel products utilizing membrane processed dairy solids.
15. Sensory characterization, technology standardization, value addition and shelf life extension of traditional Indian dairy products
16. Target delivery of nutraceuticals/active functional ingredients through dairy matrices
17. Technology of novel and exotic cheeses
18. Utilization of dairy by-products

List of Journals

1. *Australian Journal of Dairy Technology*
2. *British Food Journal*
3. *Cereal Chemistry*
4. *Cereal Foods World*
5. *Comprehensive Reviews in Food Science and Food Safety*
6. *Critical Reviews in Food Science and Nutrition*
7. *CyTA - Journal of Food (Ciencia Y TecnologiaAlimentaria)*
8. *Dairy Science and Technology (formerly Le Lait)*
9. *Drying Technology: An International Journal*
10. *Emirates Journal of Food and Agriculture*
11. *European Food Research and Technology*
12. *European Journal of Nutrition and Food Safety*

13. *Food and Bioprocess Technology*
14. *Food and Bioproducts Processing*
15. *Food and Function*
16. *Food Bioscience*
17. *Food Hydrocolloids*
18. *Food Quality and Preference*
19. *Food Research International*
20. *Food Reviews International*
21. *Indian Journal of Dairy Science*
22. *Innovative Food Science and Emerging Technologies*
23. *International Dairy Journal*
24. *International Journal of Dairy Technology*
25. *International Journal of Fermented Foods*
26. *International Journal of Food Properties*
27. *International Journal of Food Science and Technology*
28. *Irish Journal of Agricultural and Food Research*
29. *Journal of Dairy Research*
30. *Journal of Dairy Science*
31. *Journal of Food Measurement and Characterization*
32. *Journal of Food Processing and Preservation*
33. *Journal of Food Science and Technology*
34. *LWT - Food Science and Technology*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Engineering

Course Title with Credit Load
M.Tech. in Dairy Engineering

Course Code	Course Title	Credit Hours
	Major Courses	
DE-511*	Dairy and Food Engineering-I	3+0
DE-512	Analytical Heat and Mass Transfer	2+1
DE-513	Transport Phenomena	3+0
DE-514	Advances in Refrigeration Engineering	2+1
DE-515*	Design of Dairy and Food Process Equipment	3+0
DE-516	Engineering Properties of Dairy and Food Products	2+1
DE-517	Mechanization in Manufacture of Indigenous Dairy Products	3+0
DE-521*	Dairy and Food Engineering-II	3+0
DE-522	Bio-Thermal Process Engineering	3+0
DE-523*	Industrial Instrumentation and Process Control	2+1
DE-524	Industrial Automation and Robotics	2+1
DE-525	Unit Operations	2+1
DE-526	Environmental Engineering	2+0
DE-527	Energy Management and Auditing in Dairy and Food Plants	2+1
DE-591	Masters' Seminar	1+0
DE-599	Masters' Research	0+30

Course Contents
M.Tech. in Dairy Engineering

I. Course Title : Dairy and Food Engineering-I
II. Course Code : DE 511
III. Credit Hours : 3+0

IV. Why this course?

The development in mechanization and automation of the dairy and food processing are dependent on deeper knowledge of rheological, thermal and physical properties of the dairy and food products. Energy conservation and preservation of food quality during processing using emerging and non-thermal processes are the need of the hour. Therefore, this course is designed to provide the students a deeper understanding of the role of rheology and other food properties in the design, handling and operation of various processing equipment. Also, newer and emerging technologies are introduced to reduce the impact of processing on food quality.

V. Aim of the course

- To familiarize with the study of rheological properties of food and their measurements.
- To introduce the developments in thermal and non-thermal processing of foods

VI. Theory

Unit I

Viscoelastic characterisation of materials, stress-strain behaviour, creep, stress relaxation, solving problems on creep and stress relaxation of foods, non-Newtonian fluids; Viscometry-capillary and rotational viscometers, derivation on principle of operation of capillary and rotational viscometers, fitting of flow models; Rheometers: types and applications, temperature sweep, amplitude sweep and frequency sweep; identification of LV region.

Unit II

Freezing: IQF, Cryogenic freezing- process and equipment details, freezing curves, freezing time calculations, design of freezing equipment, freeze drying, freeze concentration.

Unit III

Design of single and multi-effect evaporators, design of TVR and MVR, design and selection of evaporator pumps, calculation of wetting rate, concept of condenser free design of evaporator, design of condenser (barometric and surface), flash vessel, preheater design for bacterial destruction, DSI, vacuum pump, concept of fanless cooling tower, aroma recovery unit.

Unit IV

Design of spray drier and its components, design of three stage drier, selection of fans, roots blower, selection of nozzle, HPP cum homogeniser used for automation, CIP, cleanable bag filter, concept of cyclone free spray drier operation, use of computer software in design of evaporators and spray driers.

Unit V

Novel processing methods and equipment: high pressure processing, ohmic heating, ultraviolet light, pulsed electric field, pulsed light field, micro and nano-encapsulation, microwave heating, cold plasma, ultrasound processing and low dose e-beams.

Unit VI

Ultra-high temperature processing (UHT): concept, process, system; Design: plate and tubular type, their merits and demerits and selection; heat balances and concept of differential temperature; steam cleaning systems. Analysis of sterilization performance and validation, determination of residence time distribution.Pouch forming, can and carton filling systems for UHT. Cleaning and sterilization of UHT processing plants

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Case Analysis and case studies
- Guest Lectures
- Industry Visit

VIII. Learning outcome

The students will be more confident in design and operation of dairy and food process equipment. They will also be familiar with non-thermal processes and emerging processing methods in the manufacture of dairy and food products.

IX. Suggested Reading

- Burton H. 2012. *Ultra-High-Temperature Processing of Milk and Milk Products*. Springer Science.ISBN-13: 978-1461359012.
- Chauhan OP. 2019. *Non-thermal Processing of Foods*. 1st Edition, CRC Press. ISBN-13: 978-1138035843.
- Das SK and Das M. 2019. *Fundamentals and Operations in Food Process Engineering*. 1st Edition, CRC Press. ISBN-13: 978-1466560901.
- Gunasekaran S and Mehmet MAK. 2002. *Cheese Rheology and Texture*. 1st Edition, Taylor and Francis. ISBN-13: 978-1138198425.
- Heldman RD, Daryl BL and Sabliov C. 2019. *Handbook of Food Engineering*. 3rd Edition, CRC Press. ISBN-13: 978-1466563124.
- Kessler HG. 1981. *Food Engineering and Dairy Technology*. Verlag A. Kessler.
- Bourne M. 2002. *Food Texture and Viscosity: Concept and Measurement* 2nd Edition, Academic Press. ISBN-13: 978-0121190620.
- McCabe WL, Smith JC and Harriott P. 2017. *Unit Operations of Chemical Engineering.* 7th Edition, McGraw Hill Education. ISBN-13: 978-8184959635.
- Mohsenin NN. 1970. *Physical Properties of Plant and Animal Materials*. 1st Edition, Routledge. ISBN-13: 978-0677023007.
- Singh RP and Heldman DR. 2013. *Introduction of Food Engineering*. 5th Edition, Bio-Green Elsevier. ISBN-13: 978-9351073499.
- Toledo RT, Singh RK and Kong F. 2000. *Fundamentals of Food Process Engineering*. 2nd Edition, CBS. ISBN-13: 978-8123915517.

I. Course Title : Analytical Heat and Mass Transfer

II. Course Code : DE 512

III. Credit Hours : 2+1

IV. Why this course?

Heat and mass transfer are the basic transport processes occurring in all the unit operations. These are complex processes because these occur mostly simultaneously and under unsteady state conditions with continuous changes in product characteristics. These also affect the efficiency and productivity of food processing lines. Deeper analytical solutions to heat and mass transfer operations are therefore needed. This course is aimed to provide solutions to such complex heat and mass transport processes, which will help in the design of efficient process equipment.

V. Aim of the course

- To introduce two dimensional and unsteady state of heat transfer.
- To introduce the forced convective heat transfer and relationships with dimensionless numbers.
- To learn appropriate design and analytical tools to investigate heat and mass transport phenomena
- To apply various computational techniques to obtain numerical solutions of these phenomena

VI. Theory

Unit I

One-dimensional steady state heat conduction through fins (Extended surfaces): actual and approximate solution. Efficiency, effectiveness and design of profile area of fins.

Unit II

Two-dimensional steady state heat conduction: analytical and numerical solution.

Unit III

Unsteady state heat conduction: Concept of Biot number, Lumped parameter analysis, transient heat flow in semi-infinite solids, use of Heisler charts.

Unit IV

Forced convection heat transfer in flow over a flat surface: hydrodynamic and thermal boundary layer, continuity equation, momentum equation and energy equation, heat transfer coefficient/ Nusselt number in laminar and turbulent region of boundary layer. Stanton number; Colburn analogy; empirical co-relations.

Unit V

Forced convection heat transfer in flow through tubes: Nusselt number in the entrance region and fully developed laminar and turbulent region.

Unit VI

Condensation and boiling heat transfer: Film wise condensation on vertical surface; Nusselt equation, regimes of boiling, boiling heat transfer.

Unit VII

Performance analysis of parallel flow and counter flow heat exchangers. LMTD and effectiveness NTU approach. Application of computational software for process heat transfer applications.

Unit VIII

Mass transfer - Fick's law of diffusion, diffusion of gases and liquids through solids, equimolar diffusion, isothermal evaporation of water into air, mass transfer coefficients. Governing equation for mass transfer; boundary conditions. Various non-dimensional numbers and their analogy to heat transfer. Examples of simultaneous heat and mass transfer

VII. Practical Topics

- Steady state heat conduction through fins
- Two-dimensional steady state heat conduction
- Solving problems in unsteady state heat conduction and use of Heisler charts
- Experiments on forced convection heat transfer
- Experiments on drop and film-wise condensation
- Determination of heat transfer coefficient
- Solving problems in condensation and boiling heat transfer
- Solving problems on mass transfer in diffusion and evaporation
- Experiments in parallel flow/ counter flow heat exchanger test rig
- Determination of mass transfer coefficient
- Design of engineering systems involving thermofluid phenomena.

VIII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Solving problems
– Familiarising with relevant software

IX. Learning outcome

Students have better understanding of heat and mass transfer processes and the skills to obtain solutions to such complex problems. They will develop competence in the design of process equipment using the analytical solutions of heat and mass transfer.

X. Suggested Reading

- Cengel YA. 2020. *Heat and Mass Transfer*. Tata McGraw Hill Education, New Delhi, 6th Edition, ISBN: 978-9390185283.
- Domkundar S and Arora SC. 2007. *A Course in Heat and Mass Transfer*. Dhanpat Rai and Co., Ltd. ISBN-13: 978-8177000290.
- Holman JP and Bhattacharyya S. 2017. *Heat Transfer*. 10th Edition, McGraw Hill. ISBM-13: 978-0071069670.
- Majumdar P. 2017. *Computational Methods for Heat and Mass Transfer*. T&F India. ISBN-13: 978-1138044869.
- Muralidhar and Sundararajan. 2009. *Computational Heat and Mass Transfer*. Narosa.
- Nag P K. 2011. *Heat and Mass Transfer*. 3rd Edition, McGraw Hill Education. ISBN-13: 978-0070702530.
- Rajput RK. 2018. *A Textbook of Heat and Mass Transfer SI Units*. S. Chand Publishing. ISBN-13: 978-9352533848.

I. Course Title : Transport Phenomena

II. Course Code : DE 513

III. Credit Hours : 3+0

IV. Why this course?

An understanding of uniform approach to mass, energy and momentum transfer is necessary in modelling and predicting the above phenomena in food processing operations. This course provides engineering students advance methods to solve problems involving transports of momentum, energy and mass in biological, mechanical and chemical systems using a unified approach. Emphasis is given on developing the mathematical models to describe the flow phenomena.

V. Aim of the course

- To introduce the transport phenomena of mass, energy and momentum.
- To study the transport phenomena with the help of dimensional analysis.

VI. Theory

Unit I

Introduction to vector analysis, dot product and cross product and its physical significance, Stress tensor, total and partial derivatives, total acceleration, Eulerian and Lagragian frames of reference, Reynolds transport theorem, Different three-dimensional co-ordinate systems (Cartesian and Polar).

Unit II

Introduction to transport phenomena - transport processes and similarities in momentum, energy and mass transfer; Application of transport phenomena in CFD, practical examples in food engineering. Classification of flows and flow visualization; vorticity and potential and stream function, Potential flow, Cauchy Reimann equations.

Unit III

Steady-state equations - Momentum transport equations for Newtonian and non-Newtonianfluids, continuity equation in different co-ordinates; Derivation for Cartesian, cylindrical and spherical coordinate system.

Unit IV

Equations of motion - Navier-Stokes equations and their application in viscous fluid flow between parallel plates and through pipes.

Unit V

Turbulent transport mechanism - Mathematical analysis; Eddy viscosity and eddy diffusivity; Velocity, temperature and concentration distribution; time smoothing equations. Inter-phase transport in isothermal system -friction factors for various geometries.

Unit VI

Dimensional analysis- Buckingham Pi-theorem and matrix method, application to transport phenomena, analysis among mass, heat and momentum transfer, Reynolds' and Chilton –Colburn analogy.

Unit VII

Non-dimensional numbers in transport phenomena- definition, mathematical relation and physical significance; Boundary layer concept - Theoretical and exact solutions for heat, mass and momentum transfer. Governing equations, Blassius solution and Von-Karmen integral equation

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Familiarising with relevant software
- Industry Visit

VIII. Learning outcome

Student will obtain the knowledge and analytical skills to modelling and predicting the action of mass, energy and momentum transfer. They will be able to solve, using rigorous mathematics, fundamental and elucidating problems involving momentum, energy, and mass transport phenomena and apply this knowledge in design and operation of processing equipment.

IX. Suggested Reading

- Bird RB, Stewart WE and Lightfoot EN. 2006. *Transport Phenomena*. 2nd Edition. Wiley. ISBN-13: 978-8126508082.
- Deen WM. 2013. *Analysis of Transport Phenomenon.* Oxford University Press. ISBN-13: 978-0198098584.
- Foust AS, Wenzel LA, Clump CW, Maus L and Andersen LB. 2015. *Principles of Unit Operations*. 2nd Edition, Wiley.ISBN-13: 978-8126518296.
- Geankoplis CJ, Herse AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*. 4th Edition. Pearson Education India Prentice-Hall Private Ltd.ISBN-13: 978-9332549432.
- McCabe WL, Smith JC and Harriott P. 2017. Unit Operations of Chemical Engineering. 7th Edition, McGraw Hill Education.ISBN-13: 978-8184959635.
- Raj B. 2012. *Introduction to Transport Phenomena: Momentum, Heat and Mass*. Prentice Hall India Learning Private Limited.ISBN-13: 978-8120345188.
- Yanniotis, S. 2008. *Solving Problems in Food Engineering*. 2008th Edition. Springer. ISBN-13: 978-0387735139.

I. Course Title : Advances in Refrigeration Engineering

II. Course Code : DE 514

III. Credit Hours : 2+1

IV. Why this course?

Refrigeration engineering is an essential technology to preserve the food products. It is an integral part of dairy industry as milk and milk products have very short shelf life. This course is intended to impart knowledge on design aspects of refrigeration and air conditioning systems, system analysis and load calculations. Troubleshooting techniques are explained with the use of wiring diagrams, schematics and 3D sketches.

V. Aim of the course

- To study the various components and the parameters that affect the performance of vapour compression refrigeration
- To study the vapour absorption refrigeration systems

- To study heat pumps and their applications in dairy industry
- To study design and maintenance of cold stores.
- To study controls of refrigeration systems

VI. Theory

Unit I

Vapour compression refrigeration system: major components and their different types; Theoretical vapour compression cycle, theoretical COP; Effect of operating parameters on COP; actual vapour compression cycle; Multi-pressure commercial refrigeration systems.

Unit II

Vapour absorption refrigeration system; Ammonia-water system, lithium bromide - water system, vapour absorption refrigeration cycle and its representation on enthalpy-concentration diagram; Absorption system calculations.

Unit III

Heat Pumps: different heat pump circuits; analysis of heat pump cycle; Use of heat pumps in dairy plant for energy conservation.

Unit IV

Non-conventional refrigeration systems; Steam jet refrigeration, thermoelectric refrigeration, vortex tube, cooling by adiabatic demagnetization.

Unit V

Design elements of refrigeration equipment: compressor, condenser, evaporator, cooling tower, spray pond, etc. Balancing of different components. Design of brazed PHE for condensers

Unit VI

Design of cold storage and air-conditioning systems: types of cooling loads and their calculation, design of cold storage for food products, construction of cold storage, equipment selection, insulating materials, vapour barriers, ice bank tank. Concept of Ice silos, centralised distribution of ammonia through pump, PUF panel design.

Unit VII

Control and maintenance of a commercial refrigeration plant: Pressure regulating valves, Thermostatic valves, LP/ HP cut-outs, high to low side bypass valve, condenser water regulating valve, capacity control devices, pump down control, defrosting methods, liquid charging, advanced intelligent control systems; General preventive maintenance of refrigeration plant.

VII. Practical

- To find and compare the theoretical and actual COP of a small refrigeration unit on Refrigeration Tutor.
- Study and design of refrigeration components of a bulk milk chiller.
- Visit to a commercial refrigeration plant for cold storage/ ice bank unit and calculation of its theoretical COP by making cycle on P-h chart.
- Calculation of theoretical work and comparing it with actual work for some specified cooling job in a commercial plant.
- Study of various control and safety devices in a commercial refrigeration plant.

- Design problems on cold storage for different food/ dairy products.
- Use of computer software specific to cold store AC design
- Study the working of heat pump system.
- Study and design of refrigeration components of a walk-in-cooler
- Evaluate actual performance of a heat pump on heat pump tutor.
- Study of compressors used in vapour compression refrigeration system.
- Study of condensers and expansion devices used in vapour compression refrigeration system
- Study of cooling towers used in vapour compression refrigeration system.
- Industry visit

VIII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Case Analysis and case studies
- Guest Lectures
- Industry Visit

IX. Learning outcome

The students will be familiar with newer technologies like heat pumps, improved VAR systems and cold store prefabricated designs. Students will also be familiar with improved application of energy efficiencies and automation in refrigeration systems. They can apply this knowledge to perform cooling load calculations and service and troubleshoot commercial refrigeration systems.

X. Suggested Reading

- Arora CP. 2017. *Refrigeration and Air-Conditioning*. 3rd Edition, McGraw Hill Education. ISBN-13: 978-9351340164.
- Arora SC and Domkundwar S. 2018. *A Course in Refrigeration and Air- Conditioning*. Dhanpat Rai and Sons.
- *ASHRAE Handbook*. 2018. American Society of Heating and Refrigeration. ISBN-13: 978-1939200983.
- Hundy GF, Trott AR and Welch T. 2008. *Refrigeration and Air-Conditioning*. 4th Edition. Butterworth Heinemann. ISBN-13:9780750685191.
- Dincer I. 2017. *Refrigeration Systems and Applications*. 3rd Edition, Wiley. ISBN-13: 978-1119230755.
- Khurmi RS. 2006. *Textbook of Refrigeration and Air-conditioning*. S. Chand. ISBN-13:9788121927819.
- New-Comer JL. 1981. *Refrigeration and Air-Conditioning*. Venus Trading Co.
- Wang S. 2000. *Handbook of Air Conditioning and Refrigeration*. 2nd Edition, McGraw Hill Education. ISBN-13:9780070681675.
- Whitman WC, Johnson WM, John A and Silberstein E. 2016. *Refrigeration and Air Conditioning Technology*. 8th Edition, Delmar Publications. ISBN-13: 978-0357001059.

I. Course Title : Design of Food and Dairy Processing Equipment

II. Course Code : DE 515

III. Credit Hours : 2+1

IV. Why this course?

The knowledge of various design codes and steps are needed to understand the design and fabrication of dairy and food processing equipment. These are also essential to design new equipment as well as prevent equipment failure. The challenges are to develop machines/gadgets that are responsive to the customer with high quality and low cost. This course is aimed to provide the students with working knowledge of design principles as applied in food and dairy processing operations. In this course, the students will learn how to design major equipment common to most unit operations using relevant CAD/CAM software.

V. Aim of the course

To study design and various codes for pressure vessels, heat exchangers and reactors

VI. Theory

Unit I

Design of vessels: codes and regulations, Design for pressure and temperature, loading; allowable stress, minimum thickness after forming, design for internal and external pressure, cylindrical and spherical shells, formed heads, reinforcement openings; fabrication requirements, inspection, tests and non-destructive examination, pressure tests, design and stress evaluation, design problem.

Unit II

Design of storage vessels/ tanks, horizontal and vertical tanks, design of insulated and un-insulated tanks, nozzles and mountings, Design problems.

Unit III

Design of high-pressure vessels: constructional features, material for high pressure, multi shell construction, solid walled vessel.

Unit IV

Supports for vessel: bracket support or Lug support, web (gusset plates), skirt support, skirt design, skirt bearing plate, saddle support, Design problems.

Unit V

Heat exchangers: shell and tube heat exchangers, construction codes, general design considerations, U- tube heat exchangers, double pipe exchanger, scraped surface exchanger, spiral tube exchangers, joints; welded tube joints, baffles and tube bundles, tube sheet, double tube sheet construction; plate type heat exchanger; air cooled heat exchangers; Computer software for design of heat exchanger, Design problems.

Unit VI

Design of reactor vessel: material of construction, agitation, classification, heating systems, design consideration, tank coils, design of agitation system components, baffles, power requirement for agitation, Hygienic engineering design.

Unit VII

Fundamentals of CAD/ CAM for design of dairy and food processing equipment.

VII. Practical

- Design of storage tanks and silos
- Design of supports for silos and tanks
- Design of high pressure vessels
- Design of plate heat exchanger
- Design of scraped surface heat exchanger

- Design of air cooled heat exchangers
- Computation of power requirement of agitators
- Exercises on use of CAD/CAM software for design of heat exchangers
- Use of computational software for design of heat exchangers

VIII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Case Analysis and case studies
– Guest Lectures
– Industry Visit

IX. Learning outcome

The students will understand the impact of various constraints on product design and process planning. The knowledge and understanding of design codes and procedures would help to understand, operate the processing equipment as well as design new equipment that are efficient and safe to operate. The students can analyse structures using computer software and expedite the design process of various equipment used in the dairy and food industry.

X. Suggested Reading

- Evans FL. 2016. *Equipment Design Handbook for Refineries and Chemical Plants*. Gulf Publishing, Houston, Texas. ISBN-13: 978-0872012660.
- Farrall AW. 2018. *Engineering for Dairy and Food Products*. 3rd Edition, MedTech. ISBN-13: 978-9386800718.
- Kessler HG. 1981. *Food Engineering and Dairy Technology*. Verlag A. Kessler.
- Mahajani VV and Umarji SB. 2016. *Joshi's Process Equipment Design*. 5th Edition, Laxmi Publications. ISBN-13: 978-9351380191.
- Saravacos GD and Kostaropoulos AE. 2012. *Handbook of Food Processing Equipment*. Springer. ISBN-13: 978-1461352129.

I. Course Title : Engineering Properties of Dairy and Food Products

II. Course Code : DE 516

III. Credit Hours : 2+1

IV. Why this course?

The successful and efficient design and operation of process equipment depend on the information and knowledge of engineering properties of dairy and food products. This course is to acquaint the students with different techniques of measurement of engineering properties of biological materials and their importance in the design of food processing equipment. The student will be taught to design and conduct experiments for measuring different properties of biological materials, as well as to analyze and interpret data. Also, the students will acquire knowledge on the application of physical properties to design a system, component, or engineering process to meet desired needs.

V. Aim of the course

- To familiarize with the engineering properties of food products and their measurement.
- To study the application of the properties in design of food process equipment.

VI. Theory

Unit I

Geometrical Properties; Shape, size, volume, density, porosity, surface areas, friction, rolling resistance, angle of repose, specific surface area, mean diameter, sphericity, particle size analysis, Hausner's ratio, Carr's index.

Unit II

Aerodynamic, Hydrodynamic and Frictional Properties; Drag coefficient, terminal velocity, Relation between drag coefficient and Reynolds number, terminal velocity from time distance relation. Pressure drop through packed beds.

Unit III

Thermal properties; Specific heat, thermal conductivity, thermal diffusivity, methods of determination, steady state and transient heat flow, enthalpy, surface heat transfer coefficient freezing point. Measurement of thermal properties and prediction techniques.

Unit IV

Electrical conductivity, capacitance, inductance, Dielectric properties, viz. dielectric and microwave, dielectric constant, Dielectric loss factor, loss tangent, energy absorption, heating; Optical properties, colorimetry, transmittance and reflectance.

Unit V

Non-destructive quality evaluation techniques; Measurement techniques and instruments for food quality determination, destructive and non-destructive quality evaluation, UV-VIS NIR spectroscopy, X-ray, CT, NMR, machine vision system. FTIR, DSC, machine vision system, particle size determination by laser diffraction, e-nose, biosensors, etc.

Unit VI

Application of engineering properties in equipment design, processing and handling of dairy and food products.

VII. Practical

- Determination of geometric mean diameter, sphericity and surface area
- Determination of angle of repose and coefficient of internal friction
- Determination of bulk density, tapped density, true density, porosity, Hausner's ratio and Carr's index
- Particle size distribution analysis
- Determination of aerodynamic properties such as terminal velocity, lift and drag force for grains and particulates.
- Use of empirical equations for determination of thermal properties
- Determination of thermal conductivity, thermal resistivity and specific heat of food materials
- Estimation of surface heat transfer coefficient
- Measurement of electrical conductivity and dielectric properties
- Colour measurement and determination of CIELAB colour parameters
- Study of machine vision system

VIII. Teaching Methods

– Lecture

– Assignment Writing
– Student presentation
– Solving problems
– Familiarising with relevant software

IX. Learning outcome

The student will be familiar with engineering properties of food products and methods to determine these properties. They will be able to apply the fundamentals of engineering sciences to characterize the physical and rheological properties of biological materials. The students can apply the physical, aerodynamic and rheological data in the design of agricultural and food processing machines and processing systems and to various unit operations in the food industry.

X. Suggested Reading

- Arana I. 2016. *Physical Properties of Foods: Novel Measurement Techniques and Applications*. 1st Edition, CRC Press. ISBN-13: 978-1138627130.
- Gunasekaran S. 2000. *Non-destructive Food Evaluation: Techniques to Analyze Properties and Quality*. 1st Edition, CRC Press. ISBN-13: 978-0824704537.
- Heldman DR and Singh PR. 2012. *Food Process Engineering*. 2nd Edition, Springer Science and Business Media. ISBN-13: 978-0870553806
- Mohsenin NN. 1970. *Physical Properties of Plant and Animal Materials*. 1st Edition, Routledge. ISBN-13: 978-0677023007.
- Mohsenin NN. 2020. *Thermal Properties of Food and Agricultural Materials*. Gordon and Breach Science Publishers (CRC Press). ISBN: 0677054505.
- Rahman MS. 2016. *Food Properties Handbook*. 2nd Edition, CRC press. ISBN-13: 978-1138627598.

I. Course Title : Mechanization in Manufacturing of Indigenous Dairy Products

II. Course Code : DE 517

III. Credit Hours : 3+0

IV. Why this course?

The focus of the industry today is now on hygienic, mechanized and mass production of indigenous dairy products. This trend is due to the greater urbanization and higher disposable income and life style change. This course is going to cover all these aspects.

V. Aim of the course

- To design equipment suitable for manufacture of indigenous dairy products.
- To adopt, modify SSHE for continuous manufacture of indigenous dairy products.
- To upscale these equipment for a large scale, hygienic and safe production of indigenous dairy products

VI. Theory

Unit I

Present status of mechanization in manufacture of indigenous dairy products.

Unit II

Preliminary design calculations and material selection, design considerations like force alignment and vibration. Analysis of stresses and strains in rectangular and polar coordinates; Cauchy's formula, principal stresses and principal strains. Failure modes and effects analysis. Manufacturing system types and principles, manufacturing models- physical and mathematical models, realistic model building and design of prototypes.

Unit III

Design of liquid-filled SSHE for preheating applications; Design of equipment for batch and continuous mechanized manufacture of khoa, khoa-based sweets, chhana and chhana-based sweets; Conical process vat, single SSHE, triple SSHE, etc. Equipment for manufacture of batch and continuous manufacture of fermented dairy products, paneer, butter and ghee. Sizing and optimization. Cooling systems for viscous products. Machining standards for stainless steel.

Unit IV

Instrumentation and automation in manufacturing of indigenous dairy products. Automatic filling machines. Changes in engineering properties of milk during manufacture of indigenous dairy products.

Unit V

Design, layout and preparation of project report for establishing unit for the manufacture of indigenous dairy products. Scaling up of prototypes to commercial capacity.

VII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Familiarising with relevant software
– Industry visit

VIII. Learning outcome

The student familiarizes with equipment manufacture suitable for the typical indigenous dairy products. Also the ability to adopt heat exchanger design suitable to manufacture these products in large scale, continuous manufacture under hygienic condition

IX. Suggested Reading

- Aneja RP, Mathur BN, Chandan RC and Banerjee AK. 2002. *Technology of Indian Milk Products*. Dairy India Publications, New Delhi. ISBN-13: 978-8190160308.
- Askin RG. and Standridge CR. 1993. *Modeling and Analysis of Manufacturing System*. John Wiley and Sons. ISBN-13: 978-0471514183.
- Gupta V. 2018. *Dairy India*. 7th Edition. Dairy India Year Book.ISBN-13: 978-8190160339.
- Haik Y, Sivaloganathan S and Shahin MT. 2009. *Engineering Design Process*. 3rd Edition, Cengage Learning.ISBN-13: 978-8131510599.
- Kessler HG. 1981. *Food Engineering and Dairy Technology*. Verlag A. Kessler.
- Kutz M. 2019. *Handbook of Farm, Dairy and Food Machinery Engineering*. 3rd Edition, Academic Press Inc. ISBN-13: 978-0128148037.
- Pahl G, Beitz W, Feldhusen J and Grote KH. 2014. *Engineering Design- A Systematic Approach*. 3rd Edition, Springer. ISBN-13: 978-1447160250.
- Sukumar De. 2001. *Outlines of Dairy Technology*, 1st Edition, Oxford University Press. ISBN-13: 978-0195611946.

I. **Course Title** : **Dairy and Food Engineering-II**
II. **Course Code** : **DE 521**
III. **Credit Hours** : **3+0**

IV. Why this course?

Shelf life of a food is governed by internal and external factors and the type of packaging used. Thus, water activity, package permeability and temperature determine the shelf life of a food. This course is aimed to acquaint the students to integrate these factors to evaluate, model and validate the shelf life of a food product. Also newer methods of non-thermal preservation process like membrane technology and also some of the efficient thermal processes like microwave heating to be better understood and applied.

V. Aim of the course

- To study role of water activity in food preservation.
- To study different packaging material, their properties and effect on shelf life of food products
- To study membrane processing and microwave heating of food products

VI. Theory

Unit I

Water activity and states: a thermodynamic quantity, water sorption isotherms, hysteresis, theories of sorption hysteresis, water activity measurement methods, water binding, control of water activity and moisture; Relationship between water activity and glass transition. Diffusion and sorption kinetics of water in foods

Unit II

Different types of packaging materials, their key properties and applications, Plastic packaging, different types of polymers used in food packaging and their barrier properties. Recent innovations in packaging, identification and testing of packaging materials

Unit III

Permeability and shelf-life: theoretical considerations, permeability to gases and vapours, measurement methods, permeability of multiplayer materials, permeability in relation to packaging requirements of food products. Development of shelf-life models based on moisture gain, lipid oxidation and light.

Unit IV

Calculation of shelf life and requirements for packaging, deteriorative reactions accelerated testing, relationship between transport properties of the package and shelf life of packaged products, simulation of product package- environment interaction, shelf life simulation for moisture, oxygen and light sensitive products.

Unit V

Theory of ultra-filtration, reverse osmosis and electrodialysis, selection and types of membrane and properties, concentration polarization, mathematical description of flow through membrane, application and use in dairy industry. Design calculation and selection of various membrane systems.

Unit VI

Microwave energy absorption, physical parameters in microwave heating processes, heat transfer phenomena, equipment and application in dairy food industry. Types of waveguides, electromagnetic resonators and microwave tubes.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Familiarising with relevant software
- Industry visit

VIII. Learning outcome

Students can design and select packaging material to achieve desired shelf life of a wide variety of food and dairy products. An understanding of application of newer technologies such as Membrane processing, and Microwave heating is also achieved.

IX. Suggested Reading

- Barbosa-Cánovas GV, Fontana AJ, Schmidt SJ and Labuza TP. 2020. *Water Activity in Foods. Fundamentals and Applications*. 2nd Edition, Blackwell Publishing. ISBN-13: 978-0813824086.
- Brennan JG. 2012. *Food Processing Handbook*. 2nd Edition, Wiley-VCH. ISBN-13: 978-3527307197.
- Cheryan M. 2016. *Ultrafiltration and Microfiltration Handbook*. Technomic Publishing. ISBN-13: 978-1498771139.
- Collin RE. 2007. *Foundations for Microwave Engineering*. 2nd Edition. Wiley. ISBN-13: 978-8126515288.
- Karel M and Lund DB. 2003. *Physical Principles of Food Preservation*. 2nd Edition, CRC Press.ISBN-13: 978-0824740634.
- Robertson GL. 2016. *Food Packaging-Principles and Practice*. CRC Press, 3rd Edition, ISBN-13: 9781138628052.
- Varzakas T and Tzia C. 2015. *Handbook of Food Processing*. 1st Edition, CRC Press. ISBN-13: 978-1466582309.

I. Course Title : Bio-Thermal Process Engineering

II. Course Code : DE 522

III. Credit Hours : 3+0

IV. Why this course?

The trend towards longer shelf life milk products is necessitating a closer look at the reaction kinetics and the areas of thermo-bacteriology and fermenters for controlled reaction studies. Also, the field of bioprocessing is developing very rapidly and needs skilled engineers with the background to design, build, control, and operate bioreactors and fermenters. This course provides students with advanced concepts and prepares them to meet the challenges of the new and emerging area of bioprocessing in the food industry.

V. Aim of the course

- To study biochemical reaction kinetics, reaction vessel design and operation.
- To study thermal effects on the UHT processed food products.

VI. Theory

Unit I

Introduction to biochemical engineering: biochemical kinetics, kinetics of substrate utilization, enzyme reaction, growth of microorganisms, fermenters, pasteurization and sterilization and thermal destruction.

Unit II

Design and analysis of fermentation vessels: residence time distribution, reactors in food processing, reactor types, analysis of reactor systems.

Unit III

Mixing in reactors: mixing equipment, power consumption, gas-liquid mixing, liquid-liquid dispersion, solids suspension and solid-liquid mass transfer. Scale-up of mixers and alternative mixing devices.

Unit IV

UHT systems and recent advances: factors affecting spoilage of food, Aseptic packaging systems and conditions.

Unit V

Thermo-bacteriology: Survivor curve, thermal death curve, Arrhenius curve, techniques for determination of heat resistance of microorganisms, analysis of thermal resistance data, processing in containers, process time, lethality, design of batch and continuous sterilisation cycles in vat.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Familiarising with relevant software

VIII. Learning outcome

Student will be familiar with biochemical reaction kinetics and the design of equipment to study the same. The student will also understand the mixing equipment and their dynamic and scale up relationships. A better understanding of UHT processes in perspective of reactions will be achieved.

IX. Suggested Reading

- Bailey JE and Ollis DF. 2017. *Biochemical Engineering Fundamentals*. 2nd Edition, McGraw Hill Education.ISBN-13: 978-0070701236.
- Blanch HW and Clark DS. 2007. *Biochemical Engineering*. T&F India. ISBN-13: 979-0824700996.
- Das H. 2008. *Food Processing Operations Analysis*. Asian Books. ISBN-13: 978-8186299784.
- Das SK and Das M. 2019. *Fundamentals and Operations in Food Process Engineering*. 1st Edition, CRC Press.ISBN-13: 978-1466560901.
- McNeil B and Harvey LM. 1990. *Fermentation: A Practical Approach*. IRL Press. ISBN-13: 978-0199630455.
- Pauline MD. 2013. *Bioprocess Engineering Principles*. Elsevier Science, 2nd Edition, ISBN-13: 978-9381269831.
- Stumbo. 1965. *Thermobacteriology in Food Processing*. 2nd Edition, Academic Press. ISBN-13: 978-0126753523.

I. Course Title : Industrial Instrumentation and Process Control

II. Course Code : DE 523

III. Credit Hours : 2+1

IV. Why this course?

With the advancements in electronics, automation has become the trend in dairy industry. Automation enables better control of the process operations resulting in improved efficiency. Therefore, understanding of computer control of instrumentation and automation is essential in the rapidly developing field of Automation in Dairy and Food Industry.

V. Aim of the course

- To study microprocessor based instruments used in industries.
- To study various control systems for process control.
- To study computer based control systems.

VI. Theory

Unit I

Introduction; Instrumentation systems and its classification, measuring instruments, characteristics of instruments, intelligent versus dumb instruments, Microprocessor based instrumentation, Function of measurement systems, its elements and applications. Industrial instrumentation, Structure of industrial instrumentation in real time applications

Unit II

Control Systems; Feedback principles. Mechanical, hydraulic and pneumatic system components. Characteristics of liquid system, gas system, thermal system. Mathematical model of liquid process, gas process, flow process, thermal process, mixing process, Chemical reaction, D.C. and A.C. Servomotors, D.C. and A.C. Tachogenerators, Potentiometers and optical encoders, Synchro and stepper motors, Modelling and objectives of modelling for batch and continuous processes, Self-regulation. Pneumatic valves

Unit III

Process Control and Controllers; Principles of automatic process control, Process characteristics, control system parameters, Process control loop, Elements of process control, process variables, Process facility considerations, controller modes, lag time, error signals, and correction signals, Actuators and Control valves; on-off, P, PI, P-I-D, cascade, feed forward, and ratio controllers, Fuzzy controllers. Data loggers and data acquisition, Introduction to computer based control systems, PLC, DCS, SCADA, HMI, etc.

Unit IV

Modern Transducers and Display Devices; Silicon micro transducers, optical transducer principles, types, characteristics of fibres and fibre optic transducers, Introduction to smart transducers and their applications, displays and their classification - Storage CRTs, Flat CRTs, LEDs, LCD display, Gas discharge plasma displays, Incandescent display, Electrophoretic image displays (EPID), Liquid vapour display (LVD).

Unit V

Introduction to computer based control; Computer based controller, data logging, supervisory control, flow chart, control system networks, basic structure and operation of programmable logic controllers (PLCs).

VII. Practical

- Study and analysis of electric switches, networks, electromechanical relays, MCB, SCR etc.
- Study of CRO and digital display devices.
- Study of automation techniques to control temperature by using PID controller.
- Study and application of digital timer to control timing of various processes, working of controllers in constant temperature water baths
- Make ladder diagrams and flow sheet diagrams for control logics in PLC.
- Study programme of a PLC and computer interface of a PLC.
- Study the characteristics of resistance transducer potentiometer and calibration of ammeter, voltmeter using DC potentiometer.
- Characteristics of LDR, photo diode, and phototransistor:
  – Variable illumination.
  – Linear displacement.
- Study of storage oscilloscope and transient response of RLC circuit.
- Study the characteristics of one solid state sensor/ fibre optic sensor
- Design and test a signal conditioning circuit for the transducers.
- Visit to a microprocessor controlled dairy plant

VIII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Solving problems
– Industry visit

IX. Learning outcome

Students will get an insight on advanced data acquisition, processing and monitoring systems that provide dynamic responses of various systems. The student will learn about various systems and levels of automation involved in operation and control of dairy plant and the link up of computer software to it.

X. Suggested Reading

- Barney GC. 2018. *Intelligent instrumentation: Microprocessor Applications in Measurement and Control*. Prentice Hall International. ISBN-13:978-0134689432.
- Bhargava NN, Kulshreshtha DC and Guptta S. (Eds.). 2017. *Basic Electronics and Linear Circuits*. 2nd edn, McGraw Hill Publication.
- Harriot P. 2012. *Process Control*, Tata McGraw Hill Publishing Co Ltd., New Delhi. ISBN: 9780070993426.
- Johnson CD. 2015. *Process Control Instrumentation Technology*, 8th Edition, Pearson Education India. ISBN-13: 978-9332549456.
- Kalsi HS. 2019. *Electronic Instrumentation and Measurements*, 4th Edition, McGraw-Hill Education. ISBN-13: 978-9353162511.
- Sawhney AK. 2015. *A Course in Electronic Measurements and Instrumentation*, Dhanpat Rai and Co. ISBN-13: 978-8177001006.
- Stephanopoulos G. 2008. *Chemical Process Control: An Introduction to Theory and Practice*, Prentice Hall India, ISBN-13: 978-8120306653.

I. Course Title : Industrial Automation and Robotics

II. Course Code : DE 524

III. Credit Hours : 3+0

IV. Why this course?

The understanding of the Microprocessor controls, SCADA and Robotics and their application in material handling, process control and supervision is essential in large food industry. This course is going to cover all these aspects.

V. Aim of the course

- To study automation, role in material handling and manufacturing systems.
- To study computer based industrial automation, SCADA, etc.
- To study elements of Robotics.

VI. Theory

Unit I

Introduction; Automation in Production System, principles and strategies of automation, basic elements of an automated system, advanced automation functions, levels of automation. Flow lines and transfer mechanisms, fundamentals of transfer lines.

Unit II

Material handling and Identification Technologies: Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems, Overview of Automatic Identification Methods.

Unit III

Automated manufacturing systems; Components, classification and overview of manufacturing systems, Manufacturing cells, GT and Cellular manufacturing, FMS, FMS and its planning and implementation. Quality control systems: Traditional and modern quality control methods, SPC tools, inspection principles and practices, inspection technologies.

Unit IV

Control technologies in automation; Industrial control systems. Manufacturing industries, continuous versus discrete control, computer process and its forms.

Unit V

Computer based industrial control; Introduction and automatic process control building blocks of automation systems; LAN, Analog and Digital I/O modules, SCADA systems and RTU. Distributed control system: Functional requirements, configurations and some popular distributed control systems. Industrial control applications in dairy and food processing industry. Microcontroller units (MCU); Arduino, Raspberry Pi sensors compatible with MCUs: temperature- RH, ultrasound and infrared sensors.

Unit VI

Basic principles of robotics, configurations, control. Application of machine vision systems, Image processing and analysis. Typical pick and place, loading and unloading, packaging and palletizing applications.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Familiarising with relevant software

VIII. Learning outcome

Student will have knowledge of application of Robotics in the operations of the food processing industry. Also acquire knowledge of microcontroller applications and the components of automation in using them.

IX. Suggested Reading

- Cichocki A, Ansari HA, Rusinkiewicz M and Woelk D. 2012. *Workflow and Process Automation: Concepts and Technology* (Vol. 432). Springer Science and Business Media. ISBN-13: 978-1461375999.
- Groover MP. 2016. *Automation, Production Systems and Computer-Integrated Manufacturing*. 4th Edition, Prentice Hall Press. ISBN-13: 978-9332572492.
- Helfrick AD and Cooper WD. 2015. *Modern Electronic Instrumentation and Measurement Techniques*. Pearson Education India.
- Hollender M. 2012. *Collaborative Process Automation Systems*. ISA.
- Kant K. 2010. *Computer-based Industrial Control*. 2nd Edition, PHI Learning Pvt. Ltd. ISBN-13: 978-8120339880.
- Moore CA. 2012. *Automation in the Food Industry*. Springer Science and Business Media. ISBN-13: 978-1461565109

I. Course Title : Unit Operations

II. Course Code : DE 525

III. Credit Hours : 2+1

IV. Why this course?

Many of processing steps are categorized and studied under independent operations called Unit Operations. It is important to study these individually, so that in the larger context, these can be seamlessly integrated into the industrial operations. Treatment of the process in terms of individual unit operations allows process engineers to move away from product specific operation to one which is general. In order to manufacture a product of desired quality with the maximum yield, each unit operation must be designed correctly. Mathematical treatment of the process can lead to prediction of conditions that give the highest efficiency. This course is specifically designed for students of food processing disciplines, so that these can be exposed to various unit operations that would enable them to improve the design and operation of food processing plants.

V. Aim of the course

- To study various unit operations in food processing.
- To study crystallization and distillation in food processing.
- To study extrusion, extraction, expelling in food processing.

VI. Theory

Unit I

Grading, cleaning, washing, sorting, shelling, dehusking, decortication, milling, polishing, pearling, drying (evaporative, osmotic and freeze drying), Mixing, clarification, coagulation, mechanical separation, sedimentation.

Unit II

Handling of food products; Mechanics of bulk solids, selection of bulk handling equipment, operation and construction of conveyors and elevators, viz. belt conveyors, screw/auger conveyors, bucket elevators and drag/chain conveyors. Estimation of energy requirement, damage to products during mechanical handling. Operation and maintenance of conveying equipment.

Unit III

Mechanical cleaning and sizing of food products – size reduction, size characteristics, particle geometry, energy for size reduction of granular materials and dry powders, size- reduction equipment, performance characteristics of size reducers. Different milling methods, cryogenic grinding.

Unit IV

Crystallization; Material and energy balance in crystallizers, Principles of crystal growth, super saturation and nuclei formation, operation of batch and continuous crystallizers.

Unit V

Distillation; Flash-off distillation, binary mixtures, differential distillation, steam distillation.

Unit VI

Flow through porous media, adsorption, pressing, expelling, extraction, palletizing, and extrusion.

VII. Practical

- Performance evaluation of cleaning and sorting equipment- destoners, spiral separators, graders, etc.
- Performance evaluation of size reduction equipment- disc grinders, hammer mill, ball mill, etc.
- Calculation of energy for size reduction through Kick's, Bond's and Rittinger's laws.
- Determination of particle size distribution of powders by ASTM sieve analysis
- Application of rotary and vacuum evaporator for concentration of liquid foods
- Use of distillation for solvent extraction of oleoresins and essential oils
- Performance evaluation of conveying equipment- screw conveyors, belt conveyors, bucket elevators, etc.

VIII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Industry visit

IX. Learning outcome

Student will have good understanding of the unit operations like size reduction, crystallization, distillation, material handling and the energies involved in these operations. This course serves to integrate the fundamental concepts learned with various industrial operations of manufacturing of food products. Also the knowledge gained in the treatment of one process can be used to a completely new process.

X. Suggested Reading

- Berk Z. 2018. *Food Process Engineering and Technology*. 3rdEdition, Academic Press. ISBN-13: 978-0123736604.
- Earle RL. 2013. *Unit Operations in Food Processing*. 2nd Edition, Pergamon press, ISBN-13: 978-1483293103.
- Fellows P. 2016. *Food Processing Technology: Principles and Practice*.4thEdition, Woodhead Publishing, ISBN-13: 978-0081019078.
- Foust AS, Wenzel LA, Clump CW, Clump CW and Andersen LB. 2008. *Principles of Unit Operations*. 2nd Edition, John Wiley and Sons. ISBN-13: 978-8126518296.
- Geankoplis CJ, Hersel AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*. 5th EditionPearson. ISBN-13: 978-0134181028.
- Ibarz and Barbosa-Carnovas GV. 2003. *Unit Operations in Food Engineering*. 1st Edition, CRC Press. ISBN-13: 978-6610546282.
- McCabe WL, Smith JC and Harriott P. 2017. *Unit Operations of Chemical Engineering*. 7th Edition, McGraw Hill Education. ISBN-13: 978- 8184959635.
- Sahay KM and Singh KK. 2004. *Unit Operations of Agricultural Processing*. 2nd Edition, Vikas Publishing House Pvt. Ltd. ISBN-13: 978-8125911425
- Singh RP and Heldman DR. 2013. *Introduction to Food Engineering*. 5th Edition, Academic press. ISBN-13: 978-0123985309.

I. Course Title : Environmental Engineering

II. Course Code : DE 526

III. Credit Hours : 2+0

IV. Why this course?

There is a continuous change in the environmental norms and regulatory standards of the country and all industries including dairy and food industry have to follow them. This requires up gradation of techniques for treatment of wastewater and solid waste from the industries. Hence, it is important to have good understanding of the latest methods of treatment of the dairy industry effluents and their safe, economic and legal disposal.

V. Aim of the course

- To study waste water characteristics, measurement and its treatment methods.
- To study air pollution and methods to control it.

VI. Theory

Unit I

Waste water sources, characteristics, standards for disposal of dairy waste water.

Unit II

Physical, chemical and biological characteristics of waste water, measurement of organic content in waste water

Unit III

Physical unit operations in waste water treatment: screening, racks, mixing, flocculation, sedimentation, floatation, elutriation, vacuum filtration and incineration.

Unit IV

Chemical unit operations in waste water treatment: reaction kinetics, chemical precipitation, aeration and gas transfer process, rate of gas transfer, adsorption and disinfection.

Unit V

Biological unit operations- aerobic and anaerobic cycles, kinetics of biological growth, application of kinetics to treatment systems, aerobic waste treatment, anaerobic waste treatment

Unit VI

Air conditioning systems: clean – room air conditioning; important pollutants of air; properties of particulate matter and air pollution control methods. Dairy plant fire hazards.

VII. Teaching Methods

- Lecture
- Assignment Writing
- Student presentation
- Solving problems
- Industry visit

VIII. Learning outcome

Student will be able to learn the advances in physical, chemical and biological operations of dairy waste treatment and effluent disposal. This will enable them to identify and implement scientific and technological solutions to various environmental problems. Also, they will learn about control methods to provide clean and conditioned air for enclosures in dairy plant operations.

IX. Suggested Reading

- Davis M and Cornwell D. 2017. *Introduction to Environmental Engineering*. 5th Edition, McGraw Hill Education ISBN-13: 978-9339204037.
- Hussain A and Ahmed S. 2018. *Advanced Treatment Techniques for Industrial Wastewater (Advances in Environmental Engineering and Green Technologies)*.1st Edition, IGI Global. ISBN-13: 978-1522557548.
- Karia GL. 2013. *Wastewater Treatment: Concepts and Design Approach*. 2nd Edition, Prentice Hall India Learning Private Limited.ISBN-13: 978-8120347359.
- Kuehn T, Ramsey J and Threlkeld J. 1998. *Thermal Environmental Engineering*. 3rd Edition, Prentice Hall of India. ISBN-13: 978-0139172205.
- Metcalf and Eddy, Tchobanoglous G, Burton F and H David Stensel. 2017. *Wastewater Engineering*: *Treatment Disposal Reuse*. Tata McGraw Hill. ISBN-13: 978-0070495395.
- Peavy HS, Rowe DR and Tchobanoglous G. 2017. *Environmental Engineering*. McGraw Hill Education. 1st Edition, ISBN-13: 978-9351340263.
- Rao MN. 2020. *Waste Water Treatment* 3rd Revised Edition. Oxford and IBH Publishing. ISBN-13: 978-8120417120.
- Syed R. Qasim and Guang Zhu. 2018. *Wastewater Treatment and Reuse Theory and Design Examples*. 1st Edition, Volume 2: Post-Treatment, Reuse, and Disposal. CRC Press. ISBN-13: 978-1138300941.

I. Course Title : Energy Management and Auditing in Dairy and Food Plants

II. Course Code : DE 527

III. Credit Hours : 3+0

IV. Why this course?

The energy cost is increasing as fossil fuels are being depleted. Lot of energy is used for heating and refrigeration purpose in the dairy industry. Therefore, there is a need for understanding and implementing various methods of 'Energy Conservation and Management' in the dairy industry. This is important in view of reducing environmental pollution too.

V. Aim of the course

- To study methods of identifying various Energy Conservation opportunities in dairy and food plants.
- To study various methods involved in Energy Management in dairy and food plants
- To study methods and steps involved in Energy Auditing in dairy and food plants.

VI. Theory

Unit I

Energy audit; its need and types. Bench marking of energy costs. Matching energy use to requirement. Optimizing the input energy requirements. Fuel and energy substitution. Energy Balance and computation of efficiency of energy.

Unit II

High efficiency boilers, improved combustion techniques, energy conservation in steam distribution systems, upkeep and maintenance of steam auxiliaries and fittings.

Unit III

Electrical load management; Demand management, Energy saving controllers, Power factor and its improvement. Transformer; Energy saving in transformers.

Unit IV

Electric motor; Selection and application, energy efficient motors. Variable speed drives and Variable Frequency drives. Industrial lighting

Unit V

Energy conservation in Refrigeration and Cold storages, cooling towers, pumps and pumping systems, fans, blowers, air compressors, Maintenance and upkeep of vacuum and compressed air pipelines.

Unit VI

Processing equipment; Improving efficiency and energy conservation opportunities in kettles, PHEs, Evaporators and Driers. Hot air generator, thermic fluid heater, steam radiator, waste heat recovery and thermal energy storage in food processing facilities, condensate recovery and reuse.

VII. Practical

- Bench marking for various dairy plant operations
- Computation of energy conservation in boilers and steam distribution
- Computation of energy demand management of a dairy plant
- Computation of energy savings in induction motors and transformers
- Exercise on variable frequency drive applications
- Computation of cooling load and energy savings in refrigeration plant and cold stores
- Computation of energy savings in air compressor and compressed air distribution
- Computation of energy savings in counter-current plate heat exchangers and HTST pasteurizer

- Computation of energy saving in multiple effect evaporators and modern dryers
- Energy audit of a dairy plant

VIII. Teaching Methods

– Lecture
– Assignment Writing
– Student presentation
– Solving problems
– Industry visit

IX. Learning outcome

Student will gain knowledge of different types of Energy Auditing, Energy Conservation and substitution with Renewable Energy. Important aspects of Electrical load management and selection and up gradation of equipment to higher energy efficiency to save energy will be covered.

X. Suggested Reading

- Abbi YP and Jain S. 2009. *Handbook on Energy Audit and Environment Management*, The Energy and Resources Institute (TERI), New Delhi. ISBN-13: 978-8179930922.
- *Bureau of Energy Efficiency*, 4th floor, Sewa Bhavan, R.K. Puram, New Delhi. Guide Books No. 1 to 4. for National Certification Examination for Energy Managers and Energy Auditors. Pub. 2015.
- Klemes J, Smith R and Kim JK. 2008. *Handbook of Water and Energy Management in Food Processing* (Woodhead Publishing series in Food Science, Technology and Nutrition). 1st Edition, Woodhead Publishing, CRC Press. ISBN-13: 978-1420077957.
- *Practical Guide to Energy Conservation in Dairy Industry*. 2011. Petroleum Conservation Research Association, Sanrakshan Bhawan, 10 Bhikaiji Cama Place, New Delhi. Pub. ISBN 978-81-908167-1-7
- Roosa SA, Doty S and Turner WC. 2018. *Energy Management Handbook*. 9th Edition, River Publishers. ISBN-13:978-1138666979.

Course Title with Credit Load
Ph.D. in Dairy Engineering

Course Code	Course Titles	Credit Hours
Major Courses		
DE 611**	Advances in Dairy Process Engineering	3+1
DE 612	Advances in Heat Transfer	3+0
DE 613	Physicochemical Processes	3+0
DE 621**	Computational Methods and Simulation in Dairy and Food Engineering	2+1
DE 622	Package Permeability and Shelf-Life Modelling	3+0
DE 624	Special Problems	0+2
DE 691	Doctoral Seminar I	1+0
DE 692	Doctoral Seminar II	1+0
DE 699	Doctoral Research	0+75

Minor Courses

The courses will be selected from the allied disciplines of Dairy Technology, Dairy Chemistry and Dairy Microbiology to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered in agricultural statistics, computer applications and IT, and other related relevant disciplines to meet the minimum credit requirements.

Common Courses

1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1

*Core courses for Master's programme;
**Core courses for Doctoral programme

Course Contents
Ph.D. in Dairy Engineering

I. Course Title : Advances in Dairy Process Engineering
II. Course Code : DE 611
III. Credit Hours : 3+1

IV. Why this course?

To provide the latest methodologies of simulation and modelling for designing of process equipment, problem solving in operation and maintenance of evaporators, driers and mixing equipment. This course is going to cover all these aspects.

V. Aim of the course

To impart knowledge on design and analysis of selected dairy equipment.

VI. Theory

Unit I

Evaporator designs and selection, piping and instrumentation diagrams of evaporator systems, heat and mass balance in single effect system, vapour recompression and impact on efficiency, layout and design calculations of multiple effect evaporator, estimation of residence time in film evaporators, fouling of evaporators and cleaning, entrainment separators.

Unit II

Drying; Design data, performance and selection and design of dryers: tray dryer, drum dryer, freeze dryer, fluidized bed dryer. Design of powder recovery systems; Automation in spray dryers, management of explosions and fire hazards in spray dryers.

Unit III

Mixing of materials; Factors in mixing, types of mixers, operation, mixing gas, liquid and solid; heat transfer in mixers, power requirement, transmission, scale-up of models.

Unit IV

Material handling; System and devices, design and applications of screw, belt, flight, apron conveyors, bucket elevators; power requirements, feeding and discharge mechanisms.

Unit V

Mathematical modelling in food processing operations; Process modelling and optimisation approaches, framework and challenges, transport phenomena models for food process simulation for optimal design and operation. Stochastic finite element analysis of thermal food processes. Neural networks approach to modelling food processing operations.

VII. Practical

- Problems on design of evaporators- effect of temperature and pressure on heat

transfer and efficiency
- Effect of boiling point rise and enthalpy of concentration on heat transfer in evaporators
- Study of vacuum pan
- Reading Piping-Instrumentation diagrams of evaporator systems
- Analysis of drying rate curves of different types of dryers
- Design of tray, drum and fluidized bed dryers
- Design of agitators for liquid systems
- Analysis of heat transfer in agitated vessels
- Effectiveness of mixing of liquids, dispersions and emulsions
- Design of belt, bucket and screw conveyors

VIII. Learning outcome

Students will acquire thorough understanding of recent advances in the design and operation of Evaporators, driers, Mixers and material handling equipment, using Modelling and optimization techniques.

IX. Suggested Reading

- Ahmed J and Shafi-ur-Rahman M. 2012. Handbook of Food Process Design. Wiley-Blackwell Publishing Ltd. ISBN-13: 978-1444330113.
- Chaudhary C, Rai D and Kumar D. (Eds.). 2018. *Advances in Food Processing Techniques*. Kalyani Publishers.
- Chen XD and Mujumdar AS. 2008. Drying Technologies in Food Processing, Blackwell Publishing Ltd. ISBN-13: 978-8126549788.
- Das H. 2008. Food Processing Operation and Analysis. Asian Books. ISBN-13: 978-8186299784.
- Geankoplis CJ, Hersel AA and Lepek DH. 2018. Transport Processes and Separation Process Principles, 5th Edition, Pearson. ISBN-13: 978-0134181028.
- Saravacos GD and Kostaropoulos AE. 2016. Handbook of Food Processing Equipment, 2nd Edition, Springer International. ISBN-13: 978-3319250182.
- Valentas KJ, Rotstein E and Paul Singh R. 1997. Handbook of Food Engineering Practice. CRC Press. ISBN-13: 978-0849386947.
- Zeki Berk. 2018. Food Process Engineering and Technology, 3rd Edition, Academic Press. ISBN: 9780128120187.

I. Course Title : Advances in Heat Transfer

II. Course Code : DE 612

III. Credit Hours : 3+0

IV. Why this course?

To enable the students to solve problems on heat transfer under steady and unsteady state conditions in 1, 2 and 3 dimensional geometries and turbulent flow conditions. This course is going to cover all these aspects.

V. Aim of the course

To develop analytical and numerical approaches for heat transfer operation

VI. Theory

Unit I

Steady state one - dimensional problems, Bessel functions, composite structures, Principal of superposition, Heterogeneous solids, Power series solutions, Properties of Bessel functions, Extended surfaces, Approximate solutions for extended surfaces.

Unit II

Steady state two- and three- dimensional problems, Separation of Variables; Orthogonal functions; Boundary value problems; Characteristic value problems; Orthogonality of characteristics functions; Fourier series. Separation of variables; Steady two-dimensional Cartesian geometry, selection of coordinates, steady two-dimensional spherical geometry, Legendre polynomials, Steady three-dimensional geometry.

Unit III

Unsteady problems - Separation of Variables, Orthogonal functions, Distributed systems having stepwise disturbances, Use of one-dimensional chart, Time - dependent boundary conditions, Duhamel's superposition integral, Laplace transforms.

Unit IV

Heat transfer in turbulent flow: turbulent flow, boundary layer, Prandtl analogy, temperature distribution in turbulent flow, empirical and practical correlation for convection heat transfer, heat transfer in packed beds. Use of computational software for modelling heat and moisture transfer in various unit operations.

VII. Learning outcome

The students will learn problem solving skills on heat transfer under steady and unsteady state conditions encountered in unit operations such as frying, baking, cooling, freezing, evaporation, drying, etc.

VIII. Suggested Reading

- Arora SC, Domkundwar S and Domkundwar AV. 2007. *A Course in Heat and Mass Transfer*. Dhanpat Rai and Co. (P) Ltd. ISBN-13: 978-8177000290.
- Bergman TL, Lavine AS, Incropera FP and DeWitt DP. 2016. *Fundamentals of Heat and Mass Transfer*. 8th Edition, Wiley Publishers. ISBN-13: 978-1119337683.
- Cengel YA and Ghajar AJ. 2017. *Heat and Mass Transfer*. 5th Edition, Tata McGraw-Hill Education Pvt. Limited. ISBN-13: 978-9339223199.
- Geankopolis CJ, Hersel AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*. 5th Edition, Prentice-Hall Private Ltd. ISBN-13: 978-0134181028.
- Holman JP. 2017. *Heat Transfer*. 10th Edition, McGraw-Hill Higher Education Publishers. ISBN-13: 978-0071069670.
- Kreith F and Manglik RM. 2017. *Principles of Heat Transfer*. 8th Edition, Cengage Learning Publishers. ISBN-13: 9781305387102.
- Kumar DS. 2013. *Basics of Heat and Mass Transfer*. S K Kataria and Son Publishers. ISBN-13: 978-9350140604.

I. Course Title : Physicochemical Processes

II. Course Code : DE 613

III. Credit Hours : 3+0

IV. Why this course?

Physicochemical processes are like cog in the wheels of various unit operations. These help in deeper understanding of the various chemical unit operations and mass separation processes in the industry. This course will impart advance knowledge of mass transfer in various chemical engineering processes, which form the backbone of dairy and food engineering operations.

V. Aim of the course

- To develop understanding of advanced physical and chemical processes, their unit operations and design.

VI. Theory

Unit I

Types of separation processes; Adsorption process; Relationship between surface tension and adsorption, adsorption equilibrium and adsorption isotherm; Commercial adsorbents; Sorption kinetics in continuous flow reactors, factors influencing adsorption; Design of fixed adsorption columns and breakthrough adsorption curve.

Unit II

Membrane processing-computation of osmotic pressure of various solutions; Mathematical description of mass transport through reverse osmosis membrane; Water and solute diffusion, mechanisms of membrane transport, membrane transport models; Factors affecting membrane performance: membrane properties, concentration polarization; Types of flow: difference between gas and liquid permeation processes; Extraction: Liquid-solid extraction, single and multi-stage extraction, liquid-liquid extraction, supercritical fluid extraction, classification and properties of supercritical fluids, design and applications.

Unit III

Electrodialysis: Minimum energy requirements, selective ion transport, power requirement of electrodialysis, design of an electrodialysis systems; Ion-exchange process: exchange resins, kinetics of exchange and resin capacity, equilibrium relations in ion exchange, ion-selectivity: Design of fixed bed ion exchange columns.

Unit IV

Aeration and gas transfer, gas transfer processes, rates of gas transfer, power requirement of aerations systems, film transfer, theories of gas transfer, liquid-phase transport involving chemical reactions.

VII. Learning outcome

The students will learn mass transfer in various physical and chemical processes which will help them to better understand dairy and food processing unit operations.

VIII. Suggested Reading

- Das H. 2008. *Food Processing Operation and Analysis*. Asian Books. ISBN-13: 978-8186299784.
- Don Green and Southard MZ. 2018. *Perry's Chemical Engineers' Handbook*, 9th Edition, McGraw-Hill Education. ISBN-13: 978-0071834087.
- Geankoplis CJ, Hersel AA and Lepek DH. 2018. *Transport Processes and Separation Process Principles*, 5th Edition, Pearson. ISBN-13: 978-0134181028.
- Martinez JL. 2007. *Supercritical Fluid Extraction of Nutraceuticals and Bioactive Compounds*, 1st Edition.CRC Press. ISBN -13: 978-0849370892.
- McCabe W, Smith J and Harriot P. 2017. *Unit Operations of Chemical Engineering*, 7th Edition, McGraw Hill Education, ISBN-13: 978-9339213237.
- Rao MA, Rizvi SSH. and Datta AK. 2014. *Engineering Properties of Foods*, 4th Edition, CRC Press, ISBN-13: 978-1466556423.
- Ruthven D M. 1984. *Principles of Adsorption and Adsorption Processes*. John Wiley and Sons.
- Sinnot RK and Towler G. 2019. *Coulson and Richardson's Chemical Engineering: Chemical Engineering Design*. (Coulson and Richardson's Chemical Engineering). Elsevier. ISBN-13: 978-9351073932.

I. Course Title : Computational Methods and Simulation in Dairy and Food Engineering

II. Course Code : DE 621

III. Credit Hours : 2+1

IV. Why this course?

With the advent of powerful computers and software, there is a paradigm shift in the computation and simulation methods used to solve complex and advanced problems in the field of dairy and food engineering. This is a mathematical course for engineers and scientists designed to solve various engineering and natural problems. It deals with the approximate solution formations of various mathematical models. This course is aimed to impart knowledge on the recent developments in Computational and Simulation techniques, with practical applications in the field of Dairy and Food Engineering.

V. Aim of the course

To develop competence in developing statistical/theoretical models.

VI. Theory

Unit I

Taylor's series expansion in development of numerical differentiation; numerical differentiation procedures, forward difference, backward difference, central difference.

Unit II

Numerical integration trapezoidal rule, Simpson's rule, improper integrals, Gauss-Legrendre Quadretuse method, numerical methods to solve ordinary differential equations.

Unit III

Euler method, improved Euler method, Runge-Kutta method, Adam's P-C method, initial value problems, numerical solution of partial differential equation: explicit method, implicit method.

Unit IV

Simulation concept, simulation methods and their limitations, statistical and theoretical models.

Unit V

Problem formulation and development of models; solution and validation of models; data collection; processing and analysis; basic modeling problems on unit operations involved in dairy and food processing.

VII. Practical

- Solution to Taylor's series approximation
- Exercises on numerical differentiation – central difference, forward difference and backward difference
- Numerical integration by Simpson's rule, trapezoidal rule, Gauss-Legrendre approximation
- Exercises on Euler's method approximation
- Exercises on Runge-Kutta method
- Numerical solution to partial differential equations

- Problem solving on unit operations in dairy and food processing
- Application of computational software for solving numerical integration, differentiation and boundary layer problems
- Concepts of simulation and validation

VIII. Learning outcome

The skills and knowledge taught in this course are fundamentally useful to students who do simulations and research in computational engineering. The students will be trained on solving complex and advanced problems in the field of dairy and food engineering using computational and simulation approaches in software such as MATLAB, CFD, COMSOL Multiphysics, etc.

IX. Suggested Reading

- Balagurusamy E. 2017. *Numerical Methods*. McGraw Hill Education. ISBN-13: 978-0074633113.
- Bober W. 2013. *Introduction to Numerical and Analytical Methods with MATLAB for Engineers and Scientists*. CRC Press. ISBN-13: 978-1466576025.
- Franks and Roger GE. 1972. *Modeling and Simulation in Chemical Engineering*. Wiley-Interscience.
- Gerald CF and Wheatley PO. 2007. *Applied Numerical Analysis*. 7th Edition. Addison Wesley. ISBN-13: 978-8131717400.
- Hamming RW. 1987. *Numerical Methods for Scientists and Engineers*. Dover Publications Inc. ISBN-13: 978-0486652412.
- Jain MK, Iyengar SR, Kanchi MB and Jain. 1993. *Computational Methods for Partial Differential Equations*, New Age Publishers. ISBN-13: 9788122404296.
- Kandaswamy P, Thilagavathy K and Gunavathi K. 2006. *Numerical Methods*. S. Chand and Company. ISBN-13: 978-8121914383.
- Kiusalaas J. 2015. *Numerical Methods in Engineering with MATLAB*. 3rd Edition, Cambridge University Press.
- Kobayashi H. 1978. *Modeling and Analysis: An Introduction to System Performance Evaluation Methodology*. Addison-Wesley Publishing. ISBN-13: 978-0201144574.
- Fausett LV. 2009. *Applied Numerical Analysis Using MATLAB*. 2nd Edition. Pearson Education India. ISBN-13: 978-8131728536.
- Sastry SS. 2015. *Introductory Methods of Numerical Analysis- Theory and Applications*. 9th Edition, Cengage learning, New Delhi.

X. Software

1. MATLAB version 9.6
2. CONSOL multi-physics version 5.4
3. CFD software like ANSYS, Fluidyn

I. Course Title : Package Permeability and Shelf-Life Modelling

II. Course Code : DE 622

III. Credit Hours : 3+0

IV. Why this course?

Traditional dairy products have very short shelf life due to poor packaging. Their shelf life can be improved by designing appropriate tailor made packaging. This course will impart the required knowledge on deteriorative reactions, their kinetics that affect the shelf life of the food and the design/ selection of appropriate flexible packaging materials for dairy products. Also, integration of water activity, deteriorative reactions and package permeability will be covered to predict the shelf life of foods.

V. Aim of the course

To impart knowledge on design of specific packaging for indigenous dairy products and to determine their shelf life.

VI. Theory

Unit I

Thermodynamics of water activity; Composition based water activity prediction models; determination of sorption isotherms; Moisture sorption types and hysteresis: Theory and Everett's classification of hysteresis, models for prediction of sorption isotherms; Composition based moisture sorption isotherm models.

Unit II

Temperature and moisture control in foods; Moisture management systems; Importance of temperature control and temperature management; Adiabatic saturation of air and its applications.

Unit III

Protective packaging of foods: Cushioning and G-factor, Use of moisture vapours permeability rates in design for a definite shelf-life; Design problems; Rates of deteriorative reactions and factors influencing them, prediction and simulation of shelf-life of foods; Validation of predictive shelf-life models.

Unit IV

Iterative procedures for moisture sensitive products, oxygen sensitive products; error analysis, water vapour permeability and oxygen barrier properties of composite packaging materials and fabricated package systems.

Unit V

Nanocomposites from biopolymers: production, mechanical properties and applications; Influence of nanocomposites and clays on barrier properties of packaging materials.

VII. Learning outcome

The students will acquire knowledge on design of packaging for indigenous dairy products and understand the intricacies among deteriorative reaction kinetics and package permeability affecting the shelf life of food. Also the students will learn about testing, prediction and validation of shelf life of dairy products in various packaging environment.

VIII. Suggested Reading

- Advani S. 2007. *Processing and Properties of Nanocomposites*. World Scientific. ISBN-13: 978-9812703903.
- Barbosa-Canovas G, Fontana AJ, Schmidt SJ and Labuza TP. 2007. *Water Activity in Foods-Fundamentals and Applications*. Blackwell Publishing.ISBN-13: 978-0-813-82408-6.
- Brennan JG. 2011. *Food Processing Handbook*. 2nd Edition, Wiley-VCH Verlag GmbH and Co. KGaA, Wienheim. Germany.ISBN-13:9783527324682.
- Karel M and Lund DB. 2003. *Physical Principles of Food Preservation*. 2nd Edition, CRC Press. ISBN-13: 978-0824740634.
- Fennema OR. 1976. *Principles of Food Science*. Part I and II. Marcel Dekker Inc. ISBN-13: 9780824763503.
- Robertson GL. 2015. *Food Packaging- Principles and Practice*. CRC Press. ISBN-13: 9781439862421.

- Simatos D and Multon JL. 2011. *Properties of Water in Foods in Relation to Quality and Stability*. Dordrecht: Martinus Nijhoff. ISBN-13: 9789401087568.

Suggested Broad Topics of Research

- Application of high pressure processing in indigenous dairy products
- Pulsed electric field and pulsed light treatment of milk and indigenous dairy products
- Studies on irradiation of dairy products
- Application of thermo and manosonification during manufacture of dairy products
- Micro- and nanoencapsulation of active food ingredients
- Energy and exergy performance evaluation of evaporators and dryers.
- Performance evaluation of agitated tanks and solids blenders
- Performance evaluation of conveyor systems
- Design modifications and upgradation of process equipment for better performance
- Hygienic design solutions
- Design of evaporators and dryers
- Freezing of dairy products
- Simultaneous momentum, heat and mass transfer analysis of thermal processing of dairy products
- Application of computational methods for heat and mass transfer analysis and simulation of dairy process equipment
- Development of computer software for the performance analysis and design of heat exchange equipment.
- Biosensors, E-nose, machine vision and non-destructive analysis and evaluation of dairy products
- Application of MATLAB in design of biothermal processes and equipment
- Recovery of heat energy and reuse for improvement of efficiency in dairy plant
- Studies on use of heat pumps in dairy plant for energy conservation
- Water activity characterization of milk products
- Shelf life simulation and modelling of moisture and oxygen sensitive products
- Design of fermenters and aeration systems
- Design of improvised wastewater treatment techniques
- Model-based fault-detection for process engineering instrumentation
- Instrumentation for measurement of engineering properties of dairy and food materials
- Controlled atmosphere storage for enhancing the shelf-life of foods
- Non-thermal processing of dairy products
- Development of simulation models for various unit operations in dairy and food processing.
- Engineering and rheological properties of food materials and characterization of food powders
- Extrusion technologies and sub-baric frying of dairy products
- Supercritical extraction of bioactive compounds
- Small scale milk processing equipment and farm level cooling and chilling systems
- Novel, edible and biodegradable packaging for dairy products
- Enhancement of thermal performance of dairy equipment by nanocoatings

List of Journals

- *Journal of Food Engineering*
- *Drying Technology*

- *Journal of Food Process Engineering*
- *Journal of Food Processing and Preservation*
- *International Dairy Journal*
- *LWT – Food Science and Technology*
- *Trends in Food Science and Technology*
- *Agricultural Engineering International*
- *Journal of Food Science and Technology*
- *Indian Journal of Dairy Science*
- *Indian Journal of Agricultural Engineering*
- *Food Research International*
- *European Food Research and Technology*
- *International Journal of Food Science and Technology*
- *Applied Thermal Engineering*
- *Heat and Mass Transfer*
- *International Heat and Mass Transfer*
- *Journal of Food Measurement and Characterization*
- *Industrial Crops and Products*
- *Industrial and Engineering Chemistry Research*
- *Powder Technology*
- *Advanced Powder Technology*
- *Journal of Encapsulation*
- *Biosystems Engineering*
- *International Journal of Dairy Technology*
- *Journal of Dairy Science*
- *Computers and Electronics in Agriculture*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Chemistry

Course Title with Credit Load
M.Tech. in Dairy Chemistry

Course Code	Course Title	Credit Hours
DC 511	Physico-chemical Aspects of Milk Constituents	2+1
DC 512*	Milk Carbohydrates, Minerals and Water Soluble Vitamins	2+1
DC 513*	Chemistry of Milk Lipids	2+1
DC 514	Chemistry of Food Constituents	2+1
DC 521*	Chemistry of Milk Proteins	3+1
DC 522*	Chemistry of Processed Dairy Foods	3+1
DC 523	Chemical Quality Assurance and Management Tools	2+1
DC 524	Research Techniques	1+2
DC 591	Master's Seminar	1+0
DC 599	Master's Research	0+30

Course Contents
M.Tech. in Dairy Chemistry

I. Course Title : Physico-Chemical Aspects of Milk Constituents
II. Course Code : DC 511
III. Credit Hours : 2+1

IV. Why this course?

This course will help the students while working in dairy industry/research institutes for better understanding of behaviour of milk constituents with respect to their chemical reactions and physical state. This course is going to cover all these aspects.

V. Aim of the course

To impart knowledge on the physico-chemical aspects of milk and milk products with special reference to their processing and quality assurance.
The course is organized as follows:

No.	Blocks	Units
1.	Reaction Kinetics	I Chemical and Enzymatic reactions
		II Electrochemistry
2.	Surface and colloidal Chemistry	III Surface Chemistry
		III Foams and Emulsions
		V Micelles and Gelation

VI. Theory

Block 1: Reaction Kinetics

Unit I: Chemical and Enzymatic reactions

Basics of chemical reaction kinetics, Order and molecularity of a reaction. Kinetics of denaturation of whey proteins and Maillard browning. Kinetics of enzymatic reactions; the role of enzymes as biological catalysts; factors affecting the rate of enzyme reaction: concentration of substrate, concentration of enzyme, concentration of reaction products, pH, temperature, time, activators and inhibitors. Thermal inactivation of enzymes present in milk. Concept of activation energy

Unit II: Electrochemistry

Electrolytic dissociation: activity, ionic strength and dissociation constants of acids and bases; effect of ionic strength on dissociation constants. Buffer, buffer capacity and buffer index of milk and milk products. Redox reactions and photo-oxidation of milk.

Block 2: Surface and colloidal Chemistry

Unit III: Surface Chemistry

Adsorption at solid – vapour interphase; Monolayer and multilayer adsorption; capillary condensation; adsorption isotherms; Hysteresis. Sorption of water on milk constituents and milk products and its relation to stability of dairy products.

Unit IV: Foams and Emulsions

Colloidal and surface phenomena in milk; adsorption at solid-liquid and liquid-liquid interphases; Gibb's equations. Interfacial tension, surface tension, surface active agents, general aspects of foaming, churning and whipping of cream; emulsion and emulsion stability; coalescence and dispersion; an introduction to the concept of Nano emulsion and Nano micelles.

Unit V: Micelles and Gelation

Micelles: definition, critical micelle concentration, formation and stability; Colloidal stability of casein micelles in milk, zeta potential, size distribution of casein micelles and fat globules. Gels and their formation, structure and stability; acid and rennet gels.

VII. Practical

- Determination of the order of hydrolysis of an ester and measurement of activation energy.
- Measurement of the order of hydrolysis of a carbohydrate and measurement of activation energy.
- Assessment of the progress curve obtained during the hydrolysis of p-nitrophenyl phosphate by milk alkaline phosphatase.
- Analysis of effect of substrate concentration on hydrolysis of p-nitrophenyl phosphate by milk alkaline phosphatase.
- Study of effect of enzyme concentration on hydrolysis of p-nitrophenyl phosphate by milk alkaline phosphatase.
- Michaelis constant determination for the digestion of casein by trypsin.
- Measurement of pH and buffering capacity of different types of milk.
- Preparation of a buffer of a given molarity/ionic strength and pH and determination of pH of the buffer.
- Stability analysis of an oil-in-water emulsion stabilised by milk proteins
- Foaming capacity and foam stability of caseins/whey proteins.
- Study of the gel formation and gel stability of milk proteins.
- Drawing of an adsorption isotherm of water on casein.
- Measurement of thermal inactivation of enzymes (Alkaline phosphatase, Lactoperoxidase).

VIII. Teaching Methods/ Activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Apply basics of reaction kinetics in understanding different phenomenon in milk during processing and storage.
– Role of different constituents of milk in formation and stability of emulsions, foams and gel

X. Suggested Reading

- Ancheyta J. 2017. *Chemical Reaction Kinetics: Concepts, Methods and Case Studies*. John Wiley and Sons.
- Dickinson E. 1995. *Food Macromolecules and Colloids*, RSC Special Publication.
- Dickinson E. 2005. *Food Colloids: Interactions, Microstructure and Processing*, RSC advancing chemical series.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- McClements DJ. 2016. *Food Emulsions: Principles, Practices and Techniques*, 3rd Edn, CRC press Taylor and Fracis group.
- Puri BR, Sharma LR, Pathania MS. 2016. *Principles of Physical Chemistry,* 47th Edition Vishal Publishing Co.
- Rockland LB and Beuchat LR. 1987. *Water Activity: Theory and Applications to Food*, Marcel Dekker Inc, NY.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.

I. Course Title : Milk Carbohydrates, Minerals and Water Soluble Vitamins

II. Course Code : DC-512

III. Credit Hours : 2+1

IV. Why this course?

This coursewill givean overview of carbohydrates, minerals and vitamins present in milk. This knowledge will help the students to understand the various physicochemical reactions occur during processing and storage of dairy foods.

V. Aim of the course

To impart basic knowledge on aspects of milk carbohydrates, minerals and water soluble vitamins and to project the importance of these milk constituents on the quality of milk and milk products as well as in human health.

The course is organized as follows:

No.	Blocks	Units
1.	Lactose	I. Chemistry of lactose
		II. Physical properties of lactose
		III. Chemical properties of lactose
2.	Mineral	IV. Minerals in milk
		V. Physical equilibrium amongst milk salts
		VI. Effect of Processing on Minerals
3.	Vitamins	VII. Water soluble vitamins:

VI. Theory

Block 1: Lactose

Unit I: Chemistry of lactose

Lactose: occurrence, isomers, molecular structure, levels in milk of different species.

Unit II: Physical properties of lactose

Physical properties of lactose: crystalline habits, hydrates, lactose glass, specific rotation, equilibrium of different isomers in solution, solubility, density, sweetness.

Unit III: Chemical properties of lactose

Chemical properties of lactose: hydrolysis; Pyrolysis; Oxidation; Reduction; Degradation with strong bases; Derivatives; Dehydration and Fragmentation; Browning reaction; Oligosaccharides in milk-health significance.

Block 2: Mineral

Unit IV: Mineral in Milk

Minerals: major and minor minerals; Factors affecting variation in salt composition of milk; Distribution and importance of trace elements in milk.

Unit V: Physical equilibrium amongst milk salts

Physical equilibrium amongst milk salts; Effect of various treatments on salt equilibrium; Partitioning of salts and factors affecting them.

Unit VI: Effect of Processing on Minerals

Salt balance and its importance in the processing of milk; Protein-mineral interactions.

Block 3: Vitamins

Unit VII: Water soluble vitamins

Water soluble vitamins: molecular structure, levels in milk and milk products; factors affecting their levels; Biological significance; Ascorbic acid structure; Relation with redox potential (Eh) of milk and milk products.

VII. Practical

- Estimation of lactose in milk by volumetric method
- Estimation of lactose in milk by gravimetric method
- Estimation of lactose in milk by polarimetric method
- Estimation of lactose in milk by colorimetric methods
- Determination of sodium and potassium by (flame photometry)
- Determination of calcium and magnesium by EDTA method
- Determination of phosphorus by colorimetric method (Fiske and Subba Rao)
- Estimation of citric acid by colorimetric methods
- Determination of iron by colorimetric methods
- Estimation of vitamin C in milk by volumetric method
- Determination of HMF content in heated milk

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the significance of milk as a source of carbohydrates, minerals and water soluble vitamins.
- Understand the importance of these constituents in chemical, physical, technological, nutritional and physiological properties of milk.

X. Suggested Reading

- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- Jennes RG. 1995. *Handbook of Milk Composition*. Academic Press.
- McSweeney PLH and Fox PF. 2009. *Advanced Dairy Chemistry Volume 3: Lactose, Water, Salts and Minor Constituents*. Springer-Verlag New York.
- Paques M and Lindner C. (Eds.). 2019. Lactose: Evolutionary Role, Health Effects, and Applications. Academic press.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John and Wiley.
- Watson RR, Collier RJ and Preedy VR. (Eds.). 2017. Nutrients in dairy and their implications for health and disease. Academic Press.
- Young W. Park and George F.W. Haenlein. 2013. *Milk and Dairy Products in Human Nutrition*. John Wiley and Sons, UK.
- Zadow JG. 1992. *Whey and Lactose Processing*. Elsevier Science Publishers Ltd- Springer Netherlands.

I. Course Title : Chemistry of Milk Lipids

II. Course Code : DC 513

III. Credit Hours : 2+1

IV. Why this course?

The course will provide in-depth coverage of milk lipids. It makes the students capable to understand various chemical reactions occur during processing and storage of milk and milk products. This course is going to cover all these aspects.

V. Aim of the course

To impart the basic knowledge on different aspects of milk lipids and to project the importance of milk lipids in the quality of dairy products as well as in human health.

The course is organized as follows:

No.	Blocks	Units
1.	Milk Lipids	I. Classification of milk lipids II. Properties of milk lipids III. Unsaponifiable matter
2.	Chemical properties of milk lipids	IV. Chemical Reaction of milk fat V. Oxidation of milk fat

VI. Theory

Block 1: Milk Lipids

Unit I: Classification of milk lipids

Milk lipids: General classification, neutral and polar lipids (phospholipids) in milk, gross composition of milk lipids in different species, physico-chemical properties of milk lipids; role of major milk lipids in milk and milk products and biological significance of milk lipids; Composition of milk fat globule membrane.

Unit II: Properties of milk lipids

Fatty acid profile of milk lipids; factors affecting the profile of fatty acids; Different properties of fatty acids

Unit III: Unsaponifiable matter

Unsaponifiable matter and its importance; Composition of unsaponifiable matter; Chemistry, levels and physiological functions of sterols; Fat soluble vitamins and carotenoids in milk.

Block 2: Chemical properties of milk lipids

Unit IV: Chemical Reaction of milk fat

Chemical properties of milk lipids: hydrolysis by alkali, water and enzymes; hydrogenation, halogenation, transesterification, inter-esterification and fractionation.

Unit V: Oxidation of milk fat

Autoxidation: Definition, theories, induction period, secondary products of autoxidation, factors affecting, prevention and measurement; various methods for evaluating primary and secondary oxidation products; Antioxidants: Definition, types, reaction mechanism and estimation. Thermal oxidation of fat

VII. Practical

- Determination of melting point/slip point and B.R reading of milk fat.
- Determination of conjugated dienes, peroxide value and anisidine value of milk fat.
- Analysis of milk fat for its thiobarbituricacid-(TBA) value.
- Estimation of carbonyl value of milk fat
- Determination of unsaponifiable matter in milk fat.
- Total cholesterol estimation in milk fat.
- Determination of vitamin A and D in milk fat
- Estimation of total phospholipids and free fatty acids in milk fat.
- Preparation of fatty acid methyl esters and their analysis by GLC.
- Quantitative determination of butylatedhydroxylanisole (BHA) in milk fat.

VIII. Teaching Methods/ Activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic aspects of milk lipids in terms of quality of dairy products and human health
– Understand the different reactions taking place during processing and storage of milk fat

X. Suggested Reading

- Akoh CC and Min DB. 1997. *Food Lipids: Chemistry, Nutrition and Biotechnology*. Marcel Dekker.
- Fox PF and McSweeney PLH. 2006. *Advanced Dairy Chemistry Volume 2: Lipids*. Springer-US.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and*

Biochemistry. Springer International Publishing-Switzerland.
- Mathur MP, Datta Roy D and Dinakar P. 1999. *Text Book of Dairy Chemistry*. ICAR.
- Truong T, Lopez C, Bhandari B and Prakash S. 2020. *Dairy Fat Products and Functionality*.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.
- Wong NP, Jenness R, Keeney M and Elmer HM. 1988 *Fundamentals of Dairy Chemistry*. Van Nostrand Reinhold Co.

I. Course Title : Chemistry of Food Constituents

II. Course Code : DC 514

III. Credit Hours : 2+1

IV. Why this course?

This course will help the students to get more insight into chemistry of food constituents such as water, carbohydrates, protein, lipids, phytochemicals and food additives. This course will also enrichthe knowledge of students for working in food industry/research institutes for better understanding of processed food products development.

V. Aim of the course

To impart knowledge on different chemical aspects of food components
The course is organized as follows:

No.	Blocks	Units
1.	Major Constituents of Foods	I. Water II. Carbohydrates III. Proteins IV. Food Lipids
2.	Minor constituent of foods	V. Phyotchemicals VI. Food Additives

VI. Theory

Block 1: Major Constituents of Foods

Unit I: Water

Water: Forms of water in foods; water- solute interactions, and food stability in relation to water activity; solute mobility; property of ice crystals; role of ice in the stability of food at sub-freezing temperatures.

Unit II: Carbohydrates

Carbohydrates: Starch; Types, swelling behaviour, gelatinization and their role in bread making; modification of starches for industrial applications, physico-chemical changes taking place during malting. Oligosaccharides: Structural units of commercially available oligosaccharide, their properties and preparation methods, Hydrocolloids, their properties and utilization in different food preparations; mutual interactions among hydrocolloids and interactions with proteins.

Unit III: Proteins

Proteins: Classification, distribution and physico-chemical properties of food proteins from various sources; structure-function relationship and their modifications; denaturation of food proteins. Application of enzymes in food Industry; Immobilized enzymes, Browning reactions in foods: enzymatic browning and non-enzymatic browning (caramelization and maillard reaction).

Unit IV: Food Lipids

Food Lipids: Physico-chemical properties of food lipids and their modifications; Composition of various types of edible oils/fats with special reference to their quality; auto-oxidation of food lipids.

Block 2: Minor constituent of foods

Unit V: Phyotchemicals

Phytochemicals: Chemistry of polyphenols, phenolic acid, flavonoids, phytosterols, phytostanol.

Unit VI: Food Additives

Food Additives: Sweeteners, anticaking agents, antioxidants, humectants, preservatives, neutralizers, stabilizers, emulsifiers, texture modifiers, flavours and colours etc.

VII. Practical

- Estimation of fat content in cereal products by Soxhlet method.
- Determination of total nitrogen in cereal products.
- Determination of gluten content in wheat flour.
- Analysis of starch in flour by polarimetric method.
- Estimation of crude fibre in food product.
- Determination of polyphenol content in tea and coffee.
- Determination of antioxidant activity in various foods using DPPH/FRAP methods
- Detection of adulteration of mustard oil with argemone oil.
- Detection of artificial colours in various spices.
- Determination of level of artificial sweeteners (saccharin and aspartame)
- Visit to a food plant.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Forms of water in food and its role in stability of food during storage at low temperature
- Types of carbohydrates, proteins, lipids in various types of foods, changes in such constituents during processing, interaction of carbohydrates and proteins, application of enzymes in food industry including immobilization of enzymes
- Types of phytochemicals in foods and role of additives to impart various functions in foods.

X. Suggested Reading

- Belitz HD, Grosch W and Schieberle P. 2004. *Food Chemistry*. 3rd Ed. Springer.

- Connie M. Weave. 2017. *The Food Chemistry Laboratory: A Manual for Experimental Foods*, Dietetics, and Food Scientists, Second Edition CRC Press.
- Damodaran S, Parkin KL and Feenema OR. 2008. *Fennema's Food Chemistry*. 4th Ed. CRC Press.
- Dwidvedi A. 2016. *Enzyme Immobilization: Advances in Industry, Agriculture, Medicine, and the Environment*. 1st edition. Springer.
- Fennema OR. 1985. *Food Chemistry*. Marcer Dekker.
- Peter CK and Bhavbhuti M. 2015. *Handbook of Food Chemistry*. Springer-Verlag Berlin Heidelberg.
- Srinivas D and Alan Praf. 1997. *Food Proteins and their Applications*. Marcel Dekker.
- Velisek J, Koplik R and Cejpek K. 2020. *The Chemistry of Food*. John Wiley and Sons.

I. Course Title : Chemistry of Milk Proteins

II. Course Code : DC 521

III. Credit Hours : 3+1

IV. Why this course?

This course will help the students of dairying to get more insight into chemistry of milk proteins and in understanding the various physicochemical reactions occur during milk processing. This course is going to cover all these aspects.

V. Aim of the course

To impart knowledge on different aspects of milk proteins
The course is organized as follows:

No.	Blocks	Units
1.	Milk proteins	I. Basic concept of milk proteins
		II. Major milk proteins
		III. Whey proteins
		IV. Minor milk proteins
2.	Properties of milk proteins	V. Denaturation of proteins
		VI. Enzymes

VI. Theory

Block 1: Milk proteins

Unit I: Basic concept of milk proteins

Milk proteins of different species and their variability. Distribution and fractionation of different nitrogen fractions of milk proteins; nomenclature of milk proteins; genetic polymorphism and biological significance of milk proteins.

Unit II: Major milk proteins

Major milk proteins: caseins (acid and micellar), methods of isolation; Fractionation of casein and heterogeneity; Physico-chemical properties; amino acid composition; Casein micelle models; Primary structure of different caseins; Modification of casein: Physical, chemical (glycosylation, phosphorylation) and enzymatic.

Unit III: Whey proteins

Alpha-lactalbumin and beta-lactoglobulin, bovine serum albumin: distribution and methods of isolation and their physico-chemical properties.

Unit IV: Minor milk proteins

Minor milk proteins: Proteose-peptone, immunoglobulins, lactoferrin, and fat globule membrane proteins.

Block 2: Properties of milk proteins

Unit V: Denaturation of proteins

Denaturation of milk proteins, various factors affecting denaturation; Casein-whey protein interactions.

Unit VI: Enzymes

Indigenous milk enzymes: Properties and their significance with particular reference to lipases, proteases, phosphatases, catalase, peroxidase, xanthine oxidase, lysozyme, lactoperoxidase and galactosyltransferase

VII. Practical

- Estimation of different nitrogen fractions of milk by Kjeldahl method.
- Preparation of acid and rennet casein; urea fractionation of acid casein; isolation of alpha-lactalbumin and beta-lactoglobulin by ammonium sulphate precipitation.
- Milk protein estimation by Folin method.
- Polyacrylamide gel electrophoresis of milk proteins.
- Assay of indigenous milk enzyme activity like protease, lipase, alkaline phosphatase and lactoperoxidase.
- Estimation of hexoses and sialic acid in casein.
- Measurement of degree of hydrolysis of milk proteins.
- Measurement of denaturation of whey proteins.

VIII. Teaching Methods/ Activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic aspects of milk proteins in terms of major and minor milk proteins
– Understand the effect of different processing of milk on interaction of milk proteins

X. Suggested Reading

- Boland M and Singh H. (Eds.). 2019. Milk proteins: from expression to food. Academic Press.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- Mathur M, Datta Roy D and Dinakar P. 1999. *Text Book of Dairy Chemistry*. ICAR.
- McSweeney PLH, O'Mahony and James A. 2013. *Advanced Dairy Chemistry Volume 1A: Proteins: Applied Aspects*. Springer-Verlag, New York.
- McSweeney PLH, O'Mahony and James A. 2016. *Advanced Dairy Chemistry Volume 1B: Proteins: Applied Aspects*. Springer-Verlag, New York.
- Robert G Jensen 1991. *Handbook of Milk Composition*. Academic Press.

- Wong NP, Jenness R, Keeney M and Elmer HM. 1988 *Fundamental of Dairy Chemistry*. 3rd Ed. Van Nostrand Reinhold Co.

I. Course Title : Chemistry of Processed Dairy Foods

II. Course Code : DC 522

III. Credit Hours : 3+1

IV. Why this course?

To gain insights in the underlying chemical changes during processing of milk for preparation of concentrated, dried, fermented and fat rich dairy products and frozen desserts. This course is going to cover all these aspects.

V. Aim of the course

To understand the physico-chemical changes and effects of various milk constituents of milk products during manufacture and storage of processed dairy foods.

The course is organized as follows:

No.	Blocks	Units
1.	Concentrated and Dried milks and dried milks	I. Process induced changes in concentrated II. Human milk and infant food III. Heat induced changes in milk
2.	Chemistry of Dairy Products	IV. Cheese and other fermented dairy products V. Cream, butter and ghee VI. Ice cream and frozen desserts

VI. Theory

Block 1: Concentrated and Dried milks

Unit I: Process induced changes in concentrated and dried milks

Process induced changes in milk constituents during preparation and storage of concentrated and dried milks.

Unit II: Human milk and infant food

Role of biologically active components in human milk; Standards, composition and properties of infant milk and infant food formulations

Unit III: Heat induced changes in milk

Heat induced changes in milk leading to coagulation; Heat stability of concentrated milk as affected by different process variables, Milk constituents and additives; Age gelation: Mechanism and control.

Block 2: Chemistry of Dairy Products

Unit IV: Cheese and other fermented dairy products

Biochemical changes during ripening of different varieties of cheese; Lactic acid fermentation in cheese and other fermented dairy products; chemical defects in cheese.

Unit V: Cream, butter and ghee

Storage stability of cream, butter and ghee. Physico-chemical properties of ghee; Ghee flavour, texture (grains) and colour in ghee.

Unit VI: Ice cream and frozen desserts

Role of different ingredients during processing and storage of ice cream/ frozen desserts; Concept of antifreeze protein/ice structuring protein in ice cream

VII. Practical

- Determination of lactose and sucrose in condensed milk and ice-cream.
- Determination of weight per litre of ice-cream.
- Determination of heat stability of milk and concentrated milks.
- Determination of WPNI of skim milk powder.
- Determination of fat in cream and butter by Mojonnier method.
- Determination of salt in butter.
- Determination of diacetyl and acetyl methyl carbinol in butter/ cultured products.
- Determination of RM, Polenske value, iodine value, saponification value of ghee.
- Determination of soluble proteins, salt and free fatty acids in cheese.
- Determination of rennet clotting time of milk.

VIII. Teaching Methods/ Activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic aspects of dairy chemistry in terms of processing of different dairy products
– Understand the different reactions taking place during storage of dairy products

X. Suggested Reading

- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
- Koca N. (Ed.). 2018. *Technological Approaches for Novel Applications in Dairy Processing*. BoD–Books on Demand.
- Mathur MP, Roy DD and Dinakar P. 1999. *Textbook of Dairy Chemistry*. ICAR.
- Official methods of AOAC. 11^{th} and 15^{th} Eds.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.
- Wong NP, Jeness R, Keeney M and Elmer HM. 1988. *Fundamentals of Dairy Chemistry*. Van Nostrand Reinhold Co.

I. Course Title : Chemical Quality Assurance and Management Tools

II. Course Code : DC 523

III. Credit Hours : 2+1

IV. Why this Course?

The course will provide in depth knowledge in preparing the reagents, testing methodologies and quality tools to understand the concept of 'Quality Assurance' in dairy industries. This course is going to cover all these aspects.

V. Aim of the course

To project the importance of chemical quality assurance and safety in relation to dairy industry and impart basic knowledge on all aspects of chemical quality and safety assurance

The course is organized as follows:

No.	Blocks	Units
1.	Quality Management Tools and Quality Assurance Organizations	I. Quality Tools and Management System II. International and National organisations
2.	Analytical Methods	III. Assessment of Quality of milk and milk products IV. Contaminants and Food Traceability

VI. Theory

Block1: Quality Management Tools and Quality Assurance Organizations

Unit I: Quality Tools and Management System

Concept of quality assurance and quality control in relation to dairy industry; Quality management systems - good manufacturing practices (GMP); HACCP certification; ISO 9001, ISO 22000, FSSC, total quality management (TQM); Lean and Six sigma, Five –S, Kaizen, Kanban and other quality tools; Good laboratory practices (GLP), laboratory accreditation

Unit II: International and National Organisations

Role of international organisations such as ISO, IDF, CAC, AOAC, WTO and national organisations like BIS, FSSAI, AgMark and APEDA in dairy industry, Quality Council of India (QCI), Export Inspection Council (EIC); Guidelines for setting up quality control laboratory and chemical safety aspects; sampling of milk and milk product; Food labeling guidelines.

Block 2: Analytical Methods

Unit III: Assessment of Quality of milk and milk products

Detergents, sanitizers and disinfectants; Calibration of milk testing glassware; Preparation of standard reagents; Detection of adulterants in milk and milk products; Quality of packaging material for dairy products; Instrumentation in analysis of milk and milk products.

Unit IV: Contaminants and Food Traceability

Agro-chemicals/veterinary drug residues; occurrence of pesticide residues, antibiotic residues, heavy metals etc. in dairy products and their testing methods, Laboratory auditing, Food traceability systems, Food recall and withdrawal

VII. Practical

- Preparation of standard solutions
- Testing of available chlorine content in hypochlorites/ bleaching powder
- Determination of purity of common salt to be used for butter and cheese making
- Detection of common adulterants in milk and foreign fat/ oil in ghee
- Checking the accuracy of calibration of hydrometers/ lactometers, butyrometers, milk pipette and thermometer
- Qualitative colour tests to distinguish between azo dyes and natural dyes in butter

- Maintenance of records as per NABL and ISO criteria.
- Visit to a food analytical laboratory.

VIII. Teaching Methods/ Activities
- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the requirements and policy relating to implementation of various quality management tools.
- Apply the food safety standards to specific situations

X. Suggested Reading

- Hoorfar J. 2012. *Case Studies in Food Safety and Authenticity*. 1st Ed. Woodhead Publishing
- IDF. 1993. *Quality Assurance (QA) and Good Lab. Practices (GLP) in Dairy Laboratories*. Special Issue No. 9302.
- IDF. 1997. *Monograph on Residues and Contaminants in Milk and Milk Products*. Special Issue No. 9701.
- Konieczka P and Namiesnik J. 2018. *Quality Assurance and Quality Control in The Analytical Chemical Laboratory: A Practical Approach*. CRC Press.
- Ralph Early. 1995. *Guide to Quality Management System for Food Industry*. Blackie.
- Schrenk D and Cartus A. 2017. *Chemical Contaminants and Residues in Food.* 2nd Ed. Woodhead Publishing.
- Young W. Park and George FW. Haenlein 2013. *Milk and Dairy Products in Human Nutrition*. John Wiley and Sons, UK.

I. Course Title : Research Techniques

II. Course Code : DC 524

III. Credit Hours : 1+2

IV. Why The Course?

This course concentrates on instrumental methods of analysis. The course will beof importance to all the students, who rely on the use of instrumental analysis in their field of research while conducting research as part of their postgraduate studies.

V. Aim of the course

To impart the advanced knowledge on the use of analytical techniques in Dairy Chemistry

The course is organized as follows:

No.	Blocks	Units
1.	Separation and Purification of Biomolecules	I. Electrophoresis II. Chromatography III. Membrane processing and centrifugation
2.	Laboratory Analytical Techniques	IV. Instrumental Techniques V. ELISA and lateral flow assay

VI. Theory

Block1: Separation and Purification of Biomolecules

Unit I: Electrophoresis

Electrophoresis: principles and types, isoelectric focussing

Unit II: Chromatography

Chromatographic techniques: Principles and types (Paper and Column Chromatography, TLC, GLC, HPLC, gel-permeation, ion-exchange, affinity).

Unit III: Membrane processing and centrifugation

Separation of bio-molecules using membranes; Centrifugation: principle, types and applications.

Block 2: Laboratory Analytical Techniques

Unit IV: Instrumental Techniques

Spectrophotometry: UV, visible, IR and flame photometry; Potentiometry: principles, ion-selective electrodes; buffers. Measurement of size and zeta potential of colloidal solution or emulsion using dynamic light scattering/ particle size analyser

Unit V: ELISA and lateral flow assay

Immuno based analytical techniques such as ELISA and Lateral flow assay.

VII. Practical

- Paper chromatography, TLC separation of amino acids.
- Gel-filtration of biomolecules.
- Preparation of a buffer and measurement of its pH electro-metrically and using indicators.
- SDS gel electrophoresis and molecular weight determination.
- Plotting of UV-visible absorption spectra of a standard analyte.
- Demonstration of Beer's law using standard protein.
- Estimation of minerals using AAS.
- Separation of milk proteins using ion-exchange chromatography and affinity chromatography.
- Detection of analytes using ELISA and lateral flow assay.
- Separation of biomolecules using HPLC.
- Preparation of methyl esters of fatty acids of milk fat and analysis by GLC.
- Separation of fat/casein using centrifugation.

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Provides a sound foundation to the theory and application of modern analytical techniques.

– Impart the concept of good laboratory practice and protocol, and hands-on experience of modern analytical instrumentation.

IX. Suggested Reading

- Christian GD, Dasgupta PS and Schug K. 2014. *Analytical Chemistry*, 7th Edition Wiley Global Education.
- Clark JM and Switzer RL. 1977. *Experimental Biochemistry*. WH Freeman and Co.
- Cooper TG. 1977. *The Tools of Biochemistry*. John Wiley and Sons.

- Frank A Settle. 1997. *Handbook of Instrumental Techniques for Analytical Chemistry*. Prentice Hall.
- Leo ML and Toldra NF. *Handbook of Dairy Foods Analysis*. 1st Ed. CRC Press.
- Nielsen S Suzanne 1994. *Introduction to the Chemical Analysis of Foods*.Jones and Barlett Publ.
- Sawhaney SK and Singh R. 1985. *An Introduction to Practical Biochemistry*. Narosa Publ.
- Stock R and Rice F. 1974. *Chromatographic Methods*. Chapman and Hall.
- Su W. 2018. *Trends in Food Authentication*: Wen-Hao Su; Ioannis S. Arvanitoyanni; Da-Wen, Sun. In Modern Techniques for Food Authentication (Second Edition).
- Wilson K and Walker J. 2000. *Practical Biochemistry: Principles and Techniques*. Cambridge Univ. Press.

Course Title with Credit Load
Ph.D. in Dairy Chemistry

Major Courses

Course Code	Course Title	Credit Hours
DC 611	Advances in Chemistry of Milk Proteins	3+0
DC 612	Advances in Chemistry of Milk Lipids	3+0
DC 621	Advances in Chemistry of Dairy Processing	3+0
DC 622	Advances in Analytical Techniques in Dairy Chemistry	3+0
DC 691	Doctoral Seminar-I	1+0
DC 692	Doctoral Seminar-II	1+0
DC 699	Doctoral Research	0+75

Minor Courses

The courses will be selected from the major courses of the allied disciplines of Dairy Technology, Dairy Microbiology, Dairy Engineering and Animal Biochemistry to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered in agricultural statistics, computer applications and IT, and other related relevant disciplines to meet the minimum credit requirements.

Common Courses

1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1
5.	Agricultural Research, Research Ethics and Rural Development Programmes	1

Course Contents
Ph.D. in Dairy Chemistry

I. Course Title : Advances in Chemistryof Milk Proteins

II. Course Code : DC-611

III. Credit Hours : 3+0

IV. Why this course?

To gain insights in the underlying structure-function aspects of milk proteins, biological role of bioactive milk proteins, properties of bioactive peptides and allergy aspects of milk proteins.

V. Aim of the course

To understand the advances in area of functionality of milk proteins
The course is organized as follows:

No.	Blocks	Units
1.	Biosynthesis and Structure Function relationship of milk Proteins	I. Biosynthesis of milk proteins II. Structure of milk protein with respect to function III. Modification of milk proteins with respect to function
2.	Biological role of milk proteins	IV. Antimicrobial protein in milk V. Significance of bioactive peptides VI. Nutritive and therapeutic aspects of milk proteins

VI. Theory

Block 1: Biosynthesis and structure Function relationship of milk Proteins

Unit I: Biosynthesis of milk proteins

Biosynthesis of milk proteins, milk fat globule membrane (MFGM) proteins.

Unit II: Structure of milk protein with respect to function

Primary structure of casein, structural properties of casein and whey proteins and their structure-functional relationship

Unit III: Modification of milk proteins with respect to function

Physical, chemical and enzymatic modification of milk proteins and their functional characteristics

Block 2: Biological roles of milk proteins

Unit IV: Antimicrobial protein in milk

Mechanism of action and biological role of specific and non-specific antimicrobial factors in milk- immunoglobulins, lactoferrin, lactoperoxidase and lysozyme

Unit V: Significance of bioactive peptides

Milk protein derived bioactive peptides – their properties; significance and application; bitter peptides in cheese; growth factors in milk.

Unit VI: Nutritive and therapeutic aspects of milk proteins

Nutritive and therapeutic aspects of milk proteins and peptides;
Milk protein allergy: mechanism and method of their reduction in dairy products

Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic mechanism on functionality of major milk proteins and bioactive milk proteins
- Understand the aspects on biosynthesis of milk proteins, bioactive peptides and nutritive properties of milk proteins

VIII. Suggested Reading

- Damodaran S and Paraf A. 1997. *Food Proteins and their Applications*. Marcel Dekker.
- Gigli I. (Ed.). 2016. *Milk Proteins: From Structure to Biological Properties and Health Aspects.* BoD–Books on Demand.
- Hettiarachchy NS, Sato K, Maurice R, Marshall MR and Kannan A. 2016. *Bioactive Food Proteins and Peptides: Applications in Human Health*. CRC Press.
- Deeth HC and Bansal N. 2018. *Whey Proteins from Milk to Medicine*. 1st Edition, Academic Press
- McSweeney PLH, O'Mahony and James A. 2013. *Advanced Dairy Chemistry Volume 1A: Proteins: Applied Aspects*. Springer-Verlag, New York.
- McSweeney PLH, O'Mahony and James A. 2016. *Advanced Dairy Chemistry Volume 1B: Proteins: Applied Aspects.* Springer-Verlag, New York.
- Popay AI and Prosser CG.1997. *Biotech in Agric*. Series No. 18, CABI.
- Visser Hans. 1992. *Protein - Interactions*. VCS.
- Welch RAS, Burns DJW and Davis SR. 1997. *Milk Composition, Production and Biotechnology*. CABI.

I. Course Title : Advances in Chemistry of Milk Lipids

II. Course Code : DC-612

III. Credit Hours : 3+0

IV. Why this course?

This is an advanced course for in-depth understanding of milk fat including recent research work in the area of milk fat. This course is going to cover all these aspects.

V. Aim of the course

To impart the students with the in-depth understanding of various facets of milk fat including synthesis, changes during processing, various constituents of milk fat including minor components. The course also gives the opportunity to learn the

recent research work being done in the area of milk fat.
The course is organized as follows:

No.	Blocks	Units
1.	Composition and Structure	I. Origin, composition, structure and physical chemistry of milk fat globule membrane II. Lipolytic enzymes in milk of different species III. Fatty acids and other components in milk fat
2.	Stability and Health Significance	IV. Deterioration of milk fat due to oxidization and heating V. Significance of milk fat in human health

VI. Theory

Block 1: Composition and Structure

Unit I: Origin, composition, structure and physical chemistry of milk fat globule membrane

Origin, composition, structure and physical chemistry of milk fat globule membrane; Comparative aspects of milk lipids from different species such as human, bovine, buffalo, sheep, goat, and camel. Changes in milk fat globule membrane during processing and its effect on digestion.

Unit II: Lipolytic enzymes in milk of different species

Lipolytic enzymes in milk of different species including human; Bile salt stimulated lipase and esterases, induced and spontaneous lipolysis in milk. Assay for lipase activity; Biosynthesis of fatty acids, glycerol, neutral lipids, phospholipids, sphingolipids and cholesterol.

Unit III: Fatty acids and other components in milk fat

Essential fatty acids, prostaglandins and flavour compounds. Conjugated linoleic acids – different isomers, factors affecting their levels in dairy products and their significance.

Unit IV: Deterioration of milk fat due to oxidization and heating

Chemistry of oxygen in relation to autoxidation of milk fat including effect of milk components and environmental factors; Types of oxidations; Thermal oxidation; Chemical and biological properties of heated and oxidized fats.

Unit V: Significance of milk fat in human health

Significance of milk lipids in human health. Role of milk lipids in consumer acceptance of dairy products. Polymorphism and milk fat crystallization

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student’s Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Have in-depth understanding of milk fat including its origin in mammary gland
- Lipolytic enzyme in milk of various species including lipolysis
- Types of minor milk components and their structure
- Deterioration of milk fat due to oxidation
- Significance of milk fat in human health.

IX. Suggested Reading

- Fox PF. 1995. *Advanced Dairy Chemistry*. Vol. II. *Lipids*. 2nd Ed. Chapman and Hall.
- Fox PF and McSweeney PLH. 2006. *Advanced Dairy Chemistry Volume 2: Lipids*. Springer-US.
- Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA. 2015. *Dairy Chemistry and Biochemistry*. 2nd Edition. Springer.
- Jensen RG. 2018. The lipids of human milk. CRC Press.
- Nollet LML and Toldra F. 2009. *Handbook of Dairy Foods Analysis*. CRC Press. Taylor and Francis Group.
- Truong T, Palmer M, Bansal N and Bhandari B. 2016. *Effect of Milk Fat Globule Size on the Physical Functionality of Dairy Products*. Springer International Publishing.
- Truong T, Lopez C, Bhandari B and Prakash S. 2020. *Dairy Fat Products and Functionality*.
- Walstra P and Jenness R. 1984. *Dairy Chemistry and Physics*. John Wiley and Sons.
- Wong NP, Jenness R, Keeney M and Elmer HM. 1988. *Fundamental of Dairy Chemistry*. 3rd Ed. Van Nostrand Reinhold Co.

I. Course Title : Advances in Chemistry of Dairy Processing

II. Course Code : DC 621

III. Credit Hours : 3+0

IV. Why this course?

This course covers the physicochemical changes during processing of milk and chemistry of different additives and ingredients with respect to their effect on functional properties of dairy foods. This course is going to cover all these aspects.

V. Aim of the course

To highlight the impact of processing parameters on the milk constituents with special reference to chemical changes involved and also to impart the basic knowledge on the chemistry and significance of bio active compounds and additives

The course is organized as follows:

No.	Blocks	Units
1.	Physicochemical changes during processing	I. Heat induced changes and interactions II. Physical changes in the fat globules after homogenisation III. Specific and non-specific enzymatic coagulation of milk IV. High Pressure Processing of milk
2.	Food additives/ ingredients	V. Encapsulation of bioactive compounds VI. Micronutrients, Stability of sweeteners and Milk fat replacers

VI. Theory

Block 1: Physicochemical changes during processing

Unit I: Heat induced changes and interactions

Heat induced changes and interactions between protein, lipids, carbohydrates and minerals during processing of milk. Effect of heat on the proteins of concentrated milk systems. Inactivation of indigenous milk enzymes during processing.

Unit II: Physical changes in the fat globules after homogenisation

Physical changes in the fat globules in unhomogenized and homogenized milk; cold agglutination – its mechanisms and role.

Unit III: Specific and non-specific enzymatic coagulation of milk

Specific and non-specific enzymatic coagulation of milk.

Unit IV: High Pressure Processing of milk

Physico-chemical and structural changes occurring in milk constituents during high pressure processing of milk.

Block 2: Food additives/ ingredients

Unit V: Encapsulation of bioactive compounds

Chemistry involved in encapsulation of bioactive compounds and factors affecting their stability during processing.

Unit VI: Micronutrients, Stability of sweeteners and Milk fat replacers

Chemistry involved in the fortification of milk with vitamins, minerals and nutraceuticals. Stability of high intensity sweeteners during processing of milk and milk products. Milk fat replacers.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the effect of processing on milk constituents
- Analyse the stability of different additives including micronutrients added to milk as affected by different processing treatments

IX. Suggested Reading

- Shortt C and Brien JO. 2004. *Handbook of Functional Dairy Products*. CRC Press.
- Deeth HC and Lewis MJ. 2017. *High Temperature Processing of Milk and Milk Products*. Wiley-Blackwell.
- Fox PF and McSweeney PLH. 1998. *Dairy Chemistry and Biochemistry*.Blackie Academic Professional, Chapman and Hall.
- IDF. 1995. Special issue. *Heat Induced Changes in Milk*. Intern. Dairy Fed.,Brussels.
- Koca, N. (Ed.). 2018. Technological Approaches for Novel Applications in Dairy Processing. BoD–Books on Demand.

- Leo ML Nollet. 2004. *Intense Sweeteners. Handbook of Food Analysis*. 2ndEd. Marcel Dekker.
- Minj, J., Sudhakaran, A. and Kumari, A. 2020. Dairy Processing: Advanced Research to Applications. Springer Singapore.
- Walstra P, Walstra P, Wouters JTM and Geurts TJ. 2005. *Dairy Science and Technology*. CRC Press

I. Course Title : Advances in Analytical Techniques in Dairy Chemistry

II. Course Code : DC 622

III. Credit Hours : 3+0

IV. Why this course?

To gain insights in the underlying principle of newer instrumental techniques and their application in the dairy science research. This course is going to cover all these aspects.

V. Aim of the course

To highlight the application of advance analytical techniques used for analysis of milk and milk products

The course is organized as follows:

No.	Blocks	Units
1.	Electrophoresis and Chromatographic techniques	I. Isoelectric focusing, 2-D gel electrophoresis, Immuno assays
		II. High performance liquid chromatography
		III. Mass spectroscopy
2.	Protein structure determination and Spectroscopy	IV. Protein sequencing
		V. X-ray crystallography
		VI. Circular dichroism spectroscopy
		VII. Atomic spectroscopy
		VIII. Infrared, Fluorescence
		IX. Differential scanning calorimetry, NMR and FTIR

VI. Theory

Block 1: Electrophoresis and Chromatographic techniques

Unit I: Isoelectric focusing, 2-D gel electrophoresis, Immuno assays

Electrophoresis: Isoelectric focusing and 2-D polyacrylamide gel electrophoresis; Capillary zone electrophoresis, Enzyme linked immune-sorbentassay, blotting techniques

Unit II: High performance liquid chromatography

High performance liquid chromatography; Theory, instrumentation and application in analysis of dairy foods

Unit III: Mass spectroscopy

Mass spectroscopy: Principle, instrumentation and application in milk proteins/ milk fat analysis

Block 2: Protein structure determination and Spectroscopy

Unit IV: Protein sequencing

Protein sequencing; Chemical reactions involved in analysis of primary structure of proteins.

Unit V: X-ray crystallography

Circular dichroism spectroscopy; Theory and application for determination of secondary structure of proteins.

Unit VI: Circular Dichroism Spectroscopy

X-ray crystallography; Theory and application for determination of tertiary structure of milk proteins.

Unit VII: Atomic spectroscopy

AAS (Atomic Absorption Spectroscopy, Atomic Emission Spectroscopy, ICPS (Inductively coupled plasma spectroscopy); Principle and application in analysis of milk and milk products.

Unit VIII: Infrared, Fluorescence

Infrared Spectroscopy, Fluorescence Spectroscopy: principle and application.

Unit IX: Differential scanning calorimetry, NMR and FTIR

Differential scanning calorimetry: principle and application for milk fat and protein analysis.
NMR (Nuclear Magnetic Resonance), FTIR (Fourier Transform Infrared). Principle, application for quality analysis of milk and milk products.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic principle on advance analytical techniques for quality assessment of milk and milk products
- Understand the aspects on structure determination of milk proteins

IX. Suggested Reading

- Blundell TL and Johnson LN. 1976. *Protein Crystallography*. Academic Press.
- Calter P. 2004. *Methods in Molecular Biology*. Vol. 244 2nd Ed. *Protein Purification Protocols*. Humana Press.
- FL Creighton T. 1998. *Protein Structure*. 2nd Ed. Portland Press.
- Nielsen SS. 1994. *Introduction to Chemical Analysis of Foods*. Part IV.Jones and Bertlett Publ.
- Leo ML and Toldra NF. *Handbook of Dairy Foods Analysis*. 1st Ed. CRC Press.
- Wilson K and Walker J. 2000. *Practical Biochemistry: Principles and Techniques*. Cambridge University Press.

- Christian GD, Dasgupta PS, Schug K. 2014. Analytical Chemistry, 7th Edition Wiley Global Education.
- Nollet, L. M. (Ed.). 2020. *Mass Spectrometry Imaging in Food Analysis*. CRC Press.
- Nordén, B., Rodger, A., and Dafforn, T. 2019. *Linear Dichroism and Circular Dichroism: A Textbook on Polarized-Light Spectroscopy*. Royal Society of Chemistry.
- Singh, D. B., and Tripathi, T. 2020. *Frontiers in Protein Structure, Function, and Dynamics.*

Suggested Broad Topics for Master's and Doctoral Research

1. Profiling of milk from indigenous breeds of cattle, buffalo, goat and other minor species for their composition, physico-chemical properties and health benefits.
2. Encapsulation of bioactive compounds using milk and food grade constituents for their use in functional foods.
3. Physico-chemical changes in milk and milk products on fortification with micronutrients and nutraceuticals.
4. Flavour profiling of indigenous dairy products.
5. Shelf life enhancement of dairy products using natural and synthetic additives.
6. Development and evaluation of new generation methods for detection of adulterants and contaminants in milk and milk products based on biotechnological and nanotechnological approaches.
7. Development and validation of methods for detection of emerging contaminants and adulterants.
8. Validation of existing methods for quantification of different claimed constituents in various dairy products.
9. Stability of newer additives in milk and milk products and development of methods for their quantification.
10. Migration from food contact materials into food products.
11. Development of methods for detection of mixed milk and ghee-species and breeds.
12. Physico-chemical changes in milk proteins and lipids during processing and storage of dairy products.
13. Isolation and purification of growth factors and bioactive peptides from colostrum, milk and whey.
14. Enzymatic modification of milk proteins and incorporation of biopeptides into food system.
15. Incorporation of whey/whey constituents in milk and milk products for enhancement of biofunctional properties.
16. Evaluation of microstructure of dairy products.

List of Journals

1. *Indian Journal of Dairy Science*
2. *International Dairy Journal*
3. *International Journal of Dairy Technology*
4. *Journal of Dairy Research*
5. *Journal of Dairy Science*
6. *Comprehensive Reviews in Food Science and Food Safety*
7. *Critical Reviews in Food Science and Nutrition*
8. *Food Additives and Contaminants: Part A and Part B*
9. *Food Analytical Methods*
10. *Food Hydrocolloids*
11. *Food Chemistry*

12. *Food Research International*
13. *Food Reviews International*
14. *Food Science and Technology - Lebensmittel-Wissenschaft and Tech*
15. *Food Science and Technology International*
16. *Food Science and Technology Research*
17. *Food and Chemical Toxicology*
18. *Indian Journal of Dairy Science*
19. *International Journal of Food Properties*
20. *International Journal of Food Science and Technology*
21. *IDF Bulletins*
22. *Journal of Agricultural and Food Chemistry*
23. *Journal of Food Biochemistry (Journal of Food Lipids)*
24. *Journal of Food Composition and Analysis*
25. *Journal of Food Processing and Preservation*
26. *Journal of Food Quality*
27. *Journal of Food Safety*
28. *Journal of Food Science*
29. *Journal of Food Science and Technology*
30. *Journal of Functional Foods*
31. *Journal of the Science of Food and Agriculture*

Restructured and Revised
Syllabi of Postgraduate Programmes

Vol. 4

Dairy Science and Technology
– Dairy Microbiology

Course Title with Credit Load
M.Tech. in Dairy Microbiology

Course Code	Course Title	Credit Hours
	Major Courses	
DM 511*	Microbial Physiology	2+1
DM 512*	Microbiology of Processed Dairy Foods	3+1
DM 513	Microbial Morphology and Taxonomy	2+1
DM 514	Microbiology of Fluid Milk and Dairy Products	2+1
DM 515	Microbial Genetics	2+1
DM 516	Environmental Microbiology	2+1
DM 517	Biotechnology in Dairy Industry	2+1
DM 521*	Dairy Starter Cultures	2+1
DM 522*	Microbial Safety and Quality	2+2
DM 523	Microbiology of Cheese and Fermented Dairy Foods	2+1
DM 524	Probiotics and Prebiotics	2+1
DM 525	Research Techniques	2+1
DM 526	Microbial Fermentation Technology	2+1
DM 591	Credit Seminar	1+0
DM 599	Master's Research	0+30

Course Contents
M.Tech. in Dairy Microbiology

I. Course Title : Microbial Physiology
II. Course Code : DM 511
III. Credit Hours : 2+1

IV. Why this course?

Microbial physiology is the study of how microbial cell structures, growth and metabolism function in living organisms. It covers the study of nutritional transport system of bacteria, electron transport chain in prokaryotes and nutritional requirements of bacteria for their growth.

V. Aim of the course

To familiarize the student with various aspects of growth and energy generating activities of bacteria for the betterment of human life.

VI. Theory

Unit I

Bacterial growth: Growth phases and kinetics; synchronous, continuous, and associative growth; factors affecting bacterial growth; growth measurement; sporulation.

Unit II

Effect of environment on the growth of bacteria: Temperature, air, osmotic pressure, pH, hydrostatic pressure, surface tension, metals, electromagnetic and other waves, sonics, various chemicals, their application in dairy industry; mechanism of action of antimicrobials.

Unit III

Bacterial nutrition; Nutrient media; Nutritional groups of bacteria; Role of growth factors; Active and passive transport.

Unit IV

Energy metabolism: Electron transport chain, fermentation, respiration and photosynthesis.

VII. Practical

- Measurement of bacterial growth by direct methods (cell number, SPC, DMC) and indirect methods (turbidometric methods, MPN, cell mass).
- Preparation of growth curve; determination of generation time.
- Determination of cell activity; Carbohydrate fermentation; Acid production/pH alteration; Starch, lipid, casein and gelatin hydrolysis.
- Effect of different factors, viz. physical (temperature, pH, osmotic pressure, surface tension), chemical (dyes, antibiotics, phenol) and nutritional (amino acid supplements, vitamin supplements, protein hydrolysates, casamino acids) on bacterial growth.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the effect of environmental factors on microbial growth of bacteria
- To have an idea about nutritional transport system of bacteria
- To know about the electron transport chain in prokaryotes.
- To have any idea about the nutritional requirements of bacteria during their growth using various growth measurement techniques.

X. Suggested Reading

- Dean Watson. 2017. *Microbial Physiology*.
- Seaman GR and Mary JD. 2012. *Experiments in Microbial Physiology and Biochemistry*. Literary Licensing, LLC, USA.
- Willey J, Sherwood L and Woolverton CJ. 2017. *Prescott's Microbiology*, 10th Edition.
- Madigan MT, Martinko JM and Parker J. 2020. *Brock Biology of Microorganisms*. 16th edition, Prentice Hall, London, UK.
- Moat AG, Foster JW and Spector MP. 2002. *Microbial Physiology*. 4th Ed. Wiley-Liss.
- Poole RK. 2006. *Advances in Microbial Physiology*. Apple Academic Press (CRC Press), USA
- Rose AH. 2009. *Chemical Microbiology: An Introduction to Microbial Physiology*. Plenum Pub. Corp.
- Tortora GJ, Funke BR and Case CL. 2020. *Microbiology: An Introduction*, 13th Edn, Pearson, Harlow, UK.

I. Course Title : Microbiology of Processed Dairy Foods

II. Course Code : DM 512

III. Credit Hours : Credit: 3+1

IV. Why this course?

Different types of processing are done in dairy and foods industry for improving the quality and shelf life of the products. Each processing step affects microbial quality. Students should have idea about such changes. Course will also coverbio-preservation system of processed dairy foods, antimicrobial or bioactive packaging systems and GMO and their regulatory systems.

V. Aim of the course

To understand the microbiology of processed foods, types of processing and their effect on microbiological quality, significance of different food microorganisms, their control and other related aspects.

VI. Theory

Unit I

Introduction to microbes in foods, history and development of food microbiology, microorganisms important in foods, microbial ecology of processed foods and food ecosystem, factors influencing microbial growth in foods; Intrinsic factors and extrinsic factors.

Unit II

High temperature food preservation, factors affecting heat resistance in microorganisms, thermal destruction of microorganisms, low temperature food preservation, food preservation by irradiation, food preservation by drying and fermentation, modern processing techniques-ohmic heating, high pressure processing, infra-red heating, cold plasma, pulsed electric field, ultra sound etc., bio preservation of foods - concepts: metabolites of lactic acid bacteria; Bacteriocins, Antifungal substances etc., protective cultures and other antimicrobials (herbs, spices and other natural antimicrobial compounds), Nanoscience in food preservation; microencapsulation.

Unit III

Microbial stress response in the food environment; Stress adaptation, sublethal stress and injury, antibiotic resistance in food bacteria, predictive modelling for food spoilage, industrial strategies for ensuring safe foods, HACCP; GMP, GHP

Unit IV

Antimicrobial packaging; concepts and development, modified atmosphere packaging (MAP), intermediate moisture foods (IMF), and hurdle technology in processed foods.

Unit V

New prospects and problems in processed dairy foods. Genetically modified foods

VII. Practical

- D and Z-value calculation of common food pathogens.
- Production of antimicrobial substances-bacteriocins.
- Production of antifungal substances.
- Application of bacteriocins for bio preservation of foods.
- Application of hurdle concepts for enhanced shelf stability of processed foods.
- Induction of bacterial cell injury and recovery of injured cells.
- Antibiotic resistance of food pathogens.
- Shelf life enhancement using antimicrobial packaging.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the latest technologies for processing of foods, biopreservation system of processed dairy foods
- To have an idea about the processing methods that do not diminish the quality attributes of food being processed
- To know about the recent antimicrobial or bioactive packaging systems that can enhance the shelf life of fresh as well as processed produce/food.
- To have any idea about the GMO and their regulatory systems.

X. Suggested Reading

- Ozer B and Evrendilek GA. 2014. *Dairy Microbiology and Biochemistry: Recent Developments*. CRC Press.
- Silva ND, Taniwaki MH, Junqueira VC, Silveira N, Nascimento MDSD and Gomes RAR. 2012. *Microbiological Examination Methods of Food and Water: A Laboratory Manual*. CRC Press, USA.
- Erkmen O and Bozoglu TF. 2016. *Food Microbiology: Principles into Practice*, 2 Volume Set. Wiley Publishing.
- Papademas P. 2014. *Dairy Microbiology: A Practical Approach*. CRC Press.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology*. Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Ray RC and Didier M. 2014. *Microorganisms and Fermentation of Traditional Foods*. CRC Press, USA.
- Ray B. 2003. *Fundamental Food Microbiology*. CRC Press.
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2nd Ed, Wiley Blackwell, New Jersey, USA.

I. Course Title : Microbial Morphology and Taxonomy

II. Course Code : DM 513

III. Credit Hours : 3+1

IV. Why this course?

Morphology is the study of the form of bacteria. This covers morphological features such as shape, size, cell structure, motility (ability to move in a liquid), and spore and capsule formation, different staining methods and micrometry etc.

V. Aim of the course

To educate the students about the morphological features and taxonomy of the various microorganisms, viz. bacteria, fungi and viruses

VI. Theory

Unit I

Evolution of life on earth, history and diversity of microorganisms

Unit II

Principles of classification and taxonomy of Eubacteria (Bacteria and Archaea); Major characteristics used in taxonomy; Cultural, Morphological, Biochemical; Physiological, Genetic and Molecular; Numerical Taxonomy (Taxometrics) and Chemotaxonomy. Assessing Microbial Phylogeny: Chronometers; Phylogenetic trees, r-RNA, DNA and proteins as indicators of phylogeny.

Unit III

Cell ultra-structure (prokaryotes and eukaryotes); Cell wall- structure, chemical composition, synthesis and inhibition; cell membrane, cytoplasmic inclusions, cytoskeleton, cell appendages- capsule, flagella, pili; sporulation - structure of endospore, composition and function of spore constituents, induction and germination.

Unit IV

Fungi: Distribution, importance and recent classification, study of yeasts and moulds in dairy foods

Unit V

History, development and scope of virology; classification and nomenclature, characteristics of viruses (acellular organization and viral genome), viral reproduction, brief account of viroidsand prions

VII. Practical

- Staining: Simple staining; differential staining - Gram's staining, spore staining, acid fast staining; special staining - cell wall staining, flagella staining, nucleoids staining, capsule staining, inclusion/storage bodies staining
- Preparation of bacterial protoplasts and spheroplasts
- Measuring dimensions of microorganisms (bacteria) using micrometry
- Morphology of fungi: yeast and moulds
- Application of computer software in bacterial identification

VIII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/Writing)
– Student's Book/Journal Articles
– Student presentation
– Group Work
– Routine Practical as per the schedule
– Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:
– To have knowledge on the Principles of classification and taxonomy of Eubacteria
– To have knowledge on the advanced techniques help in classification of organisms
– To know about the ultrastructure of microorganisms.
– To acquire the knowledge on different staining methods and micrometry.

X. Suggested Reading

- Cowan MK. 2012. *Microbiology: A Systems Approach*, 3rd Edition. The McGraw Hill Companies, New York, USA.
- Holt JG, Krieg NR, Sneath PHA, Staley JT and Williams ST. 1997. *Bergey's Manual of Determinative Bacteriology* (9th edition). Williams and Wilkins, Baltimore, Maryland, USA.
- Krejer van-Rij NJW. 1998, *The Yeasts: A Taxonomic Study*, 4th edn, Elsevier Science Publishers, Amsterdam, The Netherlands.
- Madigan MT, Martinko JM and Parker J. 2020. *Brock Biology of Microorganisms*. 16th edition, Prentice Hall, London, U.K.
- Prescott LM, Harley JP and Klein DA. 2002, *Microbiology*, 5th edn, McGraw Hill, New York, USA.

- Tolaro KP. 2011. *Foundations in Microbiology*, 8th Edn. The McGraw Hill Companies, New York, USA.
- Tortora GJ, Funke BR and Case CL. 2020. *Microbiology: An Introduction*, 13th Edn, Pearson, Harlow, UK.

I. Course Title : Microbiology of Fluid Milk and Dairy Products

II. Course Code : DM-514

III. Credit Hours : 2+1

IV. Why this course?

Milk is a complex biological fluid secreted in the mammary glands of mammals. It contains all the nutrients which help the organisms to grow well. For the safe processing and production of milk and milk products, student should have good knowledge of various handling and processing practices on market milk. Novel technologies must be applied in milk and milk product processing for the inactivation of food borne microorganisms or toxins produced by the organisms during transportation or storage or raw milk.

V. Aim of the course

To familiarize the students with microbes in milk and milk products, microbiological aspects of processing, microbiology of milk products and safety aspects

VI. Theory

Unit I

Common microbes in milk and their significance, Microflora of mastitis milk and its importance in dairy industry, Sources of microbial contamination of raw milk and their relative importance in influencing quality of milk during production, collection, transportation and storage; Clean milk production and natural antimicrobial systems in raw milk, Microbial changes in raw milk during long storage, Microbiological grading of raw milk.

Unit II

Microbiological aspects of processing techniques like bactofugation, thermization, pasteurization, sterilization, boiling, UHT, non-thermal processes (pulsedelectric field) and membrane filtration of milk; Role of psychrotrophic, mesophillic, thermophilic and thermoduric bacteria in spoilage of processed milks, their sources and prevention; Heat induced damage in bacteria and role of resuscitation in recovery of injured microbial cells. Microbiological standards (BIS/ FSSAI) of heat-treated fluid milks

Unit III

Microbiological quality of dairy products; fat rich (cream and butter), frozen (ice cream), concentrated (evaporated and condensed milk), dried milks (roller and spray dried), infant dairy foods and legal standards; Sources of contamination and factors affecting microbial quality of these products during processing, storage and distribution; Microbiological defects associated with these products and their control.

Unit IV

Microbiological quality of traditional dairy products in India; heat desiccated (khoa, burfi, peda, kheer, etc.), acid coagulated (paneer, chhana, rasogolla, etc.), fermented (dahi, lassi, srikhand, etc.) and frozen (kulfi); Sources of microbial contaminants and their role in spoilage; Importance of personnel and environmental hygiene on quality of traditional milk products; Microbiological standards for indigenous dairy foods.

Unit V

Food poisoning- Food intoxications, Food infections and Toxi-infections, pathogens associated with fluid milks, dairy products and their public health significance; Sources of pathogens and their prevention; Importance of biofilms, their role in transmission of pathogens in dairy products and preventive strategies.

VII. Practical

- Grading of raw milk based on SPC, coliforms and dye reduction tests.
- Effect of different storage temperatures on microbiological quality of fluid milk.
- Tests for mastitic milk and brucellosis.
- Microbiological quality evaluation of cream and butter for coliforms, yeasts and moulds, lipolytic and proteolytic bacteria.
- Detection of *Cronobacter sakazakii* in infant dairy foods.
- Microbial evaluation of burfiand pedafor SPC, *S. aureus*, yeast and mould counts.
- Detection of *Bacillus cereus, Salmonella,Shigella* and coagulase positive staphylococci in milk powder.
- Evaluation of ice cream for coliforms and *Escherichia coli*.
- Microbiological quality of paneer.
- Enumeration of aerobic and anaerobic spores in condensed, sterilized and dried milks.
- Line testing for determining the source of contamination of dairy products.
- Detection of toxins (staphylococcal, aflatoxins/mycotoxins) in dairy foods

VIII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/Writing)
– Student's Book/Journal Articles
– Student presentation
– Group Work
– Routine Practical as per the schedule
– Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To have knowledge on the novel technologies applied in milk and milk product processing for the inactivation of food borne microorganisms.
– To have an idea about the latest standards formulated by FSSAI on milk and milk products (Microbiological Standards).
– To know about the different toxins produced by microorganisms in milk and milk products.
– To have knowledge on Microbiological quality of traditional dairy products in India.

X. Suggested Reading

- Eozer B. 2014. *Dairy Microbiology and Biochemistry: Recent Developments*. CRC Press, USA.
- Law BA. 2012. *Microbiology and Biochemistry of Cheese and Fermented Milks*. Springer Publisher.
- Quin M. 1989. *Applied Microbiology in the Dairy Industry*. Hobsons Publishing PLC.

- Osei G. 2017. *Handbook of Dairy Microbiology*. AGri-Horti Press.
- Poltronieri P (Editor). 2017. *Microbiology in Dairy Processing: Challenges and Opportunities* John Wiley and Sons Inc.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology*: Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Fernandes R (Editor). 2009. *Microbiology Handbook: Dairy Products*. RSC Publishing.

I. Course Title : Microbial Genetics

II. Course Code : DM 515

III. Credit Hours : Credit: 2+1

IV. Why this course?

Microbial genetics is a subject area within microbiology and *genetic* engineering. *Microbial genetics* provides powerful tools for deciphering the regulation, as well as the functional and pathway organization, of cellular processes.

V. Aim of the course

To understand the fundamentals of structure, functions and synthesis of macromolecules and their genetic manipulation.

VI. Theory

Unit I

Macromolecules: DNA, RNA and their structure, types, organization, function and properties of macromolecules, DNA replication.

Unit II

Regulation and Gene Expression: Gene Expression and its regulation in Prokaryotes-Transcription, Genetic Code, Translation, Negative and Positive regulation in gene expression, Operon Models - Lac, Trp.

Unit III

Mutations: Mutations - Spontaneous and Induced, Type of mutations, Mutagenic agents – physical and chemical, Damage and repair system operating in Prokaryotes.

Unit IV

Plasmids and gene transfer systems: Plasmids and their properties, transposable elements, bacterial recombination, transformation, transduction and conjugation.

Unit V

Recombinant DNA technology, Fundamental aspects of genetic engineering/ recombinant DNA technology, restriction enzymes, plasmid vectors (cloning as well as expression vectors), PCR and real time PCR.

VII. Practical

- Isolation and quantitative estimation of chromosomal DNA from *E. coli* and *Lactobacillus* by mini prep method.
- Isolation of plasmid DNA from *E. coli* by miniprep method.
- Calcium chloride induced transformation of *E. coli* hosts with plasmids.
- Digestion of plasmid DNA with restriction enzymes and ligation into plasmid vector for transformation
- PCR based detection of microorganisms
- Demo of real time PCR machine

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the macrostructure of DNA and RNA
- To have an idea about the genetic expression and regulation in Prokaryotic system
- To know about the recent advancements in genetic engineering/recombinant DNA technology.
- To have exposure on different types of PCR and their applications.

X. Suggested Reading

- Bansal MP. 2012. *Molecular Biology and Biotechnology: Basic Experimental Protocols*. Teri Press - New Delhi.
- Hofmann A and Clokie S. (Eds.). 2018. *Wilson and Walker's principles and techniques of biochemistry and molecular biology*. Cambridge University Press.
- Watson JD, Tania AB, Stephen PB, Alexander G, Michael L and Richard L. 2017. *Molecular Biology of the Gene*.
- Russell J. Peter. 2014. *IGenetics: a molecular approach*. Pearson.
- Synder L and Champness W. 2003. *Molecular Genetics of Bacteria*. ASM Publ.
- Uldis N Streips and Ronald E Yasbin (Eds.). 2004. *Modern Microbial Genetics*. John Wiley and Sons.
- Watson JD. 2003. *Molecular Biology of Genes*. W.A. Benjamin.

I. Course Title : Environmental Microbiology

II. Course Code : DM 516

III. Credit Hours : 2+1

IV. Why this course?

Environmental microbiology is the study of the composition and physiology of microbial communities in the environment. This includes: structure and activities of microbial communities, processing of waste water using microbes, microbial interactions with bioecosytem, environmentally transmitted microbial pathogens, various bio-geochemical cycles etc.

V. Aim of the course

To understand the fundamentals of environmental microbiology for overall effects of microorganisms in combating the pollution in the environment.

VI. Theory

Unit I

Environmental microbiology; Aero-microbiology; Airborne pathogens, toxins, aerosols, nature and control of bio-aerosols, aquatic environments and microbial habitats; Soil as a microbial environment; Microbes in extreme environments.

Unit II

Bio-geochemical cycles; Carbon cycles (fixation, energy flow and respiration), nitrogen cycle (fixation, ammonia assimilation, nitrification and nitrate reduction) sulphur cycle (assimilatory sulphate reduction, sulphur mineralization, oxidation and reduction), iron cycle; microbial influenced metal corrosion, acid mine drainage, metal recovery and desulfurization.

Unit III

Environmentally transmitted microbial pathogens (*Salmonella*, *E. coli*, *Campylobacter, Yersinia* etc.) and viruses (enteric and respiratory); indicator microorganisms (concept, total and faecal coliforms, faecal streptococci, bacteriophage etc.); Biofouling and biofilms; microorganisms as indicators of environment pollution; microbial toxicants and bio-organic pollutants.

Unit IV

Waste water treatment: physical - screening, racks, mixing, flocculation, sedimentation, floatation, elutriation, vacuum filtration and incineration; biological unit operations- aerobic and anaerobic cycles; kinetics of biological growth, application of kinetics to treatment systems, aerobic waste treatment, anaerobic waste treatment; waste water utilization for value addition, disposal and reuse of Waste water after treatment, solid wastes management; environment laws.

VII. Practical

- Determination of composite microflora (i.e. total bacteria, coliforms, yeasts and moulds etc.) of soil, water, air.
- Determination of BOD in dairy and food industrial wastes.
- Determination of composite microflora of waste water samples.
- Detection of residual antibiotics/pesticides in waste water samples.
- Isolation of bacteria capable of degrading organic and microbial pollutants from waste water samples.
- Isolation and characterization of bio-indicators from environmental samples.
- Utilization of waste water for production of ethanol, microbial and biomass.
- Visit to a sewage and sludge treatment plant.

VIII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/Writing)
– Student's Book/Journal Articles
– Student presentation
– Group Work
– Routine Practical as per the schedule
– Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To have knowledge on the environmental bioecosytem (aero-microbiology).
– To have an idea about the processing of waste water using microbes
– To know about the various bio-geochemical cycles
– To have idea on environmentally transmitted microbial pathogens.

X. Suggested Reading

- Hurst CJ, Crawford RL, Garland JL, Lipson DA and Mills AL. 2007. *Manual of Environmental Microbiology*. 3rd Ed. ASM Press.
- Madsen, Eugene L. 2016. *Environmental microbiology: from genomes to biogeochemistry*.
- Maier RM, Pepper IL and Gerba CP. 2000. *Environmental Microbiology*. Elsevier.
- Maier RM, Pepper IL and Gerba CP. 2009. *Environmental Microbiology*. Elsevier Academic press, USA.
- Mitchell R and Gu JD. 2010. *Environmental Microbiology*. Wiley Blackwell.
- Varnam AH and Evans MG. 2000. *Environmental Microbiology*. Manson Publishing Ltd.

I. Course Title : Biotechnology in Dairy Industry

II. Course Code : DM 517

III. Credit Hours : 2+1

IV. Why this course?

Biotechnology is a tool for value addition to dairy foods. Genetic techniques have been employed to manipulate bacteria that have significance to the dairy industry. Biotechnological means can be used to regulate the production of flavour enhancing metabolites and to develop starter cultures that are resistant to bacteriophage and bacteriocins. Genetic engineering will be able to enhance the technological functions of Lactic acid bacteria for industrial applications using genetic approaches.

V. Aim of the course

To impart knowledge in the application of biotechnology in dairy/ food Industries

VI. Theory

Unit I

History and development of biotechnology; Status of biotechnology industries in India to meet the demands of dairy and food Industries.

Unit II

Genetic improvement of lactic starters to enhance their technological functions for industrial applications, e.g. acid, flavour, EPS, probiotic functions; Metabolic engineering of lactic acid bacteria; Production of recombinant dairy/ food enzymes/ proteins, e.g. chymosin, lactoferrin, lysozyme, lipases, proteases, immunoglobulins etc. Detection of GMOs and GM foods and their safety from public health point of view.

Unit III

Dairy based functional foods/ health foods and nutraceuticals. Value addition in dairy products through fortification/supplementation with bioactive components and probiotic cultures, Nutrigenomics.

Unit IV

Application of molecular tools, biosensors, etc. for detection of foodborne pathogens and spoilage microorganisms.

Unit V

Molecular tools for studying biodiversity; Regulatory standards, value added products for GMOs and GM foods.

VII. Practical

- Plasmid isolation from *E. coli*.
- Agarose gel electrophoresis.
- Transformation of *E. coli* with plasmid (Amp^r).
- Growth of starter cultures on MRS for "lac" marker.
- Induction of "lac"mutation using UV rays or ethidium bromide
- PCR assays for identification of LAB and foodborne pathogen detection
- Production of enzymes:protease/ â galactosidase
- Preparation of value added dairy products: fruit and probiotic based dahi/yoghurt/ lassi.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the nutrigenomics.
- To have knowledge on how to enhance the technological functions of Lactic acid bacteria for industrial applications using genetic approaches.
- To know about the advanced molecular tools for the detection of pathogens.
- To have knowledge on Biosensor and its application on dairy industry

X. Suggested Reading

- Pometto A, Shetty K, Paliyath G and Levin RE. 2005. *Food Biotechnology*. CRC Press, USA.
- Ratledge C and Kristiansen B. 2001. *Basic Biotechnology*. Cambridge University Press, USA.
- Bagchi D, Lau FC and Ghosh DK. 2010. *Biotechnology in Functional Foods and Nutraceuticals*. CRC Press, USA.
- Rai RV. 2015. *Advances in Food Biotechnology*. John Wiley and Sons Ltd.

I. Course Title : Dairy Starter Cultures

II. Course Code : DM 521

III. Credit Hours : 2+1

IV. Why this course?

Starter cultures are those microorganisms that are used in the production of cultured dairy products such as dahi, yogurt, cheese etc. A starter culture can provide particular characteristics in a more controlled and predictable fermentation. This study covers isolation and characterization of Lactic acid bacteria, methods for selection and preservation, preparation of DVS cultures, control of starter slowness and control of phage in dairy industry.

V. Aim of the course

To familiarize the students with the starter organisms, their metabolism and genetics; different types of starters, propagation, preservation and applications of starters

VI. Theory

Unit I

Taxonomy and characteristics of starter cultures: Taxonomy and natural habitat of starter cultures, Desirable properties of starter cultures with respect to various fermented milk products, Characteristics of starter organisms, bacteria (*Lactococcus, Leuconostoc, Streptococcus, Pediococcus*, *Lactobacillus*, *Bifdobacterium, Enterococcus, Propionibacterium, Brevibacterium*), yeasts and moulds.

Unit II

Carbohydrate, citrate and protein metabolism; Lactose, galactose and glucose metabolism-transport of sugars across the cell boundaries, homolactic and heterolactic fermentations, other pathways of sugar metabolism, formation of flavouring agents from citrate fermentation, proteolytic systems and protein metabolism in lactic acid bacteria: Genetics of starter bacteria: Plasmids and plasmid instability; Industrially significant genes; Genetic modification of lactic acid bacteria, transposons and insertion sequences. Genetics of flavor formation in starter bacteria; Major enzymes and pathways involved.

Unit III

Classification of starters: Single, mixed and multiple strain, mesophilic and thermophilic starter cultures; propagation and preservation of starter cultures; factors affecting propagation of starter, functional starters producing exopolysaccharides, vitamins and antimicrobial compounds, commercial starter preparations: concentrated and super concentrated starters; Production systems for bulk cultures: Lewis, Jones and Tetra-pack systems; growth media: nutritional requirements of lactic acid bacteria, growth media formulations; PIM/PRM, pH control during culturing- external and internal pH control systems; preservation of bulk starter cultures- frozen and freeze dried, spray dried cultures; direct vat starter cultures.

Unit IV

Growth inhibition of lactic acid bacteria by antibiotics, bacteriocins, bacteriophages, cleaning and sanitizing agents and naturally occurring antimicrobial systems in raw milk; sources, types and characteristics of phages associated with starters, morphology and taxonomy, phage host interaction, prevention and control of phages during starter handling and fermented milk products manufacturing, mechanisms of phage resistance in lactic acid bacteria, inhibitory substances produced by lactic acid bacteria.

VII. Practical

- Morphological examination of dairy starter cultures.
- Isolation of lactic acid bacteria from fermented milk products.
- Examination of purity and activity of starter cultures.
- Effect of physical and chemical factors on starter cultures.
- Evaluation of homo and hetero fermentation by starter cultures.
- Production of bulk starter culture.
- Preservation of starter cultures by liquid, freeze drying and other methods.
- Preparation and quality evaluation of concentrated starters.

- Inhibition of starters by antibiotic residues and other inhibitors.
- Production of bacteriocins by lactic acid bacteria.
- Production of exopolysaccharides by lactic acid bacteria.
- Detection of bacteriophages in cheese whey.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the isolation and characterization of Lactic acid bacteria
- To have an idea about biochemical pathways of Lactic acid bacteria for carbohydrate metabolisms
- To know about the freeze drying and preparation of DVS cultures.
- To have idea about causes of slowness of starter and control of phage.

X. Suggested Reading

- Speranza B, Bevilacqua A, Corbo MR and Sinigaglia M. 2017. *Starter Cultures in Food Production*. Wiley Black Well, John Wiley and Sons, Ltd, UK.
- Marth EH and Steele JL. 2001. *Applied Dairy Microbiology*. Marcel Dekker Inn. New York.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology: Microbiology of Starter Culture* 147-183. Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Puniya AK. 2015. *Fermented Milk and Dairy Products*; CRC Press/ Taylor and Francis (ISBN 9781466577978).
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2nd Ed, Wiley Blackwell, New Jersey, USA.
- Gabriel V, Ouwehand A, Salminen S and Wright AV. 2019. *Lactic acid bacteria: microbiological and functional aspects*. CRC Press.
- Wood BJ and Warner PJ. (Eds.). 2003. *Genetics of Lactic Acid Bacteria*. Springer Verlag.

I. Course Title : Microbial Safety and Quality

II. Course Code : DM 522

III. Credit Hours : 2+1

IV. Why this course?

Food Quality and Standards Service is committed to the enhancement of *food safety and quality* along the *food* chain to prevent diseases and trade disruptions. This course covers principles of safety in a food microbiological laboratory, conventional and rapid methods for detection of hygiene indicators or pathogens, antibiotic resistance in bacteria etc.

V. Aim of the course

To impart knowledge pertaining to quality and safety functions in dairy processing unit and measure to control quality and safety of dairy products.

VI. Theory

Unit I

Principles of quality and safety functions in dairy processing unit:
Introduction to ISO standards– ISO: 9000:2000; ISO: 9004:2000; ISO: 9001:2000: Brief concept and principles of QMS and standard requirements for certification HACCP, Hazard Analysis and Risk-Based Preventive Controls (HARPC), SAFE, GMP, SSOP, FSMS, personnel hygiene and food handling in dairy industry.
Principles of safety in a food microbiological laboratory-Bio-safety concept, Biosafety level-1-4 containment design and layout; Standard microbiological practices for safe handling in food laboratory, safety equipment, facility design.

Unit II

General principles for establishment of microbiological criteria
Definition, purpose and components of microbiological criteria; mandatory and advisory criteria
Sampling methods - two and three class sampling plan as per International council for microbiological standards for foods (ICMSF)
Establishment of microbiological standards, guidelines and specifications for different dairy foods as recommended by ICMSF, CODEX, FSSAI

Unit III

Conventional and rapid methods for detection of hygiene indicators;
definition, selection criteria of indicator organisms as an index of food quality
Conventional detection methods for indicator organisms – Standard plate count (SPC), coliforms, *E. coli*, yeast and mould Counts (YMC), spore counts; enterobacteriaceae count; Faecal streptococci count; Dye reduction tests
Rapid techniques like D-count, petrifilm, ATP bioluminance including commercial kits for monitoring hygiene indicators

Unit IV

Conventional and rapid methods for detection of safety indicators;
definition, selection criteria of indicator Organisms as an index of food safety;
Conventional detection methods for detection of pathogenic organisms as per ISO protocol specified by FSSAI – *Staphylococcus aureus*; *Bacillus cereus*; Pathogenic *E.coli*; *Salmonella*; *Shigella*; *Listeria monocytogenes*; *Enterobacter sakazakii*; Sulphite reducing clostridia (SRC), *Campylobacter jejuni*;
Rapid techniques like–VIDAS, SPR, RT-PCR including commercial kits, for monitoring safety indicators.

Unit V

Bio-sensors and micro-techniques for rapid monitoring of contaminants;
definition, history, basic characteristics of bio-sensors; classification based on bio-recognition molecule - Microbial, spore, Aptamer, DNA, immune and enzyme etc.
Biosensors based on Transducers - electrochemical, optical, mechanical and calorimetric etc.
Bio-sensors for rapid detection of hygiene indicators, pathogenic bacteria, antibiotics, pesticides, heavy metal, aflatoxin M1 in milk.

VII. Practical

- Demonstration of safety principles in a food microbiological laboratory.

- Aseptic technique for ensuring safety of personnel, product and environment.
- Conventional and rapid methods for hygienic assessment of milk for SPC, coliforms, *E. coli*, YMC, Spore counts, Enterobacteriaceae count, faecal streptococci count, Dye reduction tests
- Conventional ISO methods for enumeration of safety indicators in dairy foods for *S. aureus*; *B. cereus*; *E.coli*; *Salmonella*; *Shigella*; *L. monocytogenes*; *E. sakazakii*; SRC; *Campylobacter jejuni* as per FSSAI standards.
- Rapid tests for detection of antibiotics, aflatoxin M1 and pesticides in milk.
- Determination of antibiotic resistance in bacteria using phenotypic methods.
- Shelf life studies of dairy products; effect of storage condition and packaging material on microflora of dairy foods.
- Determination of efficacy of detergents and sanitizers using capacity and suspension tests.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on principles of safety in a food microbiological laboratory
- To have an idea about the principles for establishment of microbiological criteria
- To know about the conventional and rapid methods for detection of hygiene indicators/pathogens
- To have knowledge on antibiotic resistance in bacteria.

X. Suggested Reading

- M. Brown and M Stringer. 2012. *Microbiological: Risk Assessment in Food Processing*. Woodhead Publishing 1st Edition
- Patel P. (Ed.). (2012). *Rapid Analysis Techniques in Food Microbiology*. Springer Science and Business Media.
- Borough LM. 2004. *Food Microbiology Laboratory*, CRC Press, USA
- Nordenfelt, Pontus, Collin, Mattias. 2017. *Bacterial Pathogenesis* (1st edition) Springer.
- Arvanitoyannis IS. 2012. HACCP and ISO 22000: *Application to Foods of Animal Origin* (Institute of Food Science and Technology Series). Wiley Blackwell
- Osiemo O. 2012. *Food Safety Standards in International Trade: The Case of the EU and the COMESA*. Routledge Publisher.
- Bhunia AK. 2016. *Sensors for Food Safety and Quality*. eBook

I. Course Title : Microbiology of Cheese and Fermented Dairy Foods

II. Course Code : DM 523

III. Credit Hours : 2+1

IV. Why this course?

There are several types of cheeses in the world; use of different starter culture can lead to development of specific cheese variety too. However, the technological principles involved in Cheddar cheese making are common to several varieties of cheeses, with some modifications. Cheese is getting popularized in India, especially the Pizza cheese variety that is preferentially used as a topping on pizza pie. The functional properties of cheese depend on the starter cultures used and ripening of cheeses. Specific cheese has its own typical flavour and aroma depending on type of starter cultures used for particular ripening conditions.

V. Aim of the course

To impart knowledge on basic and applied aspects of cheese and fermented dairy foods

VI. Theory

Unit I

Evolution and classification of cheeses and fermented Dairy foods; Introduction, classification and types of cheeses and fermented dairy foods. Market share and recent market trends

Unit II

Microbiology of cheese, Cheese starter cultures involved in the manufacture, their types, roles, Current classification and metabolic pathways. Rennet, rennet substitutes; Microbial and recombinant rennet used in cheese preparation. Bacteriophages of cheese starters. Microbes associated with spoilage, defects, causative organisms and preventive measures. Health aspects of cheese.

Unit III

Microbiology of cheese ripening

Microbiological changes, Factors Influencing Growth of Microorganisms, Flavour development, Role of starter flora and supplementary flora in cheese ripening.

Accelerated cheese ripening through biotechnological approaches, Cheese with high linoleic acid content, Enzyme-modified cheese, GMO

Microbiological and biochemical aspects of major cheese varieties - Cheddar, Swiss-Type Cheeses - Emmental, Very hard cheese - Parmesan, Dutch cheese varieties - Edam, Gouda, Pasta Filata/Pizza Cheese - Mozzarella, Unripened cheese - Cottage, Internal mould ripened cheese - Roquefort, Surface mould ripened cheese - Camembert, Bacterial surface ripened cheese- Limburger; Microbiology of processed cheese.

Unit IV

Microbiology of Fermented dairy foods; Dahi, lassi, yoghurt, Kefir, Koumiss, functional fermented dairy based beverages, fermented whey drinks, and dairy based fermented cereal foods, fortified fermented dairy foods - Microbes associated with spoilage and preventive measures. Safety and standards of fermented foods.

Unit V

Functional cheeses, Cheese as matrix for probiotic delivery.

Health aspects of cheese and fermented foods: nutritional value, and therapeutic benefits.

VII. Practical

- Preparation and evaluation of ethnic fermented dairy products
- Preparation of cheese with mesophilic dairy starter cultures and different microbial rennets.

- Preparation of functional/probiotic cheese
- Microbial analysis of cheeses
- Identification and characterization of specific starter cultures from different varieties of cheeses (*Leuconostoc* for Dutch type cheese, *Propioni bacterium* for Swiss type cheese).
- Determination of ß-galactosidase activity of microorganisms
- Accelerated cheese ripening using different interventions

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group work
- Routine practical as per the schedule
- Visit to the relevant industry or laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Be able to manufacture various varieties of cheeses using cheese specific starter cultures
- To have knowledge on Bacteriophages of cheese starters
- Be able to develop different fermented milk products, particularly traditional fermented milk products
- To develop the probiotic cheese using probiotic cultures

X. Suggested Reading

- Speranza B, Bevilacqua A, Corbo MR and Sinigagli M. 2017. *Starter Cultures in Food Production*. Wiley Black Well, John Wiley and Sons, Ltd, UK.
- FatihYildiz. 2009 *Development and Manufacture of Yogurt and Other Functional Dairy Products*, CRC Press, USA.
- El-Mansi EMT, Bryce CFA, Arnold L. Demain and Allman AR. (Edited). 2012. *Fermentation Microbiology and Biotechnology*, Third Edition CRC.
- McSweeney P, Fox P, Cotter P and Everett D. (Eds.) 2017. *Cheese -Chemistry, Physics and Microbiology*, 4th Edn. Academic Press.
- Puniya AK. 2015. *Fermented Milk and Dairy Products*; CRC Press/ Taylor and Francis (ISBN 9781466577978).
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2nd Ed, Wiley Blackwell, New Jersey, USA.
- Wood BJ and Warner PJ. (Eds.). 2003. *Genetics of Lactic Acid Bacteria*. Springer Verlag.

I. Course Title : Probiotics and Prebiotics

II. Course Code : DM 524

III. Credit Hours : 2+1

IV. Why this course?

Probiotics are live microorganisms intended to provide health benefits when consumed, generally by improving or restoring the gut flora. This study covers Gut microbiota and its role in human health, mechanism of action of probiotics/prebiotics, safety and regulations on probiotics or probiotic food products.

V. Aim of the course

To understand the concept of probiotics and prebiotics in relation to food formulations and health effects.

VI. Theory

Unit I

Probiotics, Prebiotics and Synbiotics: Concepts, definitions and history. Gut microbiota and its role in human health and disease

Unit II

Identification of probiotic strains isolated from different niches by polyphasic approach using phenotypic, biochemical and genotypic tools/techniques. Characterization and selection of candidate probiotic strains on the basis of FAO/WHO or ICMR/DBT guidelines.

Unit III

Mechanism of action of probiotics: Colonization in the gut; Adhesion to intestinal mucosal surface – role of surface proteins; Antimicrobial/antagonistic activity of probiotics, Pathogen exclusion; Immuno-modulatory action; Impact on gut homeostasis; Host microbe interaction and their cross talk; Role of biomarkers for probiotic functionality.

Unit IV

Mechanism of action of prebiotics and synbiotics: Selective stimulation of beneficial bacteria in the gut microbiota; Effect on gastric emptying and intestinal transit rate; Production of short chain fatty acids (SCFA); Effect of SCFA on host metabolism and immunomodulation; Anti-adhesive prebiotics. Synbiotics and their action through improved viability of probiotic microorganisms and provision of specific health benefits

Unit V

Dairy based foods as carrier of probiotics: Dairy based products as delivery vehicles – Stability towards manufacturing conditions, enhancing stability through encapsulation or drying strategies for lyophilized formulations etc., co-culture compatibility with starters, minimum effective dose, and large-scale production of probiotic biomass through fermentation for application in foods and as drugs/supplements.

Unit VI

Designer probiotics: Genetically modified probiotics as oral vaccines, enhanced adhesion properties and health promoting functions.

Unit VII

Safety, human trials and regulatory guidelines: *In vitro* and *in vivo* safety assessment of probiotics; designing human trials; regulatory guidelines - US, Canada, Europe and India.

VII. Practical

- Isolation of probiotic organisms from human milk and faecal samples.
- Tentative identification by microscopic examination, catalase and biochemical tests.
- Identification of isolates by genus and species-specific PCR.
- Evaluation of bacterial isolates for probiotic properties.

- Acid tolerance; Bile tolerance; Hydrophobicity; Antimicrobial activity.
- Specific utilization of prebiotics by probiotic bacteria.
- Survival of probiotic culture in fermented dairy products.
- Microencapsulation of probiotic bacteria.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Have knowledge on the Gut microbiota and its role in human health
- To have knowledge on identification, characterization and selection of probiotic strains using phenotypic, biochemical and genotypic tools/techniques
- To know about the different mechanism of action of probiotics/prebiotics establishing through in vitro and in vivo studies.
- To have any idea about the safety and regulations on probiotics or probiotic food products.

X. Suggested Reading

- Sungsoo C and Finocchiaro ET. 2010. *Handbook of prebiotics and probiotics ingredients: health benefits and food applications*. Boca Raton: Taylor and Francis.
- Ipek G, Vijay JK and Mohamed A. 2006. *Probiotics in Food Safety and Human Health*.
- Huffnagle GB. 2008. *The Probiotics Revolution: The Definitive Guide to Safe, NaturalHealth Solutions Using Probiotic and Prebiotic Foods and Supplements*. Bantam,USA.
- Venema K. 2015. *Probiotics and Prebiotics: Current Research and Future Trends*.
- Min-TzeLiong. 2011. *Probiotics: Biology, Genetics and Health Aspects*. Springer.
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology:* Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Di Gioia, Diana. -Biavati, Bruno. 2018. *Probiotics and Prebiotics in Animal Health and Food Safety*
- Wallace RK and Wallace S. 2017. *Gut Crisis: How Diet, Probiotics, and Friendly Bacteria Help You Lose Weight and Heal Your Body and Mind*. Dharma Publication, Fairfield, USA.

I. Course Title : Research Techniques

II. Course Code : DM-525

III. Credit Hours : 2+1

IV. Why this course?

Research techniques are required to study the tools and techniques that are used in quantitative and qualitative methods. This study covers microscopic analysis of different types of bacteria, activities of enzyme using spectrophotometric based assays, identification and characterization of microorganisms by PCR etc.

V. Aim of the course

To impart knowledge and skills related to microbiological analytical systems in microbiology and related sciences.

VI. Theory

Unit I

Microscopy: Principles, design and application of bright field, dark field, phase contrast, fluorescence, atomic force, confocal laser and electron microscopes.

Unit II

Cell fractionation: Physical and chemical methods of microbial cell lysis: Ultrasonication, glass bead lysis, micro-fluidization, enzymatic and solvent induced techniques.

Unit III

Molecular separation: Ultrafiltration, crystallography, isoelectric focusing, chromatography, SDS-PAGE, micro and ultracentrifugation.

Unit IV

Assay methods: Spectrophotometric methods, ELISA, protein and enzyme assays, microbiological assay, and microbial receptor assay.

Unit V

Studying nutritional and therapeutic attributes of microorganisms and fermented dairy foods - Use of cell culture and small animal models.

VII. Practical

- Familiarization with the construction and design of a compound microscope; use of light microscope accessories; microscopic analysis of different types of bacteria by bright field, dark field, phase contrast and fluorescence microscopes
- Disruption of bacterial cells by ultra-sonification
- Demonstration of chromatographic techniques and SDS-PAGE
- Demonstration of aerobic and anaerobic culturing techniques
- Demonstration of use of animal models in toxicity studies
- Identification and characterization of microorganisms by PCR

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Be able to do the microscopic analysis of different types of bacteria
- To measure the activities of enzyme using spectrophotometric based assays
- To know about the identification and characterization of microorganisms by PCR

X. Suggested Reading

- Murphy DB. 2001. *Fundamentals of Light Microscopy and Electronic Imaging*, Wiley-Liss, Inc., USA.
- Harisha S. 2010. *Biotechnology Procedures and Experiments Handbook*. Infinity science press LLC, Hingham, MA 02043, USA.

- Hofmann A and Clokie S. (Eds.). 2018. *Wilson and Walker's principles and techniques of biochemistry and molecular biology*. Cambridge University Press.
- Spencer JFT & Ragout AL, Nollet LML and Toldra F. 2013. *Food analysis* HPLC, Third edition, CRC press, Taylor and Francis group, Florida, USA.
- Nollet LML and Toldra F. 2013. *Food analysis* HPLC, Third edition, CRC press, Taylor and Francis group, Florida, USA.
- Nasser Hajibagheri MA.1999. *Electron Microscopy Methods and Protocols, Methods in Molecular Biology Series*, # 117.Humana Press Inc., Totowa, New Jersey, USA.
- Singer S. 2001. *Experiments in Applied Microbiology*, Academic Press, New York, USA.

I. Course Title : Microbial Fermentation Technology

II. Course Code : DM-526

III. Credit Hours : 2+1

IV. Why this course?

Fermentation technology is the use of organisms to produce food, pharmaceuticals and alcoholic beverages on a large scale industrial basis. The basic principle involved in the industrial fermentation technology is that organisms are grown under suitable conditions, by providing raw materials meeting all the necessary requirements such as carbon, nitrogen, salts, trace elements and vitamins in a suitably designed bioreactor.

V. Aim of the course

To disseminate recent information on basic and applied aspects of fermentation technology and its industrial application to the students.

VI. Theory

Unit I

Fermentation for enhancing shelf life of foods, types of fermentation - submerged/ solid state and semi-solid.

Unit II

Microbial growth, metabolism, death, membrane transport, fermentation kinetics and fermentation modelling, batch, fed batch, continuous culture systems.

Unit III

Bioreactor design, measurement and control in fermentation.
Different types of fermenters, scaling up of fermentation, sterilization, agitation; pH, Eh, temperature measurement and control, downstream processing and product recovery, immobilization in fermentation

Unit IV

Biosensors in fermentation applications
Biosensors, basic principles; application in detection of sugars, alcohol, amino acids

Unit V

Industrial production of microbial cell biomass, organic acids, enzymes, antibiotics, micro-nutrients, amino acids, vitamins, ethanol, SCP and alcoholic beverages

VII. Practical

- Bacterial growth in batch culture.
- Different methods of microbial cultivation.

- Fermenter operation and measurement.
- Production of antimicrobial substances/ bacteriocins
- Production of microbial enzymes
- Production of baker yeast, SCP/microbial biomass.
- Production of alcohol, lactic acid.
- Production of alcoholic beverages and whey beverage

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Routine Practical as per the schedule
- Visit to the relevant industry or Laboratory

IX. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the Bioreactor design, measurement and control in fermentation
- Be able to produce the microbial cell biomass, organic acids, enzymes, antibioticsetc. using fermenter
- To have an idea about the construction, design and application of biosensor
- Be able to produce alcoholic and whey beverages.

X. Suggested Reading

- Kulandaivelu S and Janarthanan S. 2012. *Practical Manual on Fermentation Technology*. I K International Publishing House Pvt. Ltd.
- PF Stanbury Dr Whitaker. 2008. *Principles of Fermentation Technology*, Elsevier; 2editions.
- Okafor N, Okeke BC. 2017. *Modern Industrial Microbiology and Biotechnology* (Text Book), Second Edition published by CRC press, USA.
- ArindamKuila and Vinay Sharma. 2019. *Principles and Applications of Fermentation Technology* John Wiley and Sons.
- Hutkins RW. 2019. *Microbiology and Technology of Fermented Foods*, 2^{nd} Ed, Wiley Blackwell, New Jersey, USA.
- Gabriel V, Ouwehand A, Salminen S and Wright AV. 2019. *Lactic acid Bacteria: Microbiological and Functional Aspects*. CRC Press.

Course Title with Credit Load
Ph.D. in Dairy Microbiology

Course Code	Course Title	Credit Hours
DM 611**	Advances in Microbial Physiology	3+0
DM 612	Advances in Microbial Genetics	3+0
DM 621**	Advances in Dairy and Food Microbiology	3+0
DM 622	Advances in Food Safety of Dairy Products	3+0
DM 623	Advances in Probiotics and Functional Foods	3+0
DM 691	Credit Seminar-I	1+0
DM 692	Credit Seminar-II	1+0
DM 699	Doctoral Research	0+75

Minor Courses

The courses will be selected from the major courses of the allied disciplines of Dairy Chemistry, Dairy Technology, Dairy Engineering and Animal Biochemistry to meet the minimum credit requirements.

Supporting Courses

The supporting courses will be picked from the basket of courses offered in agricultural statistics, computer applications and IT, and other related relevant disciplines to meet the minimum credit requirements.

Common Courses

1. Library and Information Services 1
2. Technical Writing and Communications Skills 1
3. Intellectual Property and its Management in Agriculture 1
4. Basic Concepts in Laboratory Techniques 1
5. Agricultural Research, Research Ethics and Rural Development Programmes 1

*Core courses for Master's programme; **Core courses for Doctoral programme

Course Titles with Credit Load
Ph.D. in Dairy Microbiology

I. Course Title : Advances in Microbial Physiology

II. Course Code : DM 611

III. Credit Hours : 3+0

IV. Why this course?

Microbial physiology deals with metabolism and energy provision; reproduction and death; and regulation of vital activity on the intracellular level and on the level of microbe-microbial interactions and interactions of microorganisms with plants, animals, and man. This study covers growth kinetics of microorganisms, genetical changes during endospore formation, interactions of bacterial communities and diversity in natural eco-systems

V. Aim of the course

To understand the advances in microbial physiology and diversity for its interface with all other branches of microbiology.

VI. Theory

Unit I

Microbial growth and stress response; Mathematics and kinetics of bacterial growth, Continuous culture system (chemostat and turbidostat), Diauxic and synchronous growth, Unrestricted versus nutrient-limited growth; Advances in growth measurement, counting viable but non-culturable microbes, Growth in natural environments and limitations. Osmotic stress and osmoregulation, high and low osmolality, osmotic control of gene expression, Aerobic to anaerobic transitions, oxidative stress, regulation of the oxidative stress response,pH stress and acid tolerance,Thermal stress and heat shock response, Nutrient stress and starvation stress response, starvation protecting proteins.

Unit II

Peptidoglycans of bacterial cell walls; peptidoglycan hydrolases and synthesis; teichoic and lipo-teichoic acids, Outer membranes of Gram-negative bacteria; lipo-polysaccharide biosynthesis; Outer membranes of Gram-negative bacteria, Bacterial flagella; Chemotaxis; Swarming motility; motility in spirochetes, Endospore formation in bacillus; molecular design of a spore; Stages, physiological changes and genetic aspects of sporulation; Sporulating genes; initiation, transition, forespore development and final stages of sporulation; spore cortex and coat synthesis; Biochemical changes during sporulation, heat resistance in spores; Activation, germination, and outgrowth of bacterial endospores.

Unit III

Energy generation and transport of metabolites: Substrate-level and oxidative phosphorylation; Measurement of proton motive force; Electron transport systems;

Anaerobic respiration; Conversion of proton motive force to energy; Structure of F1F0 and the ATP operon; Energy yield; Generating ATP in alkalophiles; Energetics of chemolithotrophs; Metabolite transport; Facilitated diffusion; Mechanosensitive channels; ATP-binding cassette transporter family; Chemiosmotic-driven transport; Establishing ion gradients; New insight into Respiration and fermentation mechanism in Lactic Acid bacteria, specific transport systems; ATP-linked ion motive pumps, the histidine permease, iron, phosphotransferase system. Sugar transport in Lactic Acid bacteria.

Unit IV

Metabolic Pathways: Alternate pathways of carbohydrate metabolism; Fructose bisphosphatealdolase pathway; Alternate pathways of glucose utilization; Entner-doudoroff or ketogluconate pathway; phosphoketolase pathway; oxidative pentose phosphate cycle; Gluconeogenesis, regulation, glycogen synthesis, tricarboxylic acid cycle, glyoxylate cycle. Utilization of sugars other than glucose, lactose, galactose; maltose, mannitol, fucose and rhamnose, melibiose, raffinose, stachyose; Cellulose degradation; metabolism of starch and glycogen.

Unit V

Microbial (bacterial, archaeal, fungal and viral) diversity, Bacterial communities and diversity in natural eco-systems with special reference to Lactic Acid bacteria. Extremophiles: hyperthermophiles, extreme acidophiles, psychrophiles, barophiles halophiles, alkaliphiles, oligotrophs, radiation-resistant microorganisms, extremophiles habitats and microorganisms, Biochemistry and physiology of adaptation, biotechnology of extremophiles.

VII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/ Writing)
– Student's Book/ Journal Articles
– Student presentation
– Group Work
– Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

– To have knowledge on the growth kinetics of microorganisms
– To have an idea about the genetical changes during endospore formation
– To know about the energy generation using electron transport chains
– To have idea on interaction of bacterial communities and diversity in natural eco-systems.

IX. Suggested Reading

- Cowan MK. 2012. *Microbiology: A Systems Approach*, 3rd Edn. The McGraw Hill Companies, New York, USA.
- Madigan MT, Martinko JM and Parker J. 2012. *Brock Biology of Microorganisms*, 13th Edn. Prentice Hall, London, UK. Edition, Prentice Hall, London, UK.
- Moat AG, Foster JW and Spector MP. 2004. *Microbial Physiology*. 4th Ed. John Wiley and Sons, USA.
- Ogunseitan O. 2005. *Microbial Diversity: Form and Function in Prokaryotes* Blackwell Publishing, Malden, USA.

- Poole RK. (Ed.). 2020. *Advances in microbial physiology*. Academic Press.
- Xie *et al*. 2011. *Bacterial Flagellum as a Propeller and as a Rudder for Efficient Chemotaxis*. PNAS108 (6): 2246-51.

I. Course Title : Advances in Microbial Genetics

II. Course Code : DM 612

III. Credit Hours : 3+0

IV. Why this course?

Microbial genetics is the study of inheritance in microorganisms, including bacteria and fungi. This study covers the advancement of genetic expression and regulation in Prokaryotic system, genetic engineering/recombinant DNA technology, mutations, gene editing using advanced tools, etc. The course will also highlight applications of genetic tools.

V. Aim of the course

To familiarize the students with basic concepts of Microbial Genetics and impart them knowledge in advancements of Microbial Genetics and Genetic Engineering

VI. Theory

Unit I

Nucleic Acids: Structure of DNA – A, B and Z and triplex DNA, Function of DNA, RNA, DNA Replication models, Protein-Nucleic acid Interactions and helix-turn-helix (HTH) motif, Genetic Code.

Unit II

Mutations – Spontaneous and Induced mutations, Types of mutations; Mutagenic agents (Physical and Chemical), Molecular basis of Mutagenesis, DNA Damage and Repair – Molecular Mechanisms, Photoreactivation, Excision repair, mismatch repair, post replication repair and SOS repair. Site Directed Mutagenesis, Directed evolution, Targeted Genome Editing and CRISPR/Cas9.

Unit III

Prokaryotic Transcription; Promoters- Constitutive and Inducible; Operators; Regulatory elements; Initiation; Attenuation; Termination-Rho-dependent and independent; Transcriptional regulation-positive and negative; Operon models, - Lac, Gal and Trp. Translation: Translation machinery, translation process, Initiation, elongation, termination, factors of Protein Synthesis, peptide bond formation and translocation, Regulation of prokaryotic translation.

Unit IV

Plasmid - Structure and replication, types of plasmids, moveable genetic elements: Transposons, IS and Tn elements, molecular mechanism of transposition, Recombination in bacteria, homologous and non-homologous, 'illegitimate' recombination, and site-specific recombination; Transformation and competence factors, Transduction and Conjugation, structure of F plasmids, Hfr, Recombination methods as a tool for Gene mapping.

Unit V

Genetic Engineering/ rDNA–Restriction Enzymes – Types, Mode of action and application as a tool for gene manipulation, Vectors – Cloning and expression vectors, Construction of genomic and cDNA library, construction of full length cDNA, Microarray, Gene Silencing, Gene knock out.

Unit VI

Intracellular Signaling in microorganisms, cell-cell communication (quorum sensing), Signal transduction mechanism or pathways

Unit VII

Pyrosequencing, Illumina, Ion torrent, Nanopore sequencing technologies for whole genome and metagenome sequencing.

VII. Teaching Methods/ Activities

– Lectures
– Assignment (Reading/Writing)
– Student's Book/Journal Articles
– Student presentation
– Group Work
– Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:
– To have knowledge on the biological significance of DNA and RNA
– To have an idea about the genetic expression and regulation in Prokaryotic system
– To know about the recent advancements in genetic engineering/recombinant DNA technology.
– To have exposure on gene editing using advanced tools.

IX. Suggested Reading

- Dyson MR and Durocher Y. 2007. *Expression Systems*. Scion Publ.
- Hartl D, Jones L and Elizabeth W. 2000. *Genetic Analysis of Genes and Genomes*. Jones Bartkett Publ.
- Watson JD, Tania AB, Stephen PB, Alexander G, Michael L and Richard L. 2017. *Molecular Biology of the Gene*. Pearson.
- Keuzer H and Massey A. 2001. *Recombinant DNA and Biotechnology*. 2nd Ed. ASM Press.
- Russell Peter J. 2014. *IGenetics: a molecular approach*. Pearson
- Streips UN and Yasbin RE. 2002. *Modern Microbial Genetics*. 2nd Ed. John Wiley and Sons.
- Synder L and Champness W. 2003. *Molecular Genetics of Bacteria*. 2nd Ed. ASM Publ.

I. Course Title : Advances in Dairy and Food Microbiology
II. Course Code : DM 621
III. Credit Hours : 3+0

IV. Why this course?

Functional foods have potentially positive effects on health beyond basic nutrition and promote optimal health and help to reduce the risk of life style diseases. This course covers biochemical pathways of Lactic acid bacteria for carbohydrate metabolisms or protein metabolisms, bacteriocins and their application as biopreservatives, encapsulation of microorganisms and enzymes for the delivery to the target site etc.

V. Aim of the course

To study and understand the current trends and recent concepts related to microbiology of dairy and other foods products.

VI. Theory

Unit I

Lactic acid bacteria in food fermentations, Important metabolic pathways of microorganisms, Current status of metabolism of starters cultures; Antibiotic resistance in lactic acid bacteria, Current trends in lactic starter for industrial applications and functional foods, Special additional cultures, Biofilm and their remedies, Future aspects in research and development of LAB.

Unit II

Current concepts in starter technology, Novel starter preservation techniques, DVS, Improving starter cultures for food fermentation by genetic manipulation/metabolic engineering, Development/formulation of new products based on dairy by-products, Bioactive metabolites and biogenic amines, Designer milk, Modern concepts in cheese ripening, Nutraceuticals and functional foods, Genetically modified foods/ products, Safety aspects of genetic engineered foods.

Unit III

Bacteriocins of lactic acid bacteria, Structure, function, transport and mode of action, Application of bacteriocins in food bio preservation, Non-bacteriocin antimicrobial compounds- reuterin, antifungal compounds, milk and food derived bioactive peptides and other antimicrobial compounds, Protective cultures, Antimicrobial packaging system, active packaging.

Unit IV

Newly emerging pathogens, Concepts in food toxicology, Food borne toxins, Rapid methods for detection in food borne pathogens, Current concepts in food quality and safety management, Control of food borne pathogens, Pasteurization, dehydration, freezing, fermentation, irradiation and chemical additives, microwave processing, microfiltration, bactofugation, Hurdle technology, modified atmosphere packaging and storage, novel technology in control of food based pathogens, Use of non-thermal technologies (ultra-high voltage electric fields, thermosonication hydrostatic pressure technology, cold plasma etc.) alternate-thermal technologies (ohmic heating, dielectric heating, infrared and induction heating etc.), Biological technologies (antibacterial enzymes, proteins and peptides) in food processing.

Unit V

Encapsulation as a means for delivery of bacteria and functional ingredients-microencapsulation and nanoencapsulation, nanotechnology, Immobilization of cell and enzymes and their use in dairy and food industry.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- Have knowledge on the functional dairy foods
- To have an idea about biochemical pathways of Lactic acid bacteria for carbohydrate metabolisms or protein metabolisms
- To know about the Bacteriocins and their application as biopreservatives.
- To have any idea about the encapsulation of microorganisms and enzymes for the delivery to the target site.

IX. Suggested Reading

- Ozer B and Evrendilek GA. 2014. *Dairy Microbiology and Biochemistry: Recent Developments*. CRC Press
- Bagchi D, Lau FC and Ghosh DK. 2010. *Biotechnology in Functional Foods and Nutraceuticals* (1st Edition, 2010) CRC Press, USA.
- Kwak HS. 2015. *Nano- and Microencapsulation for Foods*. Wiley Publishing
- Erkmen O and Bozoglu TF. 2016. *Food Microbiology: Principles into Practice*, 2 Volume Set. Wiley Publishing.
- Suvendu Bhattacharya. 2014. *Conventional and Advanced Food Processing Technologies*. Wiley Publishing.

I. Course Title : Advances in Food Safety of Dairy Products

II. Course Code : DM 622

III. Credit Hours : 3+0

IV. Why this course?

Food safety is used as a scientific discipline describing handling, preparation, and storage of food in ways that prevent food-borne illness. This study covers principles of safety in advanced food microbiological laboratory, general mechanism of microbial pathogenesis, emerging food borne pathogens, antimicrobial resistance in bacteria etc.

V. Aim of the course

To develop knowledge, understanding and application of foodborne pathogens at an advanced level to ensure safety of dairy products.

VI. Theory

Unit I

Milk borne diseases, public health concern and epidemiology Trends in food borne disease and implication; Methods of diseases transmission; Changing patterns in epidemiology of milk borne diseases; Impact of agricultural and modern food manufacturing practices in transmission of food borne diseases. Public health concern associated with milk and milk products; type of microbial spoilage, defects and control measures.

Unit II

General mechanism of microbial pathogenesis: Food borne infection by colonization and adhesion factors like Pilli or fimbriae, adhesion proteins, Food borne infection by biofilm formation; invasion and intracellular residence factors; Food borne infection by phagocytosis, invasion mediated induced phagocytosis; Food borne infection by iron acquisition; motility and chemotaxis; Food borne infection by invasion of immune system; Intoxication; Toxi-infection. Structure and function of exotoxins and endotoxin; Genetic regulation and secretary system for virulence factors.

Unit III

Growth, survival characteristics, virulence and infectivity of dairy pathogens; Growth and survival characteristics of *E. coli, Enterobacter sakazaki*, Salmonella, Shigella, *Yersinia enterocolitica,* Streptococcus sp., *L. monocytogenes*, *Mycobacterium avium* subsp. *paratuberculosis*, *Brucella* sp., *Campylobacter jejuni*, *Staph.aureus*, *B. cereus, Clostridium perfringens*, toxigenic fungi and viruses in milk and milk products, their pathology of illness, mode of transmission, incidence of illness, virulence and infectivity.

Unit IV

Microbiological risk assessment of dairy foods: Risk analysis principle and concept; Hazard identification and characterization; Exposer assessment;Risk characterization in dairy products; Risk assessment models (dose response/ exposer assessment models);Risk factors affecting microbial safety of raw and processed dairy foods; Risk profiling of pathogens in milk and milk products; Risk management issues and control strategies for dairy products.

Unit V

Antimicrobial resistance in dairy animals and public health concern: Global and national perspective of AMR in dairy sector; WHO priority list/ guidelines on AMR bacteria; National action plan on AMR. Surveillance/ Incidence of AMR bacteria in dairy food chain and public health concern Mechanisms of resistance development in AMR bacteria; Conventional and rapid diagnostics for detection of AMR bacteria in dairy foods.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/ Writing)
- Student's Book/ Journal Articles
- Student presentation
- Group Work
- Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on principles of safety in advanced food microbiological laboratory
- To have an idea about the general mechanism of microbial pathogenesis
- To know about the emerging food borne pathogens
- To have knowledge on antimicrobial resistance in bacteria

IX. Suggested Reading

Schwarz S, Cavaco LM, Shen J and Aarestrup FM. 2018. *Antimicrobial Resistance in Bacteria from Livestock and Companion Animals* ASM Press.

- Haas CN, Rose JB and Gerba CP. *Quantitative Microbial Risk Assessment*. John Wiley and Sons.
- Kudva IT and Nicholson T. 2016. *Virulence Mechanisms of Bacterial Pathogens*. ASM Press.

- McVey DS, Kennedy M and Chengappa MM. 2013. *Veterinary Microbiology* John Wiley and Sons.
- Yoe C. 2016. *Principles of Risk Analysis: Decision Making Under Uncertainty*. Publisher - Technology and Engineering.
- Bhunia AK. 2019. *Foodborne Microbial Pathogens: Mechanisms and pathogenesis*. Springer-Verlag New York.

I. Course Title : Advances in Probiotics and Functional Foods

II. Course Code : DM 623

III. Credit Hours : 3+0

IV. Why this course?

Probiotics are live microbial food supplements that provide several health benefits, as they help in maintaining excellent stability and composition of the intestinal microbiota and boost the resistance against infection by pathogens. The requirement for probiotic functional foods is rapidly and progressively because of increased awareness of the public regarding the impact of food on health. This study covers prebiotics, synbiotics and postbiotics, functional food ingredients and their role in human health and nutrition, different mechanism of action of probiotics establishing through in vitro and in vivo studies, scientific assessment of probiotics/functional foods, next generation probiotics etc.

V. Aim of the course

To familiarize the student with the advancements in probiotics and functional foods

VI. Theory

Unit I

Probiotics: Characteristics of probiotics for selection, Stability during storage and passage to gastrointestinal tract.

Unit II

Probiotic mode of action and disease control: Homeostasis of disturbed commensal microbial flora in the gut, pathogen exclusion, production of antimicrobial substances, modulation of immune system, alteration of intestinal bacterial metabolite action, alteration of microecology of healthy humans and patients.

Unit III

Prebiotics, synbiotics and postbiotics: Concept and definitions, criteria, types and sources of prebiotics, prebiotics and gut microbiota.

Unit IV

Functional foods; Nutraceuticals, medical/health foods, functional foods ingredients and their role in human health and nutrition.

Unit V

Dairy based functional foods: Dahi, lassi, yoghurt, kefir, cheese, koumiss, functional fermented dairy beverages, and dairy based cereal foods, fortified fermented dairy foods.

Unit VI

Cereals, soya, plant based and other functional foods; Miso, Kimchi, Sauerkraut, Sake, Ogi, Gundruk, Natto, Doenjang, Tempeh, Douchi, Cheonggukjang, and Soy milk based fermented foods:(yoghurt, dahi, beverages and cheese), fermented meat products.

Unit VII

Microbial production of Bioactive compounds: Bacteriocins, Bioactive peptides, Conjugated Linoleic Acids, gamma-Aminobutyric acid, Vitamins (Folate, Riboflavin, Vitamin B12), Low calorie sugars (Xylitol, Sorbitol, Mannitol, Trehalose), Micronutrients (Selenium, Zinc).

Unit VIII

Health benefits of probiotics/functional foods: Gastrointestinal disorders, metabolic syndrome including cardiovascular diseases, diabetes and obesity, Brain health, Immunological disorders, cancer, health and wellbeing in Ageing, alcoholic and non-alcoholic liver disease, Reproductive and Hormonal disorders, mental health.

Unit IX

Scientific Assessment of probiotics/functional foods: Role of Biomarkers, Application of Proteomics, Metabolomics, Nutrigenetics and Nutrigenomics in establishing scientific evidence of functional foods for imparting health benefits.

Unit X

Regulations and Future prospects of probiotics and functional foods: Legal status of probiotics, safety and regulatory aspects and Future prospects.

Unit XI

Next generation probiotics (Designer probiotics): Robust probiotic strains with stress survival systems, enhanced adhesion ability and surface markers etc. and for mucosal delivery of vaccines.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Student's Book/Journal Articles
- Student presentation
- Group Work
- Visit to the relevant industry or Laboratory

VIII. Learning outcome

After undergoing this course, the students are expected to deliver the following:

- To have knowledge on the Prebiotics, synbiotics and postbiotics
- To have knowledge on functional food ingredients and their role in human health and nutrition
- To know about the different mechanism of action of probiotics establishing through *in vitro* and *in vivo* studies.
- To have any idea about the Scientific Assessment of probiotics/functional foods.

IX. Suggested Reading

- Huffnagle GB. 2008. *The Probiotics Revolution: The Definitive Guide to Safe*, Natural Health Solutions Using Probiotic and Prebiotic Foods and Supplements. Bantam, USA.
- Robert Keith Wallace (Author) and Samantha Wallace. 2017. *Gut Crisis: How Diet, Probiotics, and Friendly Bacteria Help You Lose Weight and Heal Your Body and Mind*. Dharma Publication, Fairfield, USA.
- Hae-Soo Kwak. 2015. *Nano- and Microencapsulation for Foods*. Wiley Publishing

- Edward R. (Ted) Farnworth. 2008. *Handbook of Fermented Functional Foods*. CRC Press
- Prajapati JB and Behare PV. 2018. *Textbook of Dairy Microbiology*. Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
- Puniya AK. 2015. *Fermented Milk and Dairy Products*; CRC Press/ Taylor and Francis (ISBN 9781466577978)
- Frias J, Villaluenga CM and Peñas E. (Ed.). 2016. *Fermented Foods in Health and Disease Prevention*. Elsevier Inc.
- Sungsoo C, and Finocchiaro ET. 2010. *Handbook of prebiotics and probiotics ingredients: health benefits and food applications*. Boca Raton: Taylor and Francis.
- Owen Judith A and Janis Kuby. 2013. *Kuby immunology*. New York: W.H. Freeman.
- Tamang Jyoti Prakash. 2020. *Ethnic fermented foods and beverages of India: science history and culture*. Singapore: Springer.

Suggested Broad Topics for Master's and Doctoral Research

- Application of predictive microbiology:Modeling microbial responses in foods
- A process approach to quality management system
- Air micro-flora as spoilage and infectious agents in dairy industry
- Alternative methods of microbial quantification
- Animal studies of functional attributes of dairy organisms
- Anti-microbial packaging and MAP of foods
- Bioactive peptides and Nutraceuticals
- Biodegradation of pollutants and packaging of food materials in the environment
- Biodiversity of Indian probiotic cultures/ LAB
- Biofilms in dairy industry
- Bioprospecting of dairy foods for identification, characterization and classification of prevailing microbiota
- Bioremediation of food industry wastes and metabolic engineering
- Biosensor Based assays for the detection of pathogens
- Cloning and Expression of prokaryotic and Eukaryotic genes in *E. coli* and yeast systems
- Defined strain cultures for indigenous fermented milks
- Detection and enumeration of conventional and emerging pathogenic organisms and other contaminants in dairy foods
- Detection and enumeration of indicator organisms in dairy foods
- Detection of phages in dairy and food environment
- Development of direct-fed microbial for ruminants
- Development of indicators and biosensors from microbial metabolites
- Development of synbiotic products
- Effect of different nutrients on the growth and production of microorganisms
- Effect of natural environment on microbial growth and production
- Studies on bacterial growth kinetics in batch and continuous culture systems
- Emerging Foodborne pathogens
- Enhancing shelf life of foods through microbial fermentation
- Enrichment of poor-quality roughages by solid-state fermentation
- Evaluation lactic acid bacteria for production of functional biomolecules
- Fermentation Studies for cultivation of lactic acid bacteria
- Food toxins- bioremediation
- Formulation of novel pharmaceuticals and neutraceuticals
- Genetic improvement of starter cultures
- Genetic manipulation of lactic starter cultures
- Genetic modification of dairy cultures by rDNA technology

- Genetic modification of food through the use of food grade vectors
- Genetic modification of LAB
- Genomics and Proteomics of lactic acid bacteria
- Genotypic heterogeneity and diversity of microorganisms in fermented dairy foods
- Harnessing the potential of microbial growth in environmental depollution
- Improving functionality of probiotics through metabolic engineering
- Industrial production of metabolites such as recombinant proteins/enzyme in a bioreactor and downstream processing
- Manipulation of rumen microbial ecosystem
- Metabolic engineering of LAB
- Microbial stress metabolism and ecosystem
- Microorganisms as indicators of environment pollution
- Molecular diagnostics for detection and identification of food pathogens and dairy micro-organisms
- Molecular diagnostics in dairy/food industry
- Molecular techniques for detection of foodborne pathogens and their toxins
- Metagenomic analysis of gut microbiome
- Newly emerging pathogens- rapid method of identification
- Novel bacteriocins of LAB
- Novel bacteriocins of lactic acid bacteria
- Nutrient transport systems through cell-membrane of yeast and bacteria
- Nutritional and therapeutic value of probiotic products
- PCR based identification of dairy cultures and probiotic cultures
- PCR based identification of pathogens
- Phage resistance in lactic acid bacteria
- Plasmid borne genes, chromosomal integration and technological properties of LAB
- Preservation of leguminous/ non-leguminous fodder crops by ensiling
- Principles of bio-safety in establishment of pathogen testing laboratory in food industry
- Principles of food safety control programme on HACCP, standard sanitary operating procedures (SSOP) and GMP for dairy industry
- Probiotics: characterization, product formulations, novel probiotics, validation of health claims through animal and clinical trials
- Production of microbial biomass as single cell protein
- Rapid method for detection and identification of food pathogens
- Rapid methods for detection and identification of pathogens in milk and milk products.
- Recombinant proteins/ enzymes for application in food/ dairy industry
- Recombinant proteins/enzymes for application in dairy industry
- Regulation of metabolism for lactic acid and flavour production
- Resistance of Foodborne pathogens to emerging food processing technologies.
- Role of extremophiles in microbial ecology and industry
- Screening of prebiotics
- Stress induced injury: mechanism and application in hurdle technology
- Biofilms formation in milk handling and dairy processing environment
- Mode of action of antibacterial substances on cellular organelles
- Plasmid linked properties of dairy cultures
- Probiotic organisms by growing them under anaerobic conditions and their identification by PCR method
- Study of production of functional biomolecules by lactic acid bacteria
- Ultra-structure of spore forming and non-spore forming dairy/food microorganisms with

the help of electron microscopy
- Transformation of gene of interest in the bacterial hosts
- Trends in food borne diseases and implications; method of diseases transmission; principles of safety in a food microbiological laboratory
- Understanding probiotic functionality at molecular level and role as potential probiotic markers
- Use of microorganisms in conversion of food wastes in preparation of newer foods
- Whole genome shuffling/ DNA/ Family shuffling

List of Journals

- *Advances in Applied Microbiology*
- *Advances in Bioscience and Biotechnology*
- *Advances in Genetics*
- *Advances in Microbial Physiology*
- *Annals of Microbiology*
- *Annual Review of Microbiology*
- *Antonie van Leeuwenhoek*
- *Applied and Environmental Microbiology*
- *Applied Biochemistry and Microbiology*
- *Applied Microbiology and Biotechnology*
- *Archives of Animal Nutrition*
- *Archives of Microbiology*
- *Bioscience, Biotechnology and Biochemistry*
- *BMC Microbiology*
- *BMC Molecular Biology*
- *Brazilian Journal of Microbiology*
- *British Food Journal*
- *British Journal of Nutrition*
- *Canadian Journal of Microbiology*
- *Cellular Microbiology*
- *Clinical Microbiology*
- *Comparative Immunology Microbiology and Infectious Diseases*
- *Comprehensive Reviews in Food Science and Food Safety*
- *Critical Reviews in Environmental Science and Technology*
- *Critical Reviews in Food Science and Nutrition*
- *Critical Reviews in Microbiology*
- *Current Genetics*
- *Current Microbiology*
- *Current Opinion in Biotechnology*
- *Current Science*
- *Current Topics in Microbiology and Immunology*
- *Dairy Science and Technology (Le Lait)*
- *Environmental Microbiology*
- *Enzyme and Microbial Technology*
- *Eukaryotic Cell*
- *European Food Research and Technology*
- *European Journal of Clinical Microbiology and Infectious Diseases*
- *FEMS Microbiology Ecology*
- *FEMS Microbiology Letters*
- *FEMS Microbiology Reviews*

- *Food Analytical Methods*
- *Food and Function*
- *Food Bioscience*
- *Food Biotechnology*
- *Food Control*
- *Food Microbiology*
- *Food Microbiology and Food Safety*
- *Food Quality and Preference*
- *Food Research International*
- *Food Reviews International*
- *Food Science and Technology - Lebensmittel-Wissenschaft and Tech*
- *Food Science and Biotechnology*
- *Food Science and Technology International*
- *Food Technology and Biotechnology*
- *Foodborne Pathogens and Disease*
- *Frontiers in Cellular and Infection Microbiology*
- *Frontiers in Microbiology*
- *Frontiers in Molecular Biosciences*
- *Fungal Genetics and Biology*
- *Future Microbiology*
- *Gene*
- *Indian Journal of Animal Sciences*
- *Indian Journal of Dairy Science*
- *Indian Journal of Medical Microbiology*
- *Indian Journal of Microbiology*
- *Indian Journal of Veterinary Science*
- *Innovative Food Science and Emerging Technologies*
- *International Dairy Journal*
- *International Journal of Dairy Technology*
- *International Journal of Fermented Foods*
- *International Journal of Food Microbiology*
- *International Journal of Food Properties*
- *International Journal of Food Science and Nutrition*
- *International Journal of Food Science and Technology*
- *International Journal of General and Molecular Microbiology*
- *International Journal of Probiotics and Prebiotics*
- *Journal of Agricultural and Food Chemistry*
- *Journal of Animal and Feed Sciences*
- *Journal of Animal Science*
- *Journal of Applied Animal Research*
- *Journal of Applied Microbiology*
- *Journal of Bacteriology*
- *Journal of Basic Microbiology*
- *Journal of Biological Chemistry*
- *Journal of Biotechnology*
- *Journal of Dairy Research*
- *Journal of Dairy Science*
- *Journal of Food and Drug Analysis*
- *Journal of Food Biochemistry*

- *Journal of Food Composition and Analysis*
- *Journal of Food Processing and Preservation*
- *Journal of Food Protection*
- *Letters in Applied Microbiology*
- *Journal of Food Quality*
- *Journal of Food safety*
- *Journal of Food Science*
- *Journal of Food Science and Technology*
- *Journal of Functional Foods*
- *Journal of General and Applied Microbiology*
- *Journal of Industrial Microbiology and Biotechnology*
- *Journal of Industrial Microbiology and Biotechnology*
- *Journal of Medicinal Food*
- *Journal of Microbial Food Safety Standards*
- *Journal of Microbiology*
- *Journal of Microbiology and Biotechnology*
- *Journal of Microscopy*
- *Journal of Molecular Microbiology and Biotechnology*
- *Journal of Rapid Methods and Automation in Microbiology*
- *Journal of The Science of Food and Agriculture*
- *Journal of Virology*
- *Methods in Microbiology*
- *Microbial Ecology in Health and Disease*
- *Microbial Pathogenesis*
- *Microbiological Research*
- *Microbiology*
- *Microbiology and Molecular Biology Reviews*
- *Microbiology: Bacteriology, Mycology, Parasitology and Virology*
- *Molecular Biology*
- *Molecular Genetics, Microbiology, virology*
- *Nature*
- *Nature Biotechnology*
- *Nature Reviews Microbiology*
- *Plasmid*
- *PNAS*
- *Probiotics and Antimicrobial Proteins*
- *Process Biochemistry*
- *Quality Assurance and Safety of Crops and Foods*
- *Research in Microbiology*
- *Science*
- *Science of the Total Environment*
- *Systematic and Applied Microbiology*
- *The Lancet*
- *Trends in Food Science and Technology*
- *Trends in Microbiology*
- *Veterinary Microbiology*
- *Veterinary Research*
- *World Journal of Dairy and Food Sciences*
- *World Journal of Microbiology and Biotechnology*

ANNEXURE I

List of BSMA Committee Members for Dairy Science and Technology

(Dairy Technology/Dairy Engineering/Dairy Microbiology/Dairy Chemistry)
(Constituted by ICAR vide Office order No. F.No. 7/6/2017-EQR)

Name and designation	Address	Specialization
Dr R.R.B. Singh Director	ICAR-National Dairy Research Institute, Karnal, Haryana Present Address: Joint Director (Academics), ICAR-National Dairy Research Institute, Karnal, Haryana	Chairman
Dr Anil K. Puniya Dean	College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences, University, Ludhiana Present Address: Principal Scientist and Head, Dairy Microbiology Division, ICAR-National Dairy Research Institute, Karnal, Haryana	Convener
Dr J.B. Prajapati Professor and Dean	Dairy Microbiology Division, SMC College of Dairy Science, Anand Agricultural University, Anand, Gujarat	Dairy Microbiology
Dr Bimlesh Mann Principal Scientist and Head	Dairy Chemistry Division, ICAR-National Dairy Research Institute, Karnal, Haryana	Dairy Chemistry
Dr Atanu Jana Professor and Head	Dairy Technology Division, SMC College of Dairy Science, Anand Agricultural University, Anand, Gujarat	Dairy Technology
Dr S. Ravi KumarProfessor and Head (Rtd.)	Department of Dairy Engineering, College of Dairy Technology, Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh	Dairy Engineering
Dr Savita Sharma Professor	Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, Punjab	Food Technology

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 4

Agricultural Engineering

- Farm Machinery and Power Engineering
- Processing and Food Engineering
- Irrigation and Drainage Engineering
- Renewable Energy Engineering
- Soil and Water Conservation Engineering

Contents

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Farm Machinery and Power Engineering

Preamble

Three major points were kept in mind while preparing course curricula related to Farm Machinery and Power Engineering (1) the syllabus and courses taught at UG level as recommended by 6^{th} Dean committee (2) preparing students to keep pace with future requirement of the human resource in institutions and industry (3) to align the syllabus with ARS/NET examination.

Course curricula and course outlines in Farm Machinery and Power Engineering have been designed keeping in view the courses offered by the faculties from associated/ closely related disciplines, viz. Mechanical Engineering, Mathematics, Renewable Energy Engineering, Electrical, Electronics and Computer Engineering, Processing and Food Engineering, Civil Engineering, etc.

It becomes more important for the post graduate students to not only learn the recent advances but have also to be trained/ hands on experience in the modern and latest techniques in their major disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the corporate sector.

All courses are designed to cover all basic topics and by taking into consideration demands of corporate sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required and enhancing the global competitiveness and employability of students. To meet these objectives new courses were added which covers areas: Machinery for Precision Agriculture, Automation and Control, Machinery for Horticulture and Protected Agriculture, Advance Manufacturing Technologies, Principles of Hydraulic and Pneumatic Systems, Ergonomics in Working Environment, Machinery for Special Farm Operations, Mechanics of Traction and its Application.

Further, existing courses were suitably modified and restructured by deleting topics already covered in UG, removing overlapping topics in different courses, adding topics/ courses to cover ARS/NET exam syllabus and topic important to the farm machinery industry and emerging trends in Farm Machinery & Power Engineering. The modified/revised courses cover the areas: Advances in farm machinery, Computer aided Design of Machinery, Design of Farm Machinery, Ergonomics in Working Environment, Machinery for Special Farm Operations, Mechanics of Traction and its Application.

The course content and syllabus upgraded make it more of practical oriented and as per ARS/NET Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech in Farm Machinery and Power Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
FMPE 501*	Soil Dynamics in Tillage and Traction	2+1
FMPE 502*	Testing and Evaluation of Agricultural Equipment	2+1
FMPE 503*	Ergonomics and Safety in Farm Operations	2+1
FMPE 504	Design of Tractor systems	2+1
FMPE 505	Design of Farm Machinery-I	2+1
FMPE 506	Design of Farm Machinery-II	1+1
FMPE 507*	Management of Farm Power and Machinery System	2+1
FMPE 511	Principles of Automation and Control	2+1
FMPE 512	Principles of Hydraulic and Pneumatic Systems	2+1
FMPE 513	Applied Instrumentation in Farm Machinery	2+1
FMPE 514	Systems Simulation and Computer Aided Problem Solving in Engineering	1+1
FMPE 515	Computer Aided Design of Machinery	0+2
FMPE 516	Advance Manufacturing Technologies	2+0
FMPE 517	Machinery for Precision Agriculture	2+1
FMPE 518	Machinery for Horticulture and Protected Agriculture	2+0

*Compulsory Course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
PFE 511	Engineering Properties of Biological Materials	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
ME-504	Vibrations	2+1
ME-507	Fatigue Design	2+1
ME-515	Computer Aided Design	2+1
REE 503	Biomass Energy Conversion Technologies	2+1
REE 516	Agro Energy Audit and Management	2+1
CE 501	Dimensional Analysis and Similitude	1+1
CE 510	Experimental Stress Analysis	2+1
MATHS 501	Finite Element Methods	1+1
MATHS 502	Numerical Methods for Engineers	2+0
CSE 501	Big Data Analytics	2+1
CSE 502	Artificial Intelligence	2+1
CSE 505	Database Management System	2+1

Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	0+1
*PGS 502	Technical Writing and Communications Skills	0+1
*PGS 503	Intellectual Property and its management in Agriculture	0+1
*PGS 504	Basic Concepts in Laboratory Techniques	0+1
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	0+1

*Compulsory Course

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
FMPE 591	Masters' Seminar	0+1
FMPE 599	Masters' Research	0+30

Course Contents
M.Tech in Farm Machinery and Power Engineering

I. Course Title : Soil Dynamics in Tillage and Traction

II. Course Code : FMPE 501

III. Credit Hours : 2+1

IV. Aim of the course

To have an understanding of the principles of soil mechanics as applied to interaction of tillage tools and traction devices with soil in terms of soil forces and deformation during for soil cutting and generation of traction.

V. Theory

Unit I

Characterization of state of stress in a point: Derivation, representation by Mohr's Circle. Coulomb's law of friction and cohesion. Measurement of soil resistance properties: Direct shear box, torsion shear apparatus, tri-axial apparatus. Soil behaviour considerations: Soil water pressure and movement. Critical state soil mechanics: Soil stress-strain behaviour, shear rate effects.

Unit II

Soil cutting forces: The universal earthmoving equation, two dimensional cases, smooth vertical blade, smooth and rough raked blades in cohesive soil, unconstrained tool to soil adhesion. The shape of failure surfaces. Hettiaratchi's calculations, effect of soil weight. Soil cutting force by method of trial wedges.

Unit III

Extension of theory to three dimension: Hettiaratchi, Reece-Godwin and Spoor. Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength. Concept of critical depth. Complex tool shapes: Curved tools-shank and foot tools-mould board plough. Soil Loosening and manipulation: Measurement of soil loosening and its efficiency. Draft force efficiency: Loosening and pulverization efficiency. Soil mixing and inversion: Soil properties, tool shape, tool speed and tool spacing.

Unit IV

Traction devices: Tyres, type, size, selection mechanics of traction devices. Maximum traction force: Soil deformation and slip, estimation of contact areas. Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae. Soil compaction by agricultural vehicles and machines.

VI. Practical

Measurements of soil shear strength by in-situ shear box apparatus and soil friction by friction plate. Measuring cone penetrometer resistance and working out tractive coefficients for tyres. Measurement of in-situ shear strength of soil by torsional vane shear apparatus. Solving problems on stress in soil. Solving problems on soil properties. Solving problems of tool forces. Problems on tillage tool forces, wheel slippage, tyre deflection, design and performance of traction devices.

VII. Learning outcome

The student will be able to understand the principles that govern manipulation of soil by tillage tools.

The student will be able to apply the principles of soil mechanics to theoretically calculate the forces on tillage tools during soil cutting and forces generated by tractor wheels.

VIII. Lecture schedule

S.No.	Topic	No of Lectures
1.	**Unit I** Characterization of state of stress in a point: Derivation, representation by Mohr's Circle.	2
2.	Coulomb's law of friction and cohesion.	**1**
3.	Measurement of soil resistance properties: Direct shear box, torsion shear apparatus, tri-axial apparatus.	2
4.	Soil behaviour considerations: Soil water pressure and movement.	1
5.	Critical state soil mechanics: Soil stress-strain behaviour, shear rate effects	2
6.	**Unit II** Soil cutting forces: The universal earthmoving equation, two dimensional cases, smooth vertical blade, smooth and rough raked blades in cohesive soil, unconstrained tool to soil adhesion.	3
7.	The shape of failure surfaces.	2
8.	Hettiaratchi's calculations, effect of soil weight.	2
9.	Soil cutting force by method of trial wedges.	2
10.	**Unit III** Extension of theory to three dimensions: Hettiaratchi, Reece-Godwin and Spoor.	2
11.	Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength.	2
12.	Concept of critical depth.	1
13.	Complex tool shapes: Curved tools-shank and foot tools-mould board plough.	1
14.	Soil Loosening and manipulation: Measurement of soil loosening and its efficiency.	1
15.	Draft force efficiency: Loosening and pulverization efficiency.	1
16.	Soil mixing and inversion: Soil properties, tool shape, tool speed and tool spacing.	2
17.	**Unit IV** Traction devices: Tyres, type, size, selection mechanics of traction devices.	1
18.	Maximum traction force: Soil deformation and slip, estimation of contact areas.	1
19.	Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae.	2
20.	Soil compaction by agricultural vehicles and machines.	1
		32

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Measurements of soil shear strength by *in-situ* shear box apparatus and soil friction by friction plate.	3
2.	Measuring cone penetrometer resistance and working out tractive coefficients for tyres.	2
3.	Measurement of *in-situ* shear strength of soil by torsional vane shear apparatus.	1
4.	Solving problems on stress in soil.	2
5.	Solving problems on soil properties.	2
6.	Solving problems of tillage tool forces.	1
7.	Problems on wheel slippage and tyre deflection.	3
8.	Problems on design and performance of traction devices.	1
9.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Gill WR and Van den Berg GE. 1968. *Soil Dynamics in Tillage and Traction.*
- Handbook 316, *Agricultural Research Service*, US Department of Agriculture, Washington DC, 1968.
- John BL, Paul KT, David WS and Makoto H. 2012. *Tractors and their Power Units.* 4th Edition. Springer Science & Business Media, ISBN: 81-239-0501-7, ASAE ISBN: 0-929355-72-5.
- Koolen AJ and Kuipers H. 1983. *Agricultural Soil Mechanics.* Springer-Verlag ISBN 13:978-3-642-69012-9.
- McKyes E. 1989. *Agricultural Engineering Soil Mechanics*, Elsevier science publishers B.V., P.O. Box 211, 1000 AE Amsterdam, the Netherlands.
- McKyes E. 2016. *Soil Cutting and Tillage: Vol 7.* Developments in Agricultural Engineering Elsevier R Science Publisher SBV.

I. Course Title : Testing and Evaluation of Agriculture Equipment

II. Course Code : FMPE 502

III. Credit Hours : 2+1

IV. Aim of the course

To enable the student to learn the procedure for testing of different farm machinery and the concept behind evaluation of different performance parameters of farm machinery and the standards adopted therein.

V. Theory

Unit I

Importance and significance of testing and types of testing. Test equipment, usage and limitations. Test procedures and various test codes: National and International.

Unit II

Laboratory and field testing of tillage and sowing machinery: Sub-soiler, laser land leveler, mould board Plough, disc plough, rotavator, cultivator, disc harrow, seed cum fertilizer drill and planter.

Unit III

Laboratory and field testing of manual and power operated intercultural machinery and plant protection machine.

Unit IV

Laboratory and field testing of reaper, thresher and chaff cutter.

Unit V

Laboratory and field testing of straw combine and combine harvester. Review and interpretation of test reports. Importance and need of standardization of components of agricultural equipment.

VI. Practical

Laboratory and field testing of selected farm equipment: Tillage, sowing and planting. Material testing of critical components. Accelerated testing of fast wearing components.

VII. Learning outcome

The student will be able to test farm machinery, prepare performance reports and also analyze the performance reports to find the suitability of a machinery for a given farm operation.

VIII. Lecture Schedule

S.No	Topic	No. of Lectures
1.	Introduction, various test codes, Test programs, testing terminology, procedures and type of testing systems	2
2.	Study of different types of Dynamometer	2
3.	Stationary diesel engine performance testing	2
4.	Tractor Test Codes and Data Interpretation Estimation of error	2
5.	Testing and evaluation of tillage machinery	2
6.	Testing and evaluation of seed-cum-fertilizers drills/planters	3
7.	Testing and evaluation of manually and power operated Sprayers	3
8.	Testing and evaluation of reapers and straw combines	1
9.	Testing and evaluation of combine harvester and threshers	3
10.	Testing and evaluation of manually and power operated chaff cutters	2
11.	Testing and evaluation of advanced machinery	2
12.	Reliability in Engineering with emphasis on agricultural machinery	2
13.	Discussion on Farm machinery codes	2
14.	Interpretations of the information given in different codes on farm machinery	1
15.	Formulation of test-code for machines that do not have any code.	2
16.	Current topics/discussion	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Lab testing of Stationary diesel engine for full load, variable load and governor test	2
2.	Lab Testing and evaluation of seed-cum-fertilizers drills	1
3.	Lab Testing and evaluation of seed-cum-fertilizers planters	1
4.	Lab Testing and evaluation of knapsack Sprayers	1

S.No.	Topic	No of Practicals
5.	Lab Testing and evaluation of nozzles	1
6.	Field testing of rotavators	1
7.	Lab testing of rotavators for soil sample analysis	1
8.	Testing and evaluation of reapers	1
9.	Testing and evaluation of combine harvester and threshers	1
10.	Testing and evaluation of chaff cutters	1
11.	Testing and evaluation of laser land leveler	1
12.	Case study of test reports of different agricultural implements	3
	Total	**15**

X. Suggested Reading

- Barger E L, Liljedahl J B and McKibben E C. 1967. *Tractors and their Power Units*. Eastern Wiley 4th Edition.
- *Indian Standard Codes for Agricultural Implements*. Published by BIS, New Delhi.
- Inns F M. 1986. *Selection, Testing and Evaluation of Agricultural Machines and Equipment*. FAO Service Bull. No.115.
- Mehta M L, Verma S R, Rajan P and Singh S K 2019. *Testing and Evaluation of Agricultural Machinery*. Daya Publishing House, Delhi.
- *Nebraska Tractor Test Code for Testing Tractor*, Nebraska, USA.
- Smith D W, Sims B G and O'Neill D H 2001. *Testing and Evaluation of Agricultural Machinery and Equipment -Principle and Practice*. FAO Agricultural Services Bull. 110.

I. Course Title : Ergonomics and Safety in Farm Operations

II. Course Code : FMPE 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles of the science of Ergonomics and its application to farm machinery in order to reduce drudgery in the use of tools and equipment and also make them safe and comfortable to operate.

V. Theory

Unit I

Description of human-machine systems. Ergonomics and its areas of application in the work system. History of ergonomics. Modern ergonomics.

Unit II

Anthropometry: Its role in daily life, principles in workspace and equipment design, design of manual handling tasks and application in equipment design. Human postures: Postural stress and its role in design of farm machinery.

Unit III

Human factors in tractor seat design: Entry system, controls, shape, colour coding, dial and indicators. Modern technology for comfort in driving places.

Unit IV

Physiological parameters: Psychological and mental stresses and their measurement techniques. Human energy expenditure: Calibration of subjects, human workload and its assessment.

Unit V

Safety considerations and operators protective gadgets in farm operations. Standards/codes for tractors and agricultural machinery safety.

VI. Practical

Identifying role of ergonomics in our daily life. Measurement of anthropometric dimensions of agricultural workers and establishing relationship between them. Determination of human requirements for field operation with manually operated equipment. Assessment of psychological/general load for specific agricultural operations. Calibration of human subject on bicycle ergometer and/ or treadmill for its energy output and physiological parameters like heart rate, oxygen consumption rate under laboratory conditions. Case studies of agricultural accidents and safety measure.

VII. Learning outcome

The student will be able to apply the concepts of ergonomics in the design of agricultural tools and equipment and also evaluate the ergonomic suitability of such equipment.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to ergonomics, definition of ergonomics	1
2.	Operator- machine-environment system approach	1
3.	Relative advantages of man and machine, ergonomics in daily life	1
4.	Importance of ergonomics in agriculture and farm machinery	1
5.	History of ergonomics, modern ergonomics	1
6.	Man machine environment components, broad objectives of ergonomics	1
7.	Basic issues and processes under ergonomics for design and development of machine	1
8.	Anthropometry and its uses in daily life	1
9.	First hourly examination	1
10.	Principles of applied anthropometry in ergonomics	1
11.	Availability of anthropometric database for Indian agricultural workers	1
12.	Definitions and possible applications of anthropometric dimensions	2
13.	Workspace and equipment design	1
14.	Different modes of force application	1
15.	Design of manual handling tasks	1
16.	Biomechanics aspects in machine design	1
17.	Mid-semester examination	1
18.	Human posture, posture stresses and its role in design of agricultural machinery	1
19.	Work place design for standing and seated workers	2
20.	Human factors in tractor seat design	1
21.	Entry system, controls, shape, colour coding, dial and indicators	1
22.	Modern technology for safety and comfort in driving place	1
23.	Physiological and psychological parameters for ergonomic evaluation	1
24.	Physiological and psychological stresses and measurements techniques	1
25.	Human work load assessment, human energy expenditure	1
26.	Calibration of subjects – concept, importance and techniques	1
27.	Accidents and safety in agriculture operations, general safety guidelines	1
28.	Safety feeding systems for threshers and chaff cutters	1

S.No.	Topic	No. of Lectures
29.	Safety gadgets for tractors and trailers	1
30.	Standard/ codes for agricultural machinery safety	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Identify role of ergonomics in our daily life	1
2.	Measurement of anthropometric dimensions of agriculture workers and establishing relation between them	2
3.	Measurement of strength parameters	1
4.	Determination of human requirements of field operation with manual operated equipment	2
5.	Assessment of psychological/ general load for agricultural operations	1
6.	Assessment of stress on eyes by specific agricultural operation	1
7.	Noise measurement in tractors	1
8.	Calibration of human subject on bicycle ergometer	1
9.	Calibration of human subject on treadmill	1
10.	Measurement of physiological parameter, viz. heart/ pulse rate	1
11.	Measurement of oxygen consumption under laboratory conditions	1
12.	Case study of accidents and safety on tractors and trailers	1
13.	Case study of accidents and safety on chaff cutters and threshers	1
14.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Bridger R S 2009. *Introduction to Ergonomics*. CRC Press, Boca Rotan, USA
- Sanders M S and McCormick E J 2000. *Human Factors in Engineering and Design*. McGraw Hill. 7th edition
- Astrand P, Rodahl K, Dahl H A and Stromme S B 2003. *Textbook of Work Physiology - Physiological Basis of Exercise*. McGraw Hill.
- Gite L P 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal.
- Gite L P, Agrawal K N, Mehta C R, Potdar R R and Narwariya B S. 2019. *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. Jain Brothers, New Delhi.

I. Course Title : Design of Tractor Systems

II. Course Code : FMPE 504

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the student to the principles that direct the design of a tractor and its subsystems and enable the student to apply the concept of machine design in designing the subsystems and critical components.

V. Theory

Unit I

Design and types, research, development, design procedure, technical specifications of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture.

Unit II

Engine related terminology. Selection of stroke-bore ratio. Design of engine components; Piston, connecting rod, cylinder, cylinder head, crank shaft etc.

Unit III

Design of tractor systems like clutch, gearbox, steering, steering geometry, turning force, hydraulic system & hitching, chassis, operator's seat, work-place area and controls. Tire selection, aspect ratio etc.

Unit IV

Mechanics of tractor stability. Computer aided design and its application in farm tractors.

VI. Practical

Engine design calculations, transmission component design calculations. Extensive practices on the computer aided design packages.

VII. Learning outcome

The student will have an overview of the philosophy guiding the design of a tractor and also design tractor systems and components.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
	Unit I	
1.	Design and types, research, development, design procedure, technical specifications of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture.	3
	Unit II	
2.	Engine related terminology. Selection of stroke-bore ratio.	1
3.	Design of engine components: Piston, connecting rod, cylinder, cylinder head, crank shaft etc.	3
	Unit III	
4.	Design of tractor clutch	2
5.	Design of tractor gearbox	3
6.	Tractor steering system, functional requirements, steering geometry, turning force	2
7.	Steering system design parameters and design procedure	2
8.	Hydraulic system & hitching – principles of operation	2
9.	Hydraulic system - Design parameters and design procedures including design of pump, cylinder etc.	2
10.	Design of chassis	2
11.	Human factors in tractor design. Design of operator's seat	2
12.	Work-place area and controls	2
13.	Tire selection, aspect ratio etc.	1
	Unit IV	
14.	Mechanics of tractor stability. Dynamic and static analysis of forces acting on farm tractor, case studies.	3
15.	Computer aided design and its application in farm tractors	2
	Total	**32**

IX. List of Practicals

S.No.	Practical	No. of Practical
1.	Engine design calculations - Stroke-bore ratio determination - Design of radiator - Balancing of crankshaft	2
2.	Engine design calculations - Calculation of volumetric/thermal efficiencies	1
3.	Transmission component design calculations - Design of clutch	1
4.	Transmission component design calculations - Design of gear box and calculation of speed ratios	2
5.	Design of Ackerman steering. Calculation of turning radius.	1
6.	Design of brakes (mechanical and hydraulic)	2
7.	Design of hydraulic system	2
8.	Calculation for determination of centre of gravity of tractor, moment of inertia and stability	3
9.	Practice on the Computer Aided Design (CAD) packages for design of various components	2
	Total	**16**

X. Suggested Reading

- Barger EL Liljedahl JB and McKibben EC. 1967. *Tractors and their Power Units*. Wiley Eastern Pvt. Ltd.
- Macmillan RH. 2002. *The Mechanics of Tractor – Implement Performance and Worked Example*. University of Melbourne, Australia.
- Sharma PC and Agarwal DK. 2000. *Machine Design*. S K Kataria and Sons, Delhi.

I. Course Title : Design of Farm Machinery I

II. Course Code : FMPE 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the interaction of tillage tools with soil and design the components of the tillage tools based on their requirement and also to learn how the systems of planting machinery are designed.

V. Theory

Unit I

Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity. Physico-mechanical properties of soils. Technological process of ploughing. Wedge. Working process of mould board plough, determination of basic parameters. Design of coulters, shares, mould boards.

Unit II

Constructing of mould board working surface. Design of landside, frog, jointer. Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough. Draft on ploughs, resistance during ploughing. Design disk ploughs: Concave disk working tools, forces acting.

Unit III

Machines and implements for surface and inter row tillage; Peg toothed harrow, disk harrows, rotary hoes, graders, rollers, cultivators. Design of V shaped sweeps. Rigidity of working tools. Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement. Machines with working tools executing an oscillatory motion.

Unit IV

Methods of sowing and planting: Machines, agronomic specifications. Sowing inter-tilled crop. Grain hoppers: Seed metering mechanism, furrow openers and seed tubes. Machines for fertilizer application: Discs type broadcasters. Organic fertilizer application: Properties of organic manure, spreading machines. Liquid fertilizer distributors. Planting and transplanting: Paddy transplanters, potato planters.

VI. Practical

Design of mould board working surface; Coulter, frog, share, jointer, mould board plough. Trailed, semi mounted and mounted ploughs. Design of disc plough, disc harrow, peg tooth harrow, cultivators, sweeps. Design of rotary tiller. Design of traction and transport devices.

Design of seed drills; Metering mechanism, hopper, furrow opener. Fertilizer spreader, liquid fertilizer applicators and design of its sub systems. Design of paddy transplanters and potato planters.

VII. Learning outcome

The student will be able to appreciate the principles behind the design of tillage tools and planting machinery. He will be able to arrive at design configurations for such machines.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity.	3
2.	Farm machinery design: economic considerations of durability, reliability and rigidity.	2
3.	Physio-mechanical properties of soils.	1
4.	Technological process of ploughing. Wedge. Working process of mould board plough, determination of basic parameters.	2
5.	Design of coulters, shares, mould boards.	2
6.	Constructing of mould board working surface.	1
7.	Design of landside, frog, jointer.	1
8.	Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough.Draft on ploughs, resistance during ploughing.	2
9.	Design disk ploughs: Concave disk working tools, forces acting.	2
10.	Machines and implements for surface and inter row tillage: Peg toothed harrow, disk harrows, rotary hoes, graders, rollers, cultivators.	2
11.	Design of V shaped sweeps. Rigidity of working tools.	1
12.	Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement.	2
13.	Machines with working tools executing an oscillatory motion.	1
14.	Methods of sowing and planting: Machines' agronomic specifications. Sowing inter-tilled crop, Grain hoppers Seed metering mechanism Furrow openers and seed tubes.	2

S.No.	Practical	No. of Lectures
15.	Machines for fertilizer application: Discs type broadcasters.	1
16.	Organic fertilizer application: Properties of organic manure spreading machines. Liquid fertilizer distributors.	2
17.	Planting and transplanting: Paddy transplanters, potato planters.	1
18.	Case studies	2
	Total	**30**

IX. List of Practicals

S.No.	Practical	No of Practicals
1.	Design of mould board: Coulter, frog, share	1
2.	Design of mould board: mould board plough working surface, jointer.	1
3.	Trailed, semi mounted and mounted ploughs.	1
4.	Design of disc plough	1
5.	Design of disc harrow	1
6.	Design of peg tooth harrow	1
7.	Design of cultivators and sweep.	1
8.	Design of rotary tiller.	1
9.	Design of traction and transport devices.	1
10.	Design of seed drills: Metering mechanisms	1
11.	Design of seed drills: hopper and furrow opener.	1
12.	Design of Fertilizer application equipment: fertilizer spreaders	1
13.	Design of Fertilizer application equipment: liquid fertilizer applicators and design of its sub systems	1
14.	Design of paddy transplanters	1
15.	Design of potato planters.	1
	Total	**15**

X. Suggested Reading

- Bernacki C, Haman J and Kanafajski Cz. 1972. *Agricultural Machines Theory and Construction*. Vol.I. U.S. Dept. of Commerce, National Technical Information Service, Springfield, Virginia 22151.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1990. *Theory, Construction and Calculations of Agricultural Machinery - Vol. I.* Oxonian Press Pvt. Ltd. No.56, Connaught Circle, New Delhi.
- Gill R and Vanden Berg GE. 2013. *Soil Dynamics in Tillage and Traction*. Scientific Publishers (India) ISBN-10: 8172338031.
- Yatsuk EP 1981. *Rotary Soil Working Machines Construction, Calculation and Design.* American Publishing Co. Pvt. Ltd, New Delhi.

I. Course Title : Design of Farm Machinery-II

II. Course Code : FMPE 506

III. Credit Hours : 1+1

IV. Aim of the course

To learn the engineering principles behind application of pesticides and the systems that implements the same. To learn the concepts behind design of crop harvesting and threshing equipment.

V. Theory

Unit I

Pesticide calculation examples. Multidisciplinary nature of pesticide application. Overview of chemical control integrated pest management. Targets for pesticide deposition. Formulation of pesticides.

Unit II

Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles. Air assisted hydraulic sprayer design principles. Controlled droplet application. Electrostatically charged sprayers. Spray drift and its mitigation. Aerial spraying systems. Use of drones for spraying: Design of spray generation and application issues.

Unit III

Introduction to combine harvesters: Construction, equipment subsystems, power sub systems. Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling. Properties of plant grain: Physical, mechanical, grain damage. Properties of MOG; Mechanical and aerodynamic.

Unit IV

Design of grain header; Orienting and supporting reel. Plant cutting cutter bar: Working process, cutter bar drive. Knife cutting speed pattern area. Design of auger for plant collection. Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.

Unit V

Cereal threshing and separation; Design of tangential and axial threshing units. Performance indices of threshing units. Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement. Separation process and design of straw walker. Cleaning Unit process and operation. Grain pan; Chaffer and bottom sieve. Blower design and flow orientation. Design of conveying system for grain. Straw choppers and shredders.

VI. Practical

Measurement of spray characters for different nozzles. Problems on sizing of sprayer components. Design of sprayer for special purpose: Orchard and tall trees. Harvesting machine. Problems on design of cutterbars, reels, platform auger, conveyors. Design of threshing drum: Radial and axial flow type. Design of cleaning and grading systems. Design of blowers.

VII. Learning outcome

The student will know the principles behind the design of crop spraying equipments and harvesting and threshing machinery.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Overview of chemical control integrated pest management.	1
2.	Targets for pesticide deposition. Formulation of pesticides.	1
3.	Multidisciplinary nature of pesticide application.	1
4.	Pesticide calculation examples.	2

S.No.	Topic	No of Lectures
5.	Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles.	2
6.	Controlled droplet application. Spray drift and its mitigation.	1
7.	Air assisted hydraulic sprayer design principles. Electrostatically charged sprayers.	2
8.	Aerial spraying systems. Use of drones for spraying:	1
9.	Design of spray generation and application issues.	1
10.	Introduction to combine harvesters; Construction, equipment subsystems, power sub systems.	1
11.	Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling.	1
12.	Properties of plant grain: Physical, mechanical, grain damage.	2
13.	Properties of MOG; Mechanical and aerodynamic.	2
14.	Design of grain header; Orienting and supporting reel. Plant cutting cutter bar.	2
15.	Working process, cutter bar drive. Knife cutting speed pattern area.	1
16.	Design of auger for plant collection.	1
17.	Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.	2
18.	Cereal threshing and separation, Design of tangential and axial threshing units. Performance indices of threshing units.	2
19.	Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement.	1
20.	Separation process and design of straw walker.	1
21.	Cleaning Unit process and operation. Grain pan: Chaffer and bottom sieve. Blower design and flow orientation.	2
22.	Design of conveying system for grain. Straw choppers and shredders.	2
	Total	**32**

IX. List of Practicals

S.No.	Practical	No of Practicals
1.	Measurement of spray characters for different nozzles.	1
2.	Problems on sizing of sprayer components.	1
3.	Design of spraying units – manual	1
4.	Design of spraying units – powered	1
5.	Design of sprayer for special purpose: Orchard and tall trees.	1
6.	Design of agitation units – mechanical and hydraulic	1
7.	Harvesting machines: Problems on design of shear type cutting mechanism	1
8.	Harvesting machines: Problems on design of impact type harvesting mechanism	1
9.	Harvesting machines: Problems on design of platform auger and conveyors.	1
10.	Harvesting machines: Problems on design of reels	1
11.	Design of threshing drum: Radial flow type.	1
12.	Design of threshing drum: Axial flow type.	1
13.	Design of cleaning systems.	1
14.	Design of grading systems.	1
15.	Design of blowers.	1
	Total	**15**

X. Suggested Reading

- Bernacki C, Haman J and Kanafajski Cz 1972. *Agricultural Machines Theory and Construction.* Vol-I. U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia22151.
- Bindra, OS and Singh H. 1971. *Pesticides Application Equipments.* Oxford & IBH Publishing Co., New Delhi.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1987. C*onstruction and Calculations of Agricultural Machinery - Vol.II.* Oxonian Press Pvt. Ltd. New Delhi.
- Miu P. 2016. *Combine Harvesters Modeling and Design.* CRC Press, Boca Raton, USA ISBN 13:978-1-4822-8237-5
- Thornhill EW and Matthews GA. 1995. *Pesticide Application Equipment for Use in Agriculture* Vol II. Mechanically powered equipment FAO Rome.

I. Course Title : Management of Farm Power and Machinery System

II. Course Code : FMPE 507

III. Credit Hours : 2+1

IV. Aim of the course

To understand how principles of management are applied to farm machinery systems to make them more effective and profitable.

V. Theory

Unit I

Importance and objectives of farm mechanization in Indian agriculture, its impact, strategies, myths and future needs. Estimation of operating cost of tractors and farm machinery. Management and performance of power, operator, labour. Economic performance of machinery, field capacity, field efficiency and factors affecting field efficiency.

Unit II

Tractor power performance in terms of PTO, drawbar and fuel consumption. Power requirement problems to PTO, DBHP.

Unit III

Selection of farm machinery, size selection, timeliness of operation, optimum width and problem related to its power selection. Reliability of agricultural machinery. Replacement of farm machinery and inventory control of spare parts.

Unit IV

Systems approach to farm machinery management and application of programming techniques to farm machinery selection and scheduling. Network Analysis: Transportation, CPM and PERT, dynamic programming, Markov chain.

VI. Practical

Study of latest development of different agricultural equipment and implements in India and other developing countries. Size selection of agricultural machinery. Experimental determination of field capacity of different farm machines. Study of farm mechanization in relation to crop yield. Determination of optimum machinery system for field crop and machine constraints. To develop computer program for the selection of power and machinery.

VII. Learning outcome

The student will be able to understand how farm machinery is selected and operated to make them economically viable.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Importance and scope of farm mechanization in Indian Agriculture	1
2.	Cost analysis of Farm Machinery and tractor, Breakdown analysis, Inflation.	2
3.	Measurement of power performance (PTO power, drawbar power and fuel consumption) of tractor and power tiller	3
4.	Study of field capacity and field efficiency of different farm machinery and factor affecting them	1
5.	Selection of Farm Machinery size wrt to power source and timeliness of operation	4
6.	Application of programming technique to problem of farm power and machinery selection.	4
7.	Replacement models, spare parts and inventory control	2
8.	Maintenance and scheduling of operations.	2
9.	Network analysis – transportation	2
10.	Network analysis – critical path method, PERT	2
11.	Network analysis – dynamic programming	3
12.	Network analysis – markov chain	3
13.	Linear programming, multivariable system, simplex algorithm. Theory of network.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Introduction to latest development of advanced agricultural equipment's in India	3
2.	Experimental determination of field capacity of different farm machines	3
3.	Case studies on optimum size selection of agricultural machinery	3
4.	Determination of inventory of different farm machines for a farm of size 50 ha as per regional crop rotations	3
5.	To develop computer program regarding selection of farm machinery size and power requirement for a 10, 50 and 100 ha farm size	3
	Total	**15**

X. Suggested Reading

- Carveille LA. 1980. *Selecting Farm Machinery*. Louisiana Cooperative Extn. Services Publication.
- Culpin C. 1996. *Profitable Farm Mechanization.* Lock Wood and Sons, London.
- FAO. 1990. *Agricultural Engineering in Development: Selection of Mechanization Inputs.* FAO, Agri service Bulletin.
- Hunt D. 1979. *Farm Power and Machinery Management.* Iowa State University Press, USA.
- Kapoor VK. 2012. *Operation Research: Concepts, Problems and Solutions.* Sultan Chand and Sons, India.

• Singh S and Verma SR. *Farm Machinery Maintenance and Management*. DIPA, ICAR, KAB-I, New Delhi.

I. Course Title : Principles of Automation and Control

II. Course Code : FMPE 511

III. Credit Hours : 2+1

IV. Aim of the course

To learn the principles behind systems for industrial automation and control especially with respect to electronically implemented systems.

V. Theory

Unit I

Introduction to industrial automation and control: Architecture of industrial automation systems, review of sensors and measurement systems. Introduction to process control: PID control, controller tuning, implementation of PID controllers, special control structures, feed forward and ratio control, predictive control, control of systems with inverse response, cascade control, overriding control, selective control and split range control.

Unit II

Introduction to sequence control: PLCs and relay ladder logic, sequence control, scan cycle, RLL syntax, sequence control structured design approach, advanced RLL programming, the hardware environment, Introduction to CNC machines.

Unit III

Control of machine tools: Analysis of a control loop, introduction to actuators. Flow control valves, hydraulic actuator systems, principles, components and symbols, pumps and motors. Proportional and servo valves. Pneumatic control systems, system components, controllers and integrated control.

Unit IV

Control systems: Electric drives, introduction, energy saving with adjustable speed drives stepper motors, principles, construction and drives. DC motor drives: Introduction to DC-DC converters, adjustable speed drives. Induction motor drives: Introduction, characteristics, adjustable speed drives. Synchronous motor drive-motor principles, adjustable speed and servo drives.

Unit V

Networking of sensors, actuators and controllers, the fieldbus, the fieldbus communication protocol, introduction to production control systems.

VI. Practical

Control system practical: Characteristics of DC servomotor, AC/DC position control system. ON/OFF temperature control system. Step response of second order system, temperature control system using PID level control system. Automation: Introduction to ladder logic, writing logic and implementation in ladder. PLC programming, water level controller using programmable logic controller. Batch process reactor using programmable logic controller. Speed control of AC servo motor using programmable logic controller.

VII. Learning outcome

Understanding of the principles behind implementation of systems for automation and control.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Introduction to industrial automation and control	1
2.	Architecture of industrial automation systems	1
3.	Review of sensors and measurement systems-I	1
4.	Review of sensors and measurement systems-II	1
5.	Introduction to process control	1
6.	PID control, controller tuning and implementation of PID controllers,	1
7.	Special control structures, feed forward and ratio control	1
8.	Predictive control and control of systems with inverse response	1
9.	Cascade control, overriding control	1
10.	Selective control and split range control.	1
11.	Introduction to sequence control	1
12.	PLCs and relay ladder logic, sequence control and scan cycle,	1
13.	RLL syntax, sequence control structured design approach,	1
14.	Advanced RLL programming and the hardware environment,	1
15.	Introduction to CNC machines.	1
16.	Control of machine tools	1
17.	Analysis of a control loop	1
18.	Introduction to actuators.	1
19.	Introduction to flow control valves,	1
20.	Hydraulic actuator systems, principles, components and symbols	1
21.	Introduction to hydraulic pumps and motors	1
22.	Introduction about proportional and servo valves.	1
23.	Pneumatic control systems, system components and controllers and integrated control.	1
24.	Introduction about electric control systems	1
25.	Electric drives, energy saving with adjustable speed drives	1
26.	Stepper motors, principles, construction and drives.	1
27.	DC motor drives: Introduction to DC-DC converters, adjustable speed drives.	1
28.	Induction motor drives: Introduction, characteristics, adjustable speed drives	1
29.	Synchronous motor drive-motor principles, adjustable speed and servo drives.	1
30.	Networking of sensors, actuators and controllers,	1
31.	The field bus, the field bus communication protocol,	1
32.	Introduction to production control systems.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Control system including characteristics of DC servomotor.	2
2.	AC/DC position control system	1
3.	Temperature control system	1
4.	Step response of second order system	2
5.	Temperature control system using PID level control system	1
6.	Introduction to ladder logic, writing logic and implementation in ladder.	2

S.No.	Topic	No of Practicals
7.	PLC programming	2
8.	Water level controller using programmable logic controller	1
9.	Batch process reactor using programmable logic controller	1
10.	Speed control of AC servo motor using programmable logic controller	1
	Total	**14**

X. Suggested Reading

- https://nptel.ac.in/downloads/108105063/
- Manesis S and Nikolakopoulos G. 2018. *Introduction to Industrial Automation. 1st Edition*, CRC Press. Textbook-ISBN 9781498705400-CAT#K24766

I. Course Title : Principles of Hydraulic and Pneumatic Systems

II. Course Code : FMPE 512

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles behind operation of hydraulic and pneumatic systems and their components and design simple hydraulic and pneumatic circuits and select components for the same.

V. Theory

Unit I

Hydraulic power, its advantages, applications, properties of hydraulic fluids, viscosity, bulk modulus, density. Concepts of energy of hydraulic systems, laws of fluid flow.

Unit II

Hydraulic pump and motors, principle, capacity, classifications, working, performance. Design of various types of pumps and motors.

Unit III

Actuators, types, design of linear actuator and rotary actuators. Hydraulic rams, gear motors, piston motors and their performance characteristics. Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves. Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc.

Unit IV

Hydraulic circuit design. Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.

Unit V

Power pack, pneumatic circuits, properties of air. Compressors, types. Design of pneumatic circuits.

VI. Practical

Study of various hydraulic pumps, motors, valves, directional control valves, cylinder piston arrangements, engineering properties of hydraulic fluids, hydraulic system of tractor, power steering system.

VII. Learning outcome

Ability to design simple hydraulic and pneumatic circuits and to select the components for the same. To design hydraulic and pneumatic systems of farm Machinery.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to hydraulic power, its advantages, applications.	1
2.	Properties of hydraulic fluids, viscosity, bulk modulus, density.	2
3.	Concepts of energy of hydraulic systems, laws of fluid flow.	1
4.	Introduction to hydraulic pump and motor.	1
5.	Principle of hydraulic pump and motor, capacity, classifications, working, performance.	1
6.	Design of various types of hydraulic pumps.	1
7.	Design of various types of hydraulic motors.	1
8.	Actuators, types, design of linear actuator and rotary actuators.	3
9.	Hydraulic rams, gear motors, piston, motors and their performance characteristics.	3
10.	Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves.	3
11.	Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc.	4
12.	Hydraulic circuit design.	2
13.	Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.	3
14.	Power pack, pneumatic circuits, components of pneumatic systems, properties of air.	3
15.	Compressors, types. Design of pneumatic circuits.	3
	Total	**32**

IX. List of Practicals

S.No.	Practical	No. of Practicals
1.	Study of various hydraulic pumps	1
2.	Study of various hydraulic motors	1
3.	Study of various hydraulic valves	1
4.	Study of various hydraulic directional control valves	2
5.	Study of various hydraulic cylinder piston arrangements	1
6.	Engineering properties of hydraulic fluids	2
7.	Study of hydraulic system of tractor	1
8.	Study of power steering system	1
9.	Study of power pack, pneumatic circuits, components of pneumatic systems	2
10.	Practical examination	1
	Total	**13**

X. Suggested Reading

- Anthony E. 2003. *Fluid Power with Applications*. Pearsons Education (Singapore) Pvt. Ltd.
- Krutz G. 1984. *Design of Agricultural Machines*. John Wiley and Sons.
- Majumdar S R. 2003. *Oil Hydraulics Systems: Principles and Maintenance*. Tata McGraw Hill Co.
- Merritt HE. 1991. *Hydraulic Control System*. John Wiley and Sons Inc.

I. Course Title : Applied Instrumentation in Farm Machinery

II. Course Code : FMPE 513

III. Credit Hours : 2+1

IV. Aim of the course

To understand the operation of instruments that is used in design and evaluation of farm machinery and their application.

V. Theory

Unit I

Strain gauges, types and applications in two and three dimensional force measurement in farm machinery. Various methods of determining strain/stresses experimentally. Design, selection and analysis of strain gauges.

Unit II

Introduction to transducers (sensors). Active and passive transducers, analog and digital modes, null and deflection methods. Performance characteristics of instruments including static and dynamic characteristics.

Unit III

Load cells, torque meters, flow meters types and principles of working. Devices for measurement of temperature, relative humidity, pressure, sound, vibration, displacement (LVDT) etc. Recording devices and their types. Measuring instruments for calorific value of solid, liquid, and gaseous fuels.

Unit IV

Basic signal conditioning devices, data acquisition system. Micro computers for measurement and data acquisition. Data storage and their application including wireless communication. Application of sensors in farm machinery and power: Tractor and selected farm machinery.

VI. Practical

Calibration of load cells, torque meters, flow meters etc. Experiment on LVDT, strain gauge transducer, speed measurement using optical devices, vibration measurement, making of thermocouples etc, application of sensors in farm machinery like wheel hand hoe, etc.

VII. Learning outcome

The student will be able to select and implement suitable systems for measurement of different parameters like force, torque, speed and pressure etc, that are used in design and evaluation of Farm machinery.

VIII. Lecture schedule

S.No.	Lecture	No. of Lectures
	Unit I	
1.	Strain gauges and its types; working principle, wheatstone bridge measurement, commercial available strain gauges	2
2.	Applications of strain gauges in two and three dimensional force measurement in farm machinery	2
3.	Various methods of determining strain/stresses experimentally.	2
4.	Design, selection and analysis of strain gauges.	2

S.No.	Topic	No of Lectures
	Unit II	
5.	Introduction to transducers (sensors).	1
6.	Active and passive transducers, analog and digital modes, null and deflection methods.	2
7.	Performance characteristics of instruments including static and dynamic characteristics.	2
	Unit III	
8.	Load cells, torque meters, flow meters types and principles of working	3
9.	Devices for measurement of temperature and relative humidity	2
10.	Devices for measurement of pressure and sound	2
11.	Devices for measurement of vibration and displacement (LVDT)	2
12.	Recording devices and their types	1
13.	Measuring instruments for calorific value of solid, liquid, and gaseous fuels	2
	Unit IV	
14.	Basic signal conditioning devices and data acquisition system	1
15.	Micro computers for measurement and data acquisition; general purpose microcontrollers and microprocessors	2
16.	Data storage and their application including wireless communication	2
17.	Application of sensors in farm machinery and power: Tractor and selected farm machinery	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Calibration of Load Cells	2
2.	Calibration of Torque Meters	1
3.	Calibration of Flow Meters	1
4.	Experiment on LVDT.	2
5.	Experiment on Strain Gauge	1
6.	Speed measurement using optical devices	2
7.	Vibration Measurement	2
8.	Making of Thermocouples	2
9.	Application of Sensors in Farm Machinery like wheel hand hoe etc.	3
	Total	**16**

X. Suggested Reading

- Ambrosius EE. 1966. *Mechanical Measurement and Instruments*. The Ronald Press Company.
- Doeblin EO. 2004. *Measurement System- Application and Design*. Tata McGrawHill
- Nakra BC and Choudhary KK. 1985. *Instrumentation, Measurement and Analysis*.2nd Edition Tata McGraw Hill.
- Nachtigal CL (Editor). 1990. *Instrumentation and Control. Fundamentals and Application*. Wiley Series in Mechanical Engineering.
- Oliver FJ. 1971. *Practical Instrumentation Transducers*. Hayden book company Inc.

I. Course Title : Systems Simulation and Computer Aided Problem Solving in Engineering

II. Course Code : FMPE 514

III. Credit Hours : 1+1

IV. Aim of the course

To give the student orientation in simulation of continuous and discrete systems especially using computer programme and software.

V. Theory

Unit I

Mathematical modeling and engineering problem solving: Conservation laws and engineering. Computers and software: Software development, structured programming, logical representation. Modular programming. Approximation: Round off errors, truncation errors, significant figures, accuracy and precision.

Unit II

Nature of simulation: Systems models and simulation, discreet event simulation, time advance mechanisms, components of discrete event simulation model, simulation of single server queuing system. Program organization and logic, development of algorithm. Simulation of an inventory system.

Unit III

Solving roots of equation using computers. Application in: Ideal and non-ideal gas laws, open channel flows, design of an electric circuit, vibration analysis. Solving linear algebraic equation on computers: Naïve Gauss Elimination, techniques for improving solutions, LU decomposition and matrix inversion. Application in: Steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems.

Unit IV

Optimization techniques. Search techniques: Golden Sections, quadratic interpolation. Application: Optimum design of tank, least cost treatment of waste water, power transfer for circuits. Solving ordinary differential equation on computers: Modeling engineering systems with ordinary differential equation, solution techniques using computers.

VI. Practical

Comparison of analytical and numerical solutions using Spread sheet. Generation of random variables. Generation of discreet and continuous random variate-coding. Implementation of single server queue on computer. Exercises with software packages for roots of equation: Solving linear algebraic equation, curve fitting and optimization. Solving simultaneous equation through Gauss elimination, solving steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems on computers. Application of ordinary differential equation to solve mixed reactor problems, predator prey models and chaos.

VII. Learning outcome

Ability to analyze problems from a systems perspective and apply the principles to simulation of continuous and discrete engineering systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to mathematical modeling in engineering problem solving, comparison of analytical and numerical approaches.	1
2.	Conservation laws applied to engineering, modeling simple system	1
3.	Computer modeling, computing environments software development process.	1
4.	Modular design, top down design, structured programming, – algorithm design.	1
5.	Program composition, quality control- testing and documentation software strategy.	1
6.	Approximation- round off errors- accuracy and precision – definitions, number system in the computer- truncation errors.	1
7.	Nature of simulation, systems models and simulation.	1
8.	Discreet event simulation, time advance mechanisms, components of discreet event simulation model.	1
9.	Principles of simulation of singular server queuing system.	1
10.	Programme organization and logic for single server queuing system.	1
11.	Development of algorithm, single server queuing system.	1
12.	Solving roots of equation in computers, graphical method.	1
13.	Developing algorithm for bisection method, false position method.	1
14.	Application of roots of equation to gas laws, open channel flows.	1
15.	Application of roots of equation to electric circuits, vibration analysis.	1
16.	Solving linear algebraic equation in engineering practices.	1
17.	Developing algorithm for Gaussian elimination.	1
18.	Pitfalls of elimination methods and remedies.	1
19.	Overview of LU decomposition.	1
20.	LU decomposition algorithms, calculating inverse of matrix.	1
21.	Application of linear algebraic equation to statically determinate truss.	1
22.	Application of linear algebraic equation to Circuit analysis.	1
23.	Application of linear algebraic equation to spring mass system.	1
24.	Introduction to optimization in engineering, Formulation of Problems.	1
25.	One dimensional unconstrained optimization, development of algorithm for golden sections.	1
26.	One dimensional unconstrained optimization quadratic interpolation.	1
27.	Application of optimization to design of tank.	1
28.	Application of optimization to waste water treatment problem.	1
29.	Application of optimization to power transfer circuits.	1
30.	Formulating engineering problems using ordinary differential equation.	1
31.	Solving ordinary differential equation using computers, Euler's method.	1
32.	Solving ordinary differential equation using modeling engineering systems, computers, Runge-kutta method.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Exercises in developing simple programmes in C.	1
2.	Demonstration of solutions using analytical and numerical methods for simple problems.	1
3.	Development of programmes for generation of random variables.	1
4.	Writing programme for generating random variates.	1

S.No.	Topic	No of Practicals
5.	Writing programme for event advance mechanism of single server queuing system.	1
6.	Writing programme for arrival module of single server queuing system.	1
7.	Writing programme for departure module of single server queuing system and statistical performance.	1
8.	Writing programme for solution of roots of equation.	1
9.	Solving simple engineering problems using roots of equation.	1
10.	Development of algorithm for Gaussian elimination.	1
11.	Application of Gaussian elimination to mass balance problems and statically determinate truss.	1
12.	Application of Gaussian elimination to analysis of electrical circuits.	1
13.	Development of algorithm for Golden Sections and application.	1
14.	Application of optimization technique to design of tank.	1
15.	Application of optimization technique to waste water treatment.	1
16.	Predator prey models and chaos.	1
	Total	**16**

X. Suggested Reading

- Balagurusamy E. 2000. *Numerical Methods.*Tata McGraw Hill Publishing Company limited, New Delhi.
- Chapra SC and Canale RP. 1994. *Introduction to Computing for Engineers*. 2nd Edition McGraw Hill International Edition, New York.
- Dent JB and Blackie MJ. 1979. *System Simulation in Agriculture.* Applied Science Publishers Ltd., London.
- Law AM. 2015. *Simulation Modeling and Analysis.* McGraw Hill International Edition, New York.
- Schilling RJ and Harries SL. 2002. *Applied Numerical Methods for Engineers Using MATLAB and C.*Thomson Asia Pvt. Ltd. Singapore.
- Veerarajan T and Ramachnadran T. 2004. *Numerical Methods with Programmes in C and C++*. Tata McGraw Hill Publishing company limited, New Delhi.

I. Course Title : Computer Aided Design of Machinery

II. Course Code : FMPE 515

III. Credit Hours : 0+2

IV. Aim of the course

To learn the practice of designing components and assemblies based on computer aided drafting technique.

V. Practical

Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles. Drawing and dimensioning simple 2D drawings, keyboard shortcuts. Working with blocks, block commands. Exercise in simple assembly in orthographic. Exercise in measuring and drawing simple farm machinery parts.
Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window. Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and

database management system. Working with feature manager and customizing the environment. Planning and capturing design intent. Documentation of design. Using design journal and design binder. Preliminary design review and layout.
Practice in drawing 2D sketches with sketcher and modifying sketch entries. Adding Reference geometry: Planes and axes. Adding relations and working with relations. Dimensioning a sketch. Exercises.
Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates. Organizing the assembly by using layouts.
Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.
Case studies: Measuring and drawing assemblies of farm implements and their components.

VI. Learning outcome

The student will be able to conceptualize spatial concepts and design components and assemblies of Farm machinery and make graphic models using commercial CAD software like Solid Works, Catia and AutoCAD.

VII. List of Practicals

S.No.	Topic	No of Practicals
1.	Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles.	2
2.	Drawing and dimensioning simple 2D drawings, keyboard shortcuts.	1
3.	Working with blocks, block commands. Exercise in simple assembly in orthographic.	1
4.	Exercise in measuring and drawing simple farm machinery parts.	2
5.	Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window.	2
6.	Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and database management system.	2
7.	Working with feature manager and customizing the environment. Planning and capturing design intent.	2
8.	Documentation of design. Using design journal and design binder. Preliminary design review and layout.	1
9.	Practice in drawing 2D sketches with sketcher and modifying sketch entries.	2
10.	Adding Reference geometry: Planes and axes. Adding relations and working with relations. Dimensioning a sketch. Exercises.	2
11.	Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design.	2
12.	Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates.	2
13.	Organizing the assembly by using layouts.	1
14.	Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.	2
15.	Case studies: Measuring and drawing assemblies of farm implements and their components.	5
	Total	**32**

VIII. Suggested Reading

- Jankowski G and Doyle R. 2007. *SolidWorks® For Dummies®*, 2nd Edition, Published by Wiley Publishing, Inc. ISBN: 978-0-470-12978-4
- Shih R H. 2014. *AutoCAD 2014 Tutorial-First Level: 2D Fundamentals*. SDC Publications

I. Course Title : Advanced Manufacturing Technologies

II. Course Code : FMPE 516

III. Credit Hours : 2+1

IV. Aim of the course

To learn the modern manufacturing techniques and their application to manufacture of different components and assemblies.

V. Theory

Unit I

Material and their characteristics, structure and properties of materials, wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites. Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves, heat treatments, surface treatment: Roughness and finishing.

Unit II

Measurement and quality assurance: Quality control, tolerance, limits and clearance. Automated 3-D coordinate measurements. Advance casting processes and powder metallurgy. Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.

Unit III

Workshop practices applied in prototype production, jigs and fixtures. Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes. Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM), Abrasive jet machining (AJM), and Wire-electro-discharge machining (EDM).

Unit IV

Joining processes: Gas flame processes, arc processes, brazing and soldering, adhesive and bonding.

Unit V

Numerical control: Command system codes, programme, cutter position X and Y, incremental movements, linear contouring, Z movements and commands. Manufacturing systems and automation. Robotics and robot arms. 3-D printing. Integrated manufacturing production system.

Practical

Identification of material and their application. Study of heat treatment processes and their suitability with respect to materials. Tool and equipments for measurements: Tolerance limits, clearance and surface finish. Site visits for study of advanced manufacturing techniques. Case studies.

VI. Learning outcome

The students will be able to select suitable manufacturing technique to fabricate different components used in Farm machinery.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Material and their characteristics.	1
2.	Structure and properties of materials wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites.	2
3.	Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves.	1
4.	Heat treatments, surface treatment: Roughness and finishing.	2
5.	Measurement and quality assurance: Quality control, tolerance, limits and clearance.	1
6.	Automated 3-D coordinate measurements and practice.	2
7.	Advance casting processes and powder metallurgy.	1
8.	Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.	2
9.	Forging processes, extrusion and drawing.	1
10.	Workshop practices applied in prototype production, jigs and fixtures.	1
11.	Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes.	2
12.	Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM).	2
13.	Electric discharge machining (EDM), laser beam machining (LBM).	1
14.	Abrasive jet machining (AJM), and wire-electro-discharge machining (EDM).	2
15.	Joining processes: Gas flame processes, arc processes.	2
16.	Brazing and soldering processes.	1
17.	Adhesive and bonding processes.	1
18.	Numerical control: Command system codes.	1
19.	NC Programme, Robotics and robot arms.	2
20.	Cutter position X and Y, incremental movements, linear contouring, Z movements and commands.	1
21.	Manufacturing systems and automation.	1
22.	3-D printing and integrated manufacturing production system.	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Identification of material and their application.	2
2.	Study of heat treatment processes and their suitability with respect to materials.	5
3.	Tool and equipments for measurements: Tolerance limits, clearance and surface finish.	4
4.	Site visits for study of advanced manufacturing techniques.	2
5.	Case studies.	2
6.	Practical examination	1
	Total	**16**

IX. Suggested Reading

- Begeman ML, Ostwald PF and Amstead BH. 1979. *Manufacturing Processes: SI Version*. John Wiley and Sons. 7th Edition.
- Chapman PAJ. 1996. *Workshop Technology*, Part III. CBS Publisher and distributors Pvt

Ltd. 3rd Edition international Edition.
- Gupta RB. 2017. *Production Technology*, Vol I - Production Process. Satya Prakashan, New Delhi.
- Hoyos L. 2010. *Fundamentals of Tool Design*. American Society of Tool and Manufacturer Engineers. Sixth Edition.
- Jain RK. 1994. *Production Technology: A Textbook for Engineering Students*. Khanna Publishers, New Delhi.
- Polukin P, Gringerg B, Kantenik S, Zhadan V and Vasilye D. *Metal Process Engineering*, MIR Publishers Moscow.

I. Course Title : Machinery for Precision Agriculture

II. Course Code : FMPE 517

III. Credit Hours : 2+1

IV. Aim of the course

To learn the principles behind precision agriculture and the systems for implanting the same.

V. Theory

Unit I

Importance of precision agriculture. Mapping in farming for decision making. Geographical concepts of PA.Understanding and identifying variability

Unit II

Geographical Position System (GPS) Basics (Space Segment, Receiver Segment, Control Segment), Error and correction, Function and usage of GPS. Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions. IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Remote sensing Aerial and satellite imagery. Above ground (non-contact) sensors.

Unit III

Data analysis, concepts of data analysis, resolution, Surface analysis. Analysis application interpretive products (map, charts, application map etc).

Unit IV

Electronics and Control Systems for Variable rate applications, Precision Variable Equipment, Tractor-Implement interface technology, Environmental Implications of Precision Agriculture.

Unit V

Goals based on end results of Precision Agriculture, Recordkeeping, Spatial Analysis, Variable Rate Application, Reducing of negative environmental impact, Crop/ technology cost optimization. Economic of precision agriculture and determining equipment and software, review of Cost/Benefit of Precision Agriculture, System vs. Parcels. Making a selection.

VI. Practical

Calculation of the benefits of Data and Mapping, Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints, Configuring a GPS System. Defining area of field for prescriptive treatment. Making the Grid, The Grid Sampling Process, generation of yield maps, Thematic or Spatial Resolution, Yield

Map Example, Surface Analysis in Arc-View.

VII. Learning outcome

Knowledge about the principles guiding the concept of precision agriculture and Farm Machinery and equipment systems that make muse of this principle.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Introduction to precision agriculture, its importance and applications	1
2.	Mapping in farming for decision making and geographical concepts of PA.	2
3.	Understanding and identifying variability	1
4.	Introduction to Geographical Position System (GPS). Function and usage of GPS	2
5.	Basics of GPS (Space Segment, Receiver Segment, Control Segment), Error and correction	2
6.	Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions.	2
7.	Remote sensing including aerial and satellite imagery	2
8.	IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Above ground (non-contact) sensors	2
9.	Data analysis, concepts of data analysis	3
10.	Surface analysis. Analysis application interpretive products (map, charts, application map etc)	2
11.	Precision Variable Equipment	2
12.	Electronics and Control Systems for variable rate applications	2
13.	Tractor-Implement interface technology, Environmental Implications of Precision Agriculture	2
14.	Recordkeeping, Spatial Analysis	2
15.	Rate Application, reducing of negative environmental impact, Crop/technology cost optimization	2
16.	Economic of precision agriculture and determining equipment	2
17.	Review of Cost/Benefit of Precision Agriculture, Making a selection	2
	Total	**33**

IX. Practical Schedule

S.No.	Topic	No of Practicals
1.	Calculation of the benefits of data and mapping	1
2.	Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints	2
3.	Configuring a GPS System	1
4.	Defining area of field for prescriptive treatment	1
5.	Making the grid and grid sampling process	2
6.	Collection of tractor-implement interface data	1
7.	Generation of yield maps	2
8.	Example of spatial and temporal variability and resolution	1
9.	Surface Analysis using software like Arc-View	2
10.	Economic of precision agriculture and determining equipment	2
11.	Cost/Benefit of Precision Agriculture for making a optimized selection	2
	Total	**17**

X. Suggested Reading

- Clay SA, Clay DE and Bruggeman SA. 2017. *Practical Mathematics for Precision Farming* American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Henten EJV, Goense D and Lokhorst C. 2009. *Precision Agriculture*. Wageningen Academic Publishers.
- Ram T, Lohan SK, Singh R and Singh P. 2014. *Precision Farming: A New Approach*. Astral International Pvt. Ltd., New Delhi, ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).
- Shannon DK, Clay DE and Kitchen NR (editors). 2018. *Precision Agriculture Basics* American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Singh AK and Chopra UK. 2007. Geoinformatics Applications in Agriculture. New India Publishing Agency, PritamPura, New Delhi.

I. Course Title : Machinery for Horticulture and Protected Agriculture

II. Course Code : FMPE 518

III. Credit Hours : 2+0

IV. Aim of the course

To learn about the different machinery used in cultivation of vegetable crops, orchard crops and also in protected agriculture.

V. Theory

Unit I

Vegetable cultivation, nursery machinery, tray seeders, grafting machines, vegetable trans-planters. Machinery for planting crops on raised beds, mulch laying and planting machines. Harvesting of vegetable crops: Harvesting platforms and pickers.

Unit II

Machinery for orchard crops: Pit diggers, inter-cultivators and basin forming equipment for orchards. Machinery for transplanting of trees. Harvesters for fruit crops: Shaker harvesters, types and principle of operation. Elevated platforms for orchard management and harvesting. Pruning machines.

Unit III

Machinery for orchards, vineyard machinery spraying machines, inter-cultivation machines. High clearance machines and special purpose machinery for crops on trellis. Machinery for special crops: Tea leaf harvesters, pruners and secateurs.

Unit IV

Machinery for lawn and garden: Grass cutters, special machinery for turf maintenance. Turf aerators and lime applicators.

Unit V

Protected agriculture: Principles, mechanical systems of greenhouse, ventilation systems, shading system, water fogging system, irrigation system, sensors, electrical and electronic system. Intelligent Control system for greenhouses. Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines. Robotic grafting machines. Weeding and thinning equipment. Crop protection and harvest under protected agriculture.

VI. Learning outcome

Knowledge about different principles of mechanizing cultivation of horticultural crops and in protected agriculture.

VII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	History of vegetable cultivation in India and scope of mechanization in Horticulture	1
2.	Methods of Nursery propagation techniques and machinery for nursery and tray seeders	1
3.	Machinery for field preparation for vegetables (Disc harrows, Disc plough, offset rotavator, sub soiler, bed makers)	1
4.	Principles of mulch laying and planting machines. Types of vegetable transplanters and their construction and working	1
5.	Working and construction of subsurface drip laying machine. Types of planters for vegetable crops and its working	1
6.	Principles of Pneumatic vegetable seeders and its working. Machinery for harvesting of vegetable crops like root crop harvester, its construction and working	1
7.	Types of vegetable extraction machine, its working and construction	1
8.	Types of pickers, their construction and working	1
9.	Construction and working of different types of post hole diggers	1
10.	Types of tractors and their uses in orchards	1
11.	Types of inter cultivators and its construction and working.	1
12.	Types of brush cutters and its working	1
13.	Types of basin forming equipment for orchards. Machinery for transplanting of trees and their construction and working	1
14.	Types of elevated platforms for orchard management. Types of Tree Pruners and principles and its working and construction	1
15.	Types of fruit pluckers and its working and construction	1
16.	Principles and working and construction of shaker harvesters	1
17.	Types of vineyard machinery and its working and construction	1
18.	Types of spraying machines and its working and construction. High clearance machines and special purpose machinery for crops on trellis.	1
19.	Types of orchard sprayers, its working and construction	1
20.	Types of Tea leaf harvesters, pruners and secateurs and its working and Construction	1
21.	Special purpose machinery for crops on trellis	1
22.	Types of lawn and garden mowers and its working.	1
23.	Studies on special machinery for turf maintenance working and construction of Turf aerators and lime applicators	1
24.	Introduction to protected agriculture. Principles of protected agriculture	1
25.	Greenhouses - Mechanical systems, ventilation systems, shading system, water fogging system and irrigation system.	2
26.	Sensors, electrical and electronic system. Intelligent Control system for greenhouses	1
27.	Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines	1
28.	Robotic grafting machines. Weeding and thinning equipment	1
29.	Crop protection and harvest under protected agriculture	1
	Total	**30**

VIII. Suggested Reading

- Bell B and Cousins S. 1997. *Machinery for Horticulture.* Old Pond Publishing Ltd ISBN-10: 0852363699,ISBN-13: 978-0852363690
- *Good Agricultural Practices for Greenhouse Vegetable Production in the South East European countries* FAO Rome 2017.
- Ponce P, Molina A, Cepeda P, Lugo E and MacCleery B. 2014. *Greenhouse Design and Control.* CRC Press, ISBN 9781138026292 - CAT K23481, 1st Edition.

Course Title with Credit Load
Ph.D. in Farm Machinery and Power Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
FMPE 601*	Advances in Farm Machinery and Power Engineering	2+1
FMPE 602	Advances in Machinery for Precision Agriculture	2+1
FMPE 603	Energy Conservation and Management in Production Agriculture	3+0
FMPE 604	Mechanics of Tillage in Relation to Soil and Crop	2+1
FMPE 611	Mechanics of Traction and its Application	2+1
FMPE 612*	Farm Machinery Management and Systems Engineering	2+1
FMPE 613	Machinery for Special Farm Operations	2+1
FMPE 614	Ergonomics in Working Environment	2+1
	Total	17+7

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
REE 615	Energy Planning Management and Economics	3+0
REE 602	Thermo-Chemical Conversion of Biomass	2+1
ME-507	Fatigue Design	2+1
ME-515	Computer Aided Design	2+1
CSE 506	Digital Image Processing	2+1

Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Course has been made compulsory by UGC for PhD students. Course Code and its detailed course outline to be adopted in toto as recommended by UGC.

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
FMPE 691	Doctoral Seminar-I	0+1
FMPE 692	Doctoral Seminar-II	0+1
FMPE 699	Doctoral Research	0+75

Course Contents
Ph.D. in Farm Machinery and Power Engineering

I. Course Title : Advances in Farm Machinery and Power Engineering

II. Course Code : FMPE 601

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize the students about modern developments in construction, design and analysis of farm machinery systems as applied in different areas of agriculture.

V. Theory

Unit I

Advances in mechanization as applicable to Indian context. Future outlook for improving agricultural productivity and reducing cost. Mechanization: Review of the applications of some of the advanced mechanization technologies and constraints in adaptability. Levels of mechanization and transition between levels.

Unit II

Sustainable mechanization management: Management of compaction of agricultural fields. Strategies to develop machinery and systems that reduce compaction. Concept of Controlled Traffic Farming (CTF) systems. Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability.

Unit III

Optimization of production processes to minimize energy loss in agriculture. The rationale for the use of photovoltaic systems in farming. The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.

Unit IV

board sensors, computing hardware, algorithms and software. Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.

Unit V

Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products. Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters. Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners.

VI. Practical

Case studies and presentations on: Mechanization in India-analysis of machinery data- mechanization index and relation between productivity and mechanization. Levels of mechanization in different crops. Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery. Planning use of multiple machinery-sugarcane harvesting system. Measurement of soil compaction due to heavy machinery using cone penetrometer. Machine vision system design–case studies. Challenges in development of robotic machinery in agricultural operations-case studies.

VII. Learning outcome

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems, and managing crop productivity with poor quality of waters without deteriorating soil conditions.

VIII. Lecture schedule

S.No.	Topic	No. of Lectures
1.	Advances in mechanization as applicable to Indian context.	2
2.	Mechanization in large scale agricultural fields	1
3.	Mechanization in small scale agricultural fields	1
4.	Future outlook for improving agricultural productivity and reducing cost.	1
5.	Requirements of energy and fuels for machinery operations	2
6.	Case studies of the applications of some of the advanced mechanization technologies and constraints in adaptability.	2
7.	Case studies of Technology transfer mechanisms in India	1
8.	Levels of mechanization and transition between levels.	1
9.	Sustainable mechanization management.	1
10.	Management of compaction of agricultural fields.	1
11.	Strategies to develop machinery and systems that reduce compaction.	1
12.	Concept of Controlled Traffic Farming (CTF) systems.	1
13.	Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability.	2
14.	Optimization of production processes to minimize energy loss in agriculture.	2
15.	The rationale for the use of photovoltaic systems in farming.	1
16.	The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.	2
17.	Machine vision system-hardware and software technologies, and machine learning and image analysis techniques.	1
18.	Unmanned agricultural ground vehicles (UAGVs)	1
19.	UAGVs instrumented mobile platform, on board sensors, computing hardware, algorithms and software.	1
20.	Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.	2
21.	Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products.	1
22.	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters.	2
23.	Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners.	1
24.	Silage and forage conditioners.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Case studies of Mechanization in India	1
2.	Case studies of Mechanization in SAARC countries	1
3.	To find mechanization index.	1
4.	Relation between productivity and mechanization in India and Punjab.	1
5.	Relation between productivity and mechanization in developed countries.	1
6.	Levels of mechanization in cereal crops like paddy, Wheat etc.	1
7.	Levels of mechanization in Horticulture crops	1
8.	Levels of mechanization in cotton crop and pulses and oilseed crops	1
9.	Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery.	1
10.	Planning use of multiple machinery-sugarcane harvesting system.	1
11.	Measurement of soil compaction due to heavy machinery using cone penetrometer.	1
12.	Machine vision system design–case studies.	1
13.	Machine vision system design–case studies.	1
14.	Unmanned agricultural ground vehicles (UAGVs) for different applications like spraying, imaging etc.	1
15.	Challenges in development of robotic machinery in agricultural operations-case studies.	1
16.	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters.	1
	Total	**16**

X. Suggested Reading

- Chen G. (ed). 2018. *Advances in Agricultural Machinery and Technologies*. Boca Raton: CRC Press, https://doi.org/10.1201/9781351132398.
- Edwards GTC, Hinge G, Skou-Nielsen N and Villa-Henriksen A. 2017. *Route Planning Evaluation of a Prototype Optimized in Field Route Planner for Neutral Material Flow Agricultural Operations*. *Biosystems Engineering* **153**: 149-157. https://www.sciencedirect.com/science/article/pii/S1537511016303713.
- Seyyedhasani H. 2017. *Using the Vehicle Routing Problem* (*VRP*) *to Provide Logistic Solutions in Agriculture*. Ph.D. dissertation. University of Kentucky, Kentucky, USA. https://www. researchgate.net/publication/264791116_Advances in Agricultural Machinery Management A Review.
- Srivastava A K. 2006. *Engineering Principles of Agricultural Machines*. 2nd Edition American Society of Agricultural and Biological Engineers (ISBN) 1-892769-50-6 ASAE Publication 801M0206.

I. Course Title : Advances in Machinery for Precision Agriculture

II. Course Code : FMPE 602

III. Credit Hours : 2+1

IV. Aim of the course

Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture.

V. Theory

Unit I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

Unit II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

Unit III

Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

Unit IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

VI. Practical

Simple programming for automating precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates cost of crop production.

VII. Learning outcome

Ability to understand design and operate PA systems.

VIII. Lecture schedule

S.No.	Topic	No. of Lectures
1.	Introduction about Global navigation satellite system (GNNS	1
2.	Satellite ranging including accuracy, standards etc.	1
3.	Differential GNSS Receiver, RTK etc.	1
4.	Components of GIS, data layers, map component,	1
5.	Attribute table component, function of a GIS, resolution.	1
6.	Data formats: Vector or raster.	1
7.	GIS for precision farming, data analysis, field calculator, convert to grid,	1
8.	Interpolation, reclassification, image classification, band math and interpretation of analysis.	1

S.No.	Topic	No. of Lectures
9.	Farm management information systems, and crop intelligence.	1
10.	Introduction about Yield monitors and its components	1
11.	Mass flow and impact plate sensors, measuring volume with a photoelectric sensor. Lecture 12: Microwave radiation and Gamma rays to estimate volume,	1
12.	Different types of grain moisture sens	1
13.	Fan speed sensor, elevator speed sensor, header position, yield monitor data,	1
14.	Yield monitors for non-grain crops	1
15.	Sources of soil variability, general soil sampling basics, systematic variability Lecture 17: Selecting a soil sampling strategy.	1
16.	Proximal and remote sensing based soil sensors	1
17.	Electromagnetic based sensors for soil electrical conductivity measurement	1
18.	Sensing mechanical impedance based sensors for soil compaction	1
19.	Spectroscopy for determination of soil properties	1
20.	Introduction about proximal plant sensing systems	1
21.	Remote sensing platforms: Aircraft or satellite.	1
22.	Type of plant sensors: Imaging or non imaging, active or passive.	1
23.	Use of reflected or emitted energy for vegetation detection	1
24.	The spectral signature of vegetation, vegetation indices, application to agriculture	1
25.	Sensing system for nutrient management,	1
26.	Crops canopy reflectance and fluorescence.	1
27.	Machine vision thermal sensors, mechanical sensors, acoustic sensors	1
28.	Sensors for weed detection and management	1
29.	Sensing Techniques for disease and insect management,	1
30.	Different type of sensors/devices for water management.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Simple programming for automating precision farming calculations	1
2.	Mathematics of longitude and latitude	1
3.	Spatial and temporal statistics using GIS	1
4.	Soil sampling strategies, understanding and results for precision farming	1
5.	Creation of management zones	1
6.	Measurement of yield variability in the field	1
7.	Measurement of soil Compaction in the field	1
8.	Measurement of soil EC in the field	1
9.	Measurement of soil pH in the field	1
10.	Developing and understanding prescriptive soil nutrient maps	1
11.	Measurement of essential plant nutrients in the field	1
12.	Fertilizer sources, and application rates calculations	1
13.	Deriving and using an equation to calculate economic optimum fertilizer	1
14.	Calculation of optimum seeding rates for optimized returns	1
15.	Cost of crop production using precision technologies.	1
	Total	**15**

X. Suggested Reading

- Clay DE, Clay SA and Bruggeman SA. 2017. *Practical Mathematics for Precision Farming*. American Society of Agronomy, Madison, WI, USA.
- Ram T, Lohan SK, Singh R and Singh P. 2014. *Precision Farming: A New approach*. Astral International Pvt. Ltd., New Delhi, India. ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).
- Shannon DK, Clay DE and Kitchen NR Newell. 2018. *Precision Agriculture Basics*. American Society of Agronomy, Inc., Madison, WI, USA.
- Singh AK and Chopra UK. 2007. *Geoinformatics Applications in Agriculture*. New India Publishing Agency, New Delhi, India.
- Van-Henten EJ, Goense D and Lokhorst C. (ed). 2009. *Precision Agriculture*. Wageningen Academic Publishers, Wageningen, Netherlands.

I. Course Title : Energy Conservation and Management in Production Agriculture

II. Course Code : FMPE 603

III. Credit Hours : 3+0

IV. Aim of the course

Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture.

V. Theory

Unit I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

Unit II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

Unit III

Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

Unit IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

VI. Practical

Simple programming for automating precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates cost of crop production.

VII. Learning outcome

Ability to understand design and operate PA systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction	1
2.	Classification of energy	2
3.	Energy coefficients	2
4.	Energy requirements for wheat production	2
5.	Energy requirements for paddy production	2
6.	Energy requirements for maize production	2
7.	Energy requirements for cotton production	2
8.	Energy requirements for oil seeds production	1
9.	Energy requirements for pulse production	2
10.	Energy requirements for production of other crops	2
11.	Energy requirements for vegetable production	2
12.	Energy requirements for fruit production	1
13.	Energy requirements for fish production	1
14.	Energy requirements for meat and milk production	2
15.	Limits of energy conservation	1
16.	Energy planning, management and forecasting in agriculture	3
17.	Design of integrated energy supply system	2
18.	Energy conservation and returns	2
19.	Assessment of energy conservation technology	2
20.	Case studies on application of various techniques of energy conservation and management	2
	Total	**36**

IX. Suggested Reading

- Mittal JP, Panesar BS, Singh S, Singh CP and Mannan KD. 1987. *Energy in Production Agriculture and Food Processing*. ISAE and School of Energy Studies for Agriculture, PAU Ludhiana, ISAE Publication.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press. Boca Rotan, USA.
- Singh S and Singh RS. 2014. *Energy for Production Agriculture*. DKMA, ICAR, New Delhi, India.

I. Course Title : Mechanics of Tillage in Relation to Soil and Crop

II. Course Code : FMPE 604

III. Credit Hours : 2+1

IV. Aim of the course

To have deeper understanding of the tillage process in terms of crop requirement, soil characteristics and machinery function.

V. Theory

Unit I

Soil condition and soil strength determining factors. General aspects of mechanical behavior of soil elements. Soil compaction, conditions for its occurrence. Methods of estimation of soil compaction by experimental stress distribution. Concept of soil distortion, deformation at constant volume. Expansion of soil at breaking.

Unit II

Occurrence of soil breaking fundamentals. Measures of resistance against breaking. Shear failure and Coulomb's law. Compaction v/s shear failure. Tensile failure of soil, idealized brittle failure, Griffith's Model. Loading rate and repeated loading effects. Draft calculation using mechanism of rigid soil bodies.

Unit III

Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening. Structure of seed bed. Soil properties, properties affected by tillage and those not affected by tillage. Soil compaction, formation of clods and dust. Effect of tillage on erosion and water logging. Impact of climate factors on soil. Tillage requirement for various types of soils.

Unit IV

Tillage operations for special tasks. Preparation of soil for cropping and stubble management. Primary and secondary tillage. Ploughing and its effect on soil. Disc tillage: Appropriate conditions and effect. Requirement of seed bed and techniques of creating proper seed bed. Quality of sowing and sowing methods. Modern trends and objectives of soil tillage.

Unit V

Plough bodies: Generalized representation, intake main flow and output process. Main flow under different surface curvatures. Kinetic aspects of plough bodies with different shapes. Draft of plough bodies as affected by moisture, speed and attachments.

VI. Practical

Characterization of soil condition before and after tillage. Cone penetrometer resistance, bulk density, moisture content. Measurement of forces on tillage tools under soil bin condition/ field condition. Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing. Measurement of energy required for soil breakup by different methods. Field study of crop root development in relation to soil compaction and hard pan. Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed. Field evaluation of plant establishment in relation to planting parameters.

VII. Learning outcome

Ability to design tillage machinery based on engineering principles as applied tom tillage science.

VIII. Lecture Schedule

S.No.	Topic	Lecture No
	Unit I	
1.	Soil condition and soil strength determining factors.	**1**
2.	General aspects of mechanical behavior of soil elements.	**1**
3.	Soil compaction, conditions for its occurrence.	**2**
4.	Methods of estimation of soil compaction by experimental stress distribution.	1
5.	Concept of soil distortion, deformation at constant volume.	1
6.	Expansion of soil at breaking.	1
	Unit II	
7.	Occurrence of soil breaking fundamentals.	1
8.	Measures of resistance against breaking.	1
9.	Shear failure and Coulomb's law.	1
10.	Compaction v/s shear failure.	1
11.	Tensile failure of soil, idealized brittle failure, Griffith's Model.	1
12.	Loading rate and repeated loading effects.	1
13.	Draft calculation using mechanism of rigid soil bodies.	1
	Unit III	
14.	Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening.	1
15.	Structure of seed bed. Soil properties, properties affected by tillage and those not affected by tillage.	2
16.	Soil compaction, formation of clods and dust.	1
17.	Effect of tillage on erosion and water logging.	1
18.	Impact of climate factors on soil.	1
19.	Tillage requirement for various types of soils.	1
	Unit IV	
20.	Tillage operations for special tasks.	1
21.	Preparation of soil for cropping and stubble management.	1
22.	Primary and secondary tillage. Ploughing and its effect on soil.	1
23.	Disc tillage: Appropriate conditions and effect.	1
24.	Requirement of seed bed and techniques of creating proper seed bed.	1
25.	Quality of sowing and sowing methods.	1
26.	Modern trends and objectives of soil tillage.	1
	Unit V	
27.	Plough bodies: Generalized representation, intake main flow and output process.	1
28.	Main flow under different surface curvatures.	1
29.	Kinetic aspects of plough bodies with different shapes.	1
30.	Draft of plough bodies as affected by moisture, speed and attachments.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Characterization of soil condition before and after tillage.	2
2.	Cone penetrometer resistance, bulk density, moisture content.	1
3.	Measurement of forces on tillage tools under soil bin condition/ field condition.	2
4.	Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing.	2

S.No.	Topic	No. of Practicals
5.	Measurement of energy required for soil breakup by different methods.	2
6.	Field study of crop root development in relation to soil compaction and hard pan.	2
7.	Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed.	2
8.	Field evaluation of plant establishment in relation to planting parameters.	1
	Total	**14**

X. Suggested Reading

- Birkas M. 2014. *Book of Soil Tillage*. Szent Istvan University Press, Godollo, Hungary. ISBN-978-963-269-447-4 (Unit III & IV).
- Koolen AJ and Kuipers H. 1983. *Agricultural Soil Mechanics*. Springer-Verlag. New York, USA. ISBN 13:978-3-642-69012-9 (Unit I, II, V).

I. Course Title : Mechanics of Traction and its Application

II. Course Code : FMPE 611

III. Credit Hours : 2+1

IV. Aim of the course

Learning techniques of modelling soil traction device interaction under different states of wheel and under different soil conditions by analytical and empirical method.

V. Theory

Unit I

Tractor performance in soft soils, operational states of wheel: Wismer and Luth. Path traced by point on tyre periphery. Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekke's model, derivation of resistance offered by flat rigid plate on soft soil. Measurement of sinkage parameters. Soft wheel on soft surface and rigid wheel on soft surface. Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks.

Unit II

Empirical modelling of tractor performance, tractive performance modelling and mobility number. Empirical models for rolling resistance and traction by Gee-Clough. Derivation of equations for drawbar pull and drawbar power.

Unit III

Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage. Rigid wheel at driving state: Ground reaction on rigid wheel during driving action, force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force. Energy equilibrium under driving wheel.

Unit IV

Wheel under braking state: Slip velocity and amount of slippage under braked wheel. Soil deformation under braked wheel. Distribution of shear stresses and normal stress under driving wheel.

Unit V

Tyre wheel system-deformation of tyre and area of contact. Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure. Ground reaction during pure rolling of tyre on hard surface. Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions. Relation between cornering force and self-aligning torque.

VI. Practical

Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance. Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel. Measurement of performance of tyres under soil bin condition/field condition for driving and braking. Measurement of variation in contact patch of tractor tyres under different inflation pressures. Design of lugged wheels for wet puddle soil condition. Field experiment with tractive performance of tractor.

VII. Learning outcome

Ability to model vehicle traction mechanics and provide insight into behavior of vehicles under different soil conditions.

VIII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	Tractor performance in soft soils, operational states of wheel: Wismer and Luth.	2
2.	Path traced by point on tyre periphery.	1
3.	Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekke's model, derivation of resistance offered by flat rigid plate on soft soil.	4
4.	Measurement of sinkage parameters.	1
5.	Soft wheel on soft surface and rigid wheel on soft surface.	1
6.	Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks	2
7.	Empirical modelling of tractor performance, tractive performance modelling and mobility number.	2
8.	Empirical models for rolling resistance and traction by Gee-Clough.	1
9.	Derivation of equations for drawbar pull and drawbar power.	1
10.	Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage.	2
11.	Rigid wheel at driving state: Ground reaction on rigid wheel during driving action.	2
12.	Force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force.	2
13.	Energy equilibrium under driving wheel.	1
14.	Wheel under braking state: Slip velocity and amount of slippage under braked wheel.	2
15.	Soil deformation under braked wheel.	1
16.	Distribution of shear stresses and normal stress under driving wheel.	1

S.No.	Topic	No of Lectures
17.	Tyre wheel system-deformation of tyre and area of contact.	1
18.	Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure.	1
19.	Ground reaction during pure rolling of tyre on hard surface.	1
20.	Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions.	2
21.	Relation between cornering force and self-aligning torque.	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance.	3
2.	Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel.	4
3.	Measurement of performance of tyres under soil bin condition/ field condition for driving and braking.	2
4.	Measurement of variation in contact patch of tractor tyres under different inflation pressures.	1
5.	Design of lugged wheels for wet puddle soil condition.	2
6.	Field experiment with tractive performance of tractor.	2
7.	Revision	1
8.	Revision	1
	Total	**16**

X. Suggested Reading

- Muro T and O'Brien J. 2004. *Terramechanics: Land Locomotion Mechanics*. Lisse, Netherlands. ISBN 90 5809 572 X (Unit III, IV, V).
- Macmillan RH. 2010. *The Mechanics of Tractor-Implement Performance: Theory and Worked Examples: A Textbook for Students and Engineers*. Custom Book Centre, University of Melbourne, Australia. http://hdl.handle.net/11343/33718 (Unit I, II).

I. Course Title : Farm Machinery Management and Systems Engineering

II. Course Code : FMPE 612

III. Credit Hours : 2+1

IV. Aim of the course

Understanding Farm Machinery from systems approach and ability to model the Farm machinery system.

V. Theory

Unit I

Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains. Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems.

Unit II

Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money. Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.

Unit III

Uncertainty: Concepts of probability, probability functions, distributions, sampling. Statistics, confidence limits, significance, contingency tables, analysis of variance. Regression and correlation. Monte Carlo methods and applications to farm machinery.

Unit IV

System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system. Feasibility system design-stability. Deterministic systems and stochastic systems.

Unit V

Optimum Design: Trial and error, differential calculus, calculus of variations. Allocations: Linear programming, simplex technique. Transportation and assignment technique. Critical path scheduling, dynamic programming, game and its applications to farm machinery management.

VI. Practical

Solving problems of mathematical models of field machinery, constraints, power constraints, weather constraints. Problems relates to tillage seeding chemical application harvesting and storage and irrigation systems. Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost. Case studies in machine performance modelling, Economics of machine selection, Analog components, Analog modelling stochastic system modelling and critical path scheduling.

VII. Learning outcome

Ability to understand and develop model of any farm machinery system to help in selection, management and optimization.

VIII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	Understanding Farm Machinery from systems approach and ability to model the Farm machinery system.	2
2.	Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains.	2
3.	Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems.	3
4.	Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money	1
5.	Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.	2
6.	Uncertainty: Concepts of probability, probability functions, distributions, sampling	2

S.No.	Topic	No of Lectures
7.	Statistics, confidence limits, significance, contingency tables, analysis of variance.	1
8.	Regression and correlation. Monte Carlo methods and applications to farm machinery.	3
9.	System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system.	3
10.	Feasibility system design-stability	1
11.	Deterministic systems and stochastic systems.	2
12.	Optimum Design: Trial and error, differential calculus, calculus of variations	2
13.	Allocations: Linear programming, simplex technique Transportation and assignment technique	4
14.	Critical path scheduling, dynamic programming, game and its applications to farm machinery management.	4
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Problems solving of mathematical models of field machinery, constraints, power constraints, weather constraints	3
2.	Mathematical problems relates to tillage, seeding, chemical application harvesting and storage and irrigation systems	3
3.	Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost	3
4.	Case studies in machine performance modelling, Economics of machine selection	2
5.	Case studies in machine performance modelling	2
6.	Economics of Power and machine selection	2
	Total	**15**

X. Suggested Reading

- Hunt DR. 1986. *Engineering Models for Agricultural Production*. AVI Pub. Co., Westport, CT, USA.
- Hunt D and Wilson D. 2015. *Farm Power and Machinery Management*. Waveland Press, Illinois, USA.
- Singh S and Verma SR. 2009. *Farm Machinery Maintenance and Management*. DIPA, ICAR, New Delhi.

I. Course Title : Machinery for Special Farm Operations

II. Course Code : FMPE 613

III. Credit Hours : 2+0

IV. Aim of the course

To bring to focus special farm operations that are not covered under conventional operations and the machinery used for such operations.

V. Theory

Unit I

Machinery for land development. Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers, laser levelers.

Unit II

Machines for plant protection, pneumatic, thermal type sprayers, aero/drone spraying and other methods of spraying, electrostatic charging, air sleeve boom sprayer, disinfection of seed beds by micro waves and other methods. Safety aids for operator and advances in plant protection method.

Unit III

Field plot machinery and its importance. Fertilizer and manure spreader.

Unit IV

Machines for residue management. Silage and hay making machines.

Unit V

Machinery for horticultural crops. Crop specific machines for cotton, sugarcane, forage/fodder. Machines for processing and handling of agricultural products.

VI. Learning outcome

Understanding of the broad horizon of agricultural machinery used for specialized agricultural operations.

VII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Machinery for land development	1
2.	Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers	2
3.	Laser levelers	2
4.	Machines for plant protection	1
5.	Pneumatic, thermal type sprayers	2
6.	Aero/drone spraying and other methods of spraying,	2
7.	Electrostatic charging, air sleeve boom sprayer	2
8.	Disinfection of seed beds by micro waves and other methods	1
9.	Safety aids for operator and advances in plant protection method	2
10.	Field plot machinery and its importance	1
11.	Fertilizer and manure spreader	2
12.	Machines for residue management (in situ)	4
12.	Machines for residue management (ex situ)	2
14.	Silage and hay making machines	3
15.	Machinery for horticultural crops	2
16.	Crop specific machines for cotton, sugarcane, forage/fodder	2
17.	Machines for processing and handling of agricultural products	1
	Total	**32**

VIII. Suggested Reading

- Boson ES, Sultan-Shakh EG, Smirnov II and Verniaev OV. 2016. *Theory, Construction and Calculation of Agricultural Machines*. Scientific Publishers.
- Kanafozski C and Karwowiki T. 1976. *Agricultural Machines: and Construction*. Vol. I&II, Translated and published by US Dept. of Agriculture and National Science Foundation, Washington, DC, USA.
- Kepner RA, Bainer R and Barger EL. 2017. *Principles of Farm Machinery*. CBS publishers and Distributors Pvt. Ltd, New Delhi, India.

I. **Course Title** : **Ergonomics in Working Environment**
II. **Course Code** : **FMPE 614**
III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To enable the student to understand the concept of designing the working environment and designing farm machinery and equipment to ensure operators comfort and safety.

V. **Theory**

Unit I

Musculoskeletal problems in sitting and standing postures-behavioral aspects of posture, body mechanics. Workspace design for standing and seated workers. Display units, controls and human-machine interaction, design of static work.

Unit II

Noise and noise control. Measurement of noise and safe limits. Protection from noise. Vibration and health. Vibrations generated by agricultural machines. Types of vibrations: Whole body vibrations and hand transmitted vibrations. Methods of measurements of vibrations, hazards of vibrations. Vibration White Fingers (VWF). Vibration reductions in agricultural machines.

Unit III

Working environment-heat and cold stress conditions. Thermal balance of human body. Measurement of thermal environment. Heat and cold stress condition. Thermoregulatory system of human body. Heat and cold acclimatization. Effect of climate on human performance. Environmental dust and its measurement: Organic and inorganic dust. Types of dust and their hazards: Respirable, thoracic and inhalable dust. Personal protection from dust.

Unit IV

Time motion study and its purpose. Application of Time motion study in agricultural and processing operations. Recent research works related to ergonomics in agriculture.

VI. **Practical**

Design of workspace for static work in standing and sitting positions. Study of body mechanics and postures in design of agricultural machinery. Human energy expenditure, calibration of subjects, Human work load and its assessment. Study of work and rest schedule. Measurement of visibility of tractors. Measurement and control of noise in tractors and self-propelled machines. Measurement of human vibrations in farm tractors and agricultural machines. Study of dust generated in agricultural operations.

VII. **Learning outcome**

Ability to design working environment of different agricultural machinery for efficient and safe operations.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Basics of body mechanics, stability and support	1
2.	Control of muscle function, fatigue and discomfort	1
3.	Musculoskeletal problems in sitting and standing posture	2
4.	Behavioural aspects of posture, risk factors for musculoskeletal disorders	1
5.	Importance of ergonomics in workspace design	1
6.	Workspace design for standing workers	1
7.	Workspace design for seated workers	1
8.	First hourly examination	1
9.	Visual display units, controls and human- machine interaction	1
10.	Design of static work	1
11.	Importance of noise control and safe limits for human	1
12.	Measurement of noise, reduction and protection	1
13.	Machine vibrations, human vibrations and health hazards	1
14.	Whole body vibrations and hand transmitted vibrations	1
15.	Methods of measurements of vibrations and health hazards	1
16.	Vibration reduction techniques for agricultural machines	1
17.	Mid-semester examination	1
18.	Working environment- heat and cold stress conditions, thermal balance of human body	1
19.	Measurement of thermal environment	1
20.	Thermo-regulatory system of human body, heat and cold acclimatization, effect of climate on human performance	2
21.	Environmental dust and its measurement, type of dust - organic and inorganic dust, dust health hazard	1
22.	Respirable, thoracic and inhalable dust, protection from dust	1
23.	Time motion study and its purpose	1
24.	Application of time motion study in agricultural and processing operations	1
25.	Recent research work related to physiological parameters of ergonomics in agriculture	1
26.	Recent research work related to tractor space layout and design of controls	1
27.	Recent research work related to noise studies on farm machines	1
28.	Recent research work related to vibrations studies on farm machines	1
29.	Recent research work related to accidents and safety studies on farm machines	1
30.	Revision and discussion	1
	Total	32

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design of workspace for static work in standing or sitting posture	1
2.	Study of body mechanics and posture in design of agricultural machinery	2
3.	Study of displays and controls in tractors	1
4.	Calibration of subjects on ergometer and treadmill	2
5.	Human workload and its assessment	1

S.No.	Topic	No of Practicals
6.	Study of work and rest schedule	1
7.	Measurement of visibility to tractor operators	1
8.	Measurement of noise in tractors and self-propelled machines	1
9.	Measurement of machine component vibration	1
10.	Measurement of hand arm vibrations	1
11.	Measurement of whole body vibrations	1
12.	Study of dust generated in agricultural operations	1
13.	Case study of design improvement in agricultural machine/ tool through ergonomic concept	1
14.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Astrand PO, Rodahl K, Dahl HA and Stromme SB. 2003. *Textbook of Work Physiology: Physiological Bases of Exercise*. Champaign IL: Human Kinetics.
- Bridger RS. 2009. *Introduction to Ergonomics*. 3rd edition CRC Press, Boca Raton, USA.
- Gite LP, Majmudar J, Mehta CR and Khadatkar A. 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal, India.
- Gite LP, Agrawal KN, Mehta CR, Potdar RR and Narwariya BS. 2019. *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. Jain Brothers, New Delhi.
- Kroemer KHE and Grandjean E. 1997. *Fitting the Task to the Human: A Textbook of Occupational Ergonomics*. Taylor & Francis, Philadelphia, USA.
- Pearsons K. 2003, *Human Thermal environments: The Effects of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance*. Taylor and Francis, New York, USA.
- Sanders MS and McCormick EJ. 1993. *Human Factors in Engineering and Design*. McGraw Hill, New York, USA.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Processing and Food Engineering

Preamble

(Processing and Food Engineering)

Three major points were kept in mind while preparing course curricula related to Processing and Food Engineering (1) the syllabus and courses taught at UG level as recommended by 6th Dean committee (2) preparing students to keep pace with future requirement of the human resource in institutions and industry (3) to align the syllabus with ARS/NET examination.

Course curricula and course outlines in Processing and Food Engineering have been designed keeping in view the courses offered by the faculties from associated/ closely related disciplines, viz. Mechanical Engineering, Mathematics, Renewable Energy Engineering, Electrical, Electronics and Computer Engineering, Farm Machinery and Power Engineering, Civil Engineering etc.

It becomes more important for the post graduate students to not only learn the recent advances but have also to be trained/ hands on experience in the modern and latest techniques in their major disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the corporate sector.

All courses are designed to cover all basic topics and by taking into consideration demands of corporate sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required and enhancing the global competitiveness and employability of students. To meet these objectives new courses were added which covers areas: Instrumentation and Sensors in Food Processing, Agri-Project Planning and Management, Dairy Product Processing, Design of Aquacultural Structures and Thermal Environmental Engineering for Agricultural Processing.

Further, existing courses were suitably modified and restructured by deleting topics already covered in UG, removing overlapping topics in different courses, adding topics/ courses to cover ARS/NET exam syllabus and topic important to the food industry and emerging trends in Processing and Food Engineering. The modified/revised courses cover the areas: Transport Phenomena in Food Processing, Unit Operations in Food Process Engineering, Field Crops Process Engineering, Horticultural Crops Process Engineering, Storage Engineering and Handling of Agricultural Produce, Food Package Engineering, Application of Engineering Properties in Food Processing, Food Quality and Safety, Food Processing Technologies, Food Processing Equipment and Plant Design, Seed Process Engineering, Farm Structures and Environmental Control, Processing of Meat, Poultry and Fish, Advances in Food Process Engineering, Drying and Dehydration of Food Materials, Textural and Rheological Characteristics of Food Materials, Agricultural Waste and By-Products Utilization, Mathematical Modeling in Food Processing and Bioprocess Engineering.

The course content and syllabus upgraded make it more of practical oriented and as per ARS/NET Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech. in Processing and Food Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*PFE 501	Transport Phenomena in Food Processing	2+1
*PFE 502	Unit Operations in Food Process Engineering	2+1
*PFE 503	Field Crops Process Engineering	2+1
*PFE 504	Horticultural Crops Process Engineering	2+1
PFE 505	Storage Engineering and Handling of Agricultural Produce	2+1
PFE 506	Food Package Engineering	1+1
PFE 507	Instrumentation and Sensors in Food Processing	2+1
PFE 508	Application of Engineering Properties in Food Processing	2+1
PFE 509	Food Quality and Safety	2+1
PFE 510	Food Processing Technologies	2+1
PFE 511	Food Processing Equipment and Plant Design	1+1
PFE 512	Seed Process Engineering	1+1
PFE 513	Agri-Project Planning and Management	2+1
PFE 514	Farm Structures and Environmental Control	2+1
PFE 515	Dairy Product Processing	2+1
PFE 516	Processing of Meat, Poultry and Fish	2+1
PFE 517	Design of Aquacultural Structures	2+1
PFE 518	Thermal Environmental Engineering for Agricultural Processing	2+1
	Total	**33+18**

*Compulsory Courses

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credits
ME 501	Mechatronics and Robotics in Agriculture	2+0
ME 502	Refrigeration Systems	2+1
REE 513	Energy, Ecology and Environment	3+0
REE 518	Energy Management in Food Processing Industries	1+1
FMPE 502	Testing and Evaluation of Agricultural Equipment	1+1
FMPE 514	System Simulation and Computer Aided Problem Solving in Engineering	1+1

Course Code	Course Title	Credit Hours
FMPE 515	Computer Aided Design of Machinery	0+2
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
MATHS 501	Finite Elements Method	1+1
MATHS 502	Numerical Methods for Engineers	2+1
CE 501	Dimensional Analysis and Similitude	1+1
	Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	0+1
*PGS 502	Technical Writing and Communications Skills	0+1
*PGS 503	Intellectual Property and its management in Agriculture	0+1
*PGS 504	Basic Concepts in Laboratory Techniques	0+1
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	0+1

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Course Code	Course Title	Credit Hours
PFE 591	Seminar	0+1
PFE 599	Thesis Research	0+30

Course Contents
M.Tech. in Processing and Food Engineering

I. Course Title : Transport Phenomena in Food Processing

II. Course Code : PFE 501

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the principles of heat, mass and momentum transfer and its applications in food processing

V. Theory

Unit I

Introduction to heat and mass transfer and their analogy. Steady and unsteady state heat transfer. Analytical and numerical solutions of unsteady state heat conduction equations. Use of Gurnie-Lurie and Heisler Charts in solving heat conduction problems: Applications in food processing including freezing and thawing of foods.

Unit II

Convective heat transfer in food processing systems involving laminar and turbulent flow. Heat transfer in boiling liquids. Heat transfer between fluids and solid foods. Functional design of heat exchangers: shell and tube, plate and scraped surface heat exchangers. Radiation heat transfer: governing laws, shape factors, applications in food processing.

Unit III

Momentum transfer.Mass flow and balance. Steady and unsteady flow.Theory and equation of continuity.Bernoulli's theorem and application. Flow through immerged bodies, Measurement of flow, pressure and other parameters. Flow driving mechanism.

Unit IV

Molecular diffusion in gases, liquids and solids.Molecular diffusion in biological solutions and suspensions.Molecular diffusion in solids. Unsteady state mass transfer and mass transfer coefficients.Molecular diffusion with convection and chemical reaction.Diffusion of gases in porous solids and capillaries. Mass transfer applications in food processing.

VI. Practical

Solving problems on steady and unsteady state conduction with or without heat generation.Numerical analysis.Problems in natural and forced convection, radiation.Design of heat exchangers. Experiments on heat conduction, convection and radiation heat transfer.

VII. Learning outcome

The course will impart requisite knowledge about transport phenomenon with respect to heat, mass and momentum transfer which is necessary to understand the food processing operations. After going through the course, students will be able to understand, analyse and solve numerically the food processing operations where heat/mass/momentum transfer is involved.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to basic heat and mass transfer and their analogy	2
2.	Steady and unsteady state heat transfer.	2
3.	Use of Gurnie-Lurie and Heisler Charts in solving heat conduction problems	1
4.	Applications in food processing including freezing and thawing of foods.	1
5.	Convective heat transfer in food processing systems involving laminar and turbulent flow	2
6.	Heat transfer in boiling liquids, Heat transfer between fluids and solid foods.	2
7.	Functional design of heat exchangers; Shell and tube, plate and scraped surface heat exchangers.	2
8.	Radiation heat transfer: governing laws, shape factors, applications in food processing.	2
9.	Classification of Flow Phenomena, Momentum Flow and Momentum Equation for Laminar Flow, Momentum transfer. Mass flow and balance.	2
10.	Steady and unsteady flow, Fluid Element Trajectories, Stream Function and Velocity Potential	1
11.	Theory and equation of continuity. Bernoulli's theorem and application.	1
12.	Flow through immerged bodies, Measurement of flow; Measurement of flow pressure and other parameters. Flow driving mechanism.	2
13.	Mass Transfer (Diffusion),Diffusion: Phenomenological Description, Diffusion Coefficient and Fick's Law	2
14.	Driving Force for Diffusion, Microscopic Picture of Diffusion	1
15.	Molecular diffusion in biological solutions and suspensions.	1
16.	Unsteady state mass transfer and mass transfer coefficients.	2
17.	Molecular diffusion with convection and chemical reaction	1
18.	Diffusion of gases in porous solids and capillaries	1
19.	Mass transfer applications in food processing.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Solving problems on steady conduction	1
2.	Solving problems on steady conductionwith or without heat generation	1
3.	Solving problems on steady and unsteady state conduction	2
4.	Steady and unsteady state conduction with or without heat generation	1
5.	Numerical analysis in heat transfer	1
6.	Problems in natural and forced convection	2
7.	Solving problems of heat transfer by radiation	2
8.	Design of heat exchangers.	2
9.	Experiments on heat conduction, convection	2
10.	Experiments on radiation heat transfer	1
	Total	**15**

X. Suggested Reading

- Bird, Stewart, Lightfoot 2002. *Transport Phenomena*, John Wiley & Sons.
- Bodh Raj 2012. *Introduction to Transport Phenomena*, PHI.
- Christie J. 1993. *Transport Process and Unit Operations*. Prentice-Hall of India Private Limited, New Delhi ISBN 0-13-045253-X.
- Coulson JM and Richardson JF. 1999. *Chemical Engineering*. Vol. II, IV.ThePergamon Press.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Holman JP 1992. Heat Transfer. McGraw Hill.
- Jorge Welti-Chanes, Jorge F and Velez-Ruiz 2002. *Transport Phenomena in Food Processing*. CRC Press ISBN: 9781566769938 Geankoplis.
- McCabe WL and Smith JC 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Plawsky, Joel L 2014. *Transport Phenomena Fundamentals*, CRC Press, ISBN: 978-1-4665-5535-8,1466555351.

I. Course Title : Unit Operations in Food Process Engineering

II. Course Code : PFE 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with different unit operations applicable in food industries.

V. Theory

Unit I

Review of basic engineering mathematics. Units and dimensions. Mass and energy balance. Principles of fluid flow. Heat transfer: Conduction, convection and radiation.Heat exchangers and their designs.

Unit II

Drying and dehydration: Psychrometry, theories of drying, EMC, equipment for drying of solid, pastes and liquid foods. Evaporation: Components, heat and mass balance in single and multiple effect evaporators, equipment and applications, steam economy. Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment.

Unit III

Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain.

Unit IV

Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation. Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screw conveyors.

Unit V

Size reduction: Principles of size reduction, size reduction laws. Size reduction equipment: Jaw crusher, gyratory crusher, roller mill, hammer mill.

VI. Practical

Study of fluid flow properties. Study of heat exchangers, functional design of heat exchangers.Application of psychometric chart.Determination of EMC.Study of driers. Solving problems on single and multiple effect evaporator. Elevating and conveying equipments. Size reduction equipments. Cleaning and sorting equipment. Sieve analysis. Kinetics of fruits and vegetables dehydration.Calculation of refrigeration load, solving of numerical problems. Visit to related food industry.

VII. Learning outcome

The students will get knowledge on various unit operations, backbone of all food processes. Knowledge on basic principles of thermal food processes, size reduction and separation operations involved in food processing and related equipment will prepare students to solve problems related with food processing. This will help students to solve problems of post-production processes and will also enhance employability in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Calculations of material balance related to various food processes	3
2.	Study of energy balance for processing operation and related parameters	3
3.	Study of fluid statics, fluid dynamics, flow characteristics	2
4.	Introduction to heat transfer, modes of heat transfer, heat conduction	2
5.	Introduction to Psychometrics basics	2
6.	Study of Dehydration, EMC, Mechanism of drying constant rate period, Falling rate period	2
7.	Study of drying equipments	2
8.	Evaporation, types of evaporators, Flow arrangements Mass and energy balance, Steam economy	2
9.	Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment.	3
10.	Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain.	2
11.	Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation.	2
12.	Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screw conveyors.	2
13.	Study of principles involved in the size reduction and separation. Equipment used	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Use of units, dimensions and basic mathematical applications	1
2.	To judge the students ability for solving mass balance problems	2
3.	To judge the students ability for solving Energy balance problems	2
4.	To assess the flow rate of fluids through pipes and channels	1
5.	To verify the Bernoulli's Equation	1
6.	To Study heat exchangers and calculation of log mean temperature difference	1
7.	To solve the heat transfer problems	2
8.	To study different dryers used in drying of biological materials	1
9.	To study single effect and multi effect evaporators	1
10.	To calculate the thermal process time using trapezoidal/ Simpson's formulae	1

S.No.	Topic	No. of Practicals
11.	To find the graphical solution for calculation of thermal process time	1
12.	To study different separation equipments	1
13.	To study the size reduction equipments	1
	Total	**16**

X. Suggested Reading

- Berk. 2018. *Food Process Engineering and Technology*, Academic Press, ISBN: 978-0-12-812018-7
- Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier.
- Fellows P 1988. *Food Processing Technology: Principle and Practice*. VCH Publ.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
- Singh RP and Heldman DR. 1993. *Introduction to Food Engineering*. Academic Press.
- Smith. 2011. *Introduction to Food Process Engineering*, Springer.
- Toledo. 2007. *Fundamentals of Food Process Engineering*, Springer.
- Varzakas. 2015. *Food Engineering Handbook*, CRC press.

I. Course Title : Field Crops Process Engineering

II. Course Code : PFE 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the post harvest technology of cereals, pulses and oilseeds with special emphasis on equipment used in the milling and processing.

V. Theory

Unit I

Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions. Grain quality standards and physico-chemical methods for evaluation of quality of flours.

Unit II

Pre-milling treatments and their effects on milling quality. Parboiling and drying, conventional, modern and integrated rice milling operations. Wheat roller flour milling. Processes for milling of corn, oats, barley, gram, pulses, paddy and flour milling equipment.Layout of milling plants.

Unit III

Dal mills, handling and storage of by-products and their utilization. Storage of milled products.Expeller and solvent extraction processing.Assessment of processed product quality.

Unit IV

Packaging of processed products. Design characteristics of milling equipment, selection, installation and their performance. Quality standards for various processed products. Value added products of cereals, pulses and oilseeds.

VI. Practical

Physical properties of cereals and pulses, raw and milled products quality evaluations:Parboiling and drying, terminal velocities of grains and their fractions, study of paddy, wheat, pulses and oilseeds milling equipments, planning and layout of various milling plants. Development of value added products for cereals, pulses and oilseeds, visit to related agro processing industry.

VII. Learning outcome

Student's capability to mill and process (value added products) all kinds of field crops as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions.	2
2.	Conventional, modern and integrated rice milling process, pre-milling treatments, rice parboiling, rice milling equipment and layout of rice milling plant.	5
3.	Conventional and roller wheat flour milling process, pre-milling treatments, milling equipment and layout of wheat milling plant.	4
4.	Preparation of oilseeds and pre- treatments, conventional and modern oil extraction methods viz expeller, solvent extraction and super critical fluid extraction. Milling equipment and layout of oil milling plant.	4
5.	Processes for milling of pulses, pretreatments, milling equipment and layout of pulse milling plant.	4
6.	Processes for milling of corn, oats and barley, pretreatments and milling equipments. Layout of milling plant.	3
7.	Handling, packaging and storage of milled products, by-products and their utilization.	2
8.	Assessment of processed product quality. Quality standards for various grains, processed products. Physico-chemical methods for evaluation of quality Value added products of cereals, pulses and oilseeds.	3
9.	Design characteristics of milling equipment, selection, installation and their performance.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Engineering properties of grains, raw and milled products	2
2.	Physical, milling and cooking quality of grains	2
3.	Study of paddy milling process and equipments.	1
4.	Study of wheat milling process and equipments,	1
5.	Study of oil extraction process and equipments,	1
6.	Study of pulse milling process and equipments,	1
7.	Planning and layout of various milling plants.	3
8.	Development of value added products for cereals, pulses and oilseeds	2
9.	Visit to various agro processing industry.	2
	Total	**15**

X. Suggested Reading

- Asiedu JJ. 1990. *Processing Tropical Crops*. ELBS/MacMillan.
- Chakraverty A. 1995. *Post-Harvest Technology of Cereals, Pulses and Oilseeds.* Oxford and IBH.
- Golob 2002. *Crop Post-Harvest: Science and Technology* Vol. 1, Wiley-Blackwell.
- Hodges 2004. *Crop post-harvest: science and technology* Vol. 2, Wiley-Blackwell.
- Morris Lieberman. 1983. *Post-Harvest Physiology and Crop Preservation*. Plenum Press.
- Pandey PH. 1994. *Principles of Agricultural Processing*. Kalyani.
- Pillaiyar P. 1988. *Rice - Post Production Manual.* Wiley Eastern.
- Sahay KM and Singh KK. 1994. *Unit Operations in Agricultural Processing*. Vikas Publ. House.

I. Course Title : Horticultural Crops Process Engineering

II. Course Code : PFE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with processing of fruits and vegetables and the design features of the equipment used for their processing.

V. Theory

Unit I

Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables, fruit ripening, spoilage of fruits and vegetables.

Unit II

Harvesting and washing, pre-cooling, blanching, preservation of fruits and vegetables, commercial canning of fruits and vegetables, minimal processing of fruits and vegetables.

Unit III

Cold storage of fruits and vegetables, controlled atmosphere and modified atmosphere packaging of fruits and vegetables, quality deterioration and storage.

Unit IV

Dehydration of fruits and vegetables, methods, osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources.

Unit V

Intermediate moisture foods, ohmic heating principle, high pressure processing of fruits and vegetables, applications, sensory evaluation of fruit and vegetable products, packaging technology for fruits and vegetables, general principles of quality standards and control, FPO, quality attributes.

VI. Practical

Determination of size, shape, density, area-volume-mass relationship of fruits and vegetables, sugar-acid ratio of fruits, evaluation of washer, grader and packaging methods, experiments on drying of fruits and vegetables, controlled atmosphere storage and quality evaluation.

VII. Learning outcome

Student's capability to mill and process (value added products) all kinds of horticultural crops as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables.	1
2.	Techniques for harvesting and washing of fruits and vegetables. Fruit ripening and spoilage.	2
3.	Pre-cooling of fruits and vegetables.	1
4.	Blanching: importance and objectives, blanching methods, effects on food (nutrition, colour, pigment, and texture).	1
5.	Different preservation techniques for fruits and vegetables.	1
6.	Commercial canning of fruits and vegetables.	1
7.	Minimal processing of fruits and vegetables.	1
8.	Modified and CA storage of fruits and vegetables, Cold storage, heat load calculations and design.	5
9.	Quality deterioration in fruits and vegetables.	1
10.	Different storage techniques for fruits and vegetables.	1
11.	Dehydration techniques of fruits and vegetables: osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources.	4
12.	Intermediate moisture foods.	1
13.	Ohmic heating and high pressure processing principle for fruits and vegetables.	2
14.	Applications of different processing techniques for fruits and vegetables.	1
15.	Sensory evaluation of fruit and vegetable products.	1
16.	Packaging technology for fruits and vegetables.	2
17.	General principles of quality standards and control.	2
18.	FPO, quality attributes for fruits and vegetables.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of size of fruits and vegetables	1
2.	Determination of shape of fruits and vegetables	1
3.	Determination of bulk density and true density of fruits and vegetables	1
4.	Determination of area-volume-mass relationship of fruits and vegetables	1
5.	Determination of sugar-acid ratio of fruits	1
6.	Evaluation of different types of washers for fruits and vegetables	1
7.	Evaluation of different types of graders for fruits and vegetables	1
8.	Different types of packaging methods for fruits and vegetables	1
9.	Determination of the water vapor permeability of packaging materials	1
10.	Different types of drying methods for fruits and vegetables	1
11.	Comparative evaluation of different dryers for fruits and vegetables	1

S.No.	Topic	No. of Practicals
12.	Determination of solid gain and moisture loss during osmotic dehydration in fruits	1
13.	Study of components and design of controlled atmosphere storage	1
14.	Study of quality evaluation of fruits and vegetables	2
	Total	**15**

X. Suggested Reading

- Bhatti S and Varma U. 1995. *Fruit and Vegetable Processing*. CBS.
- Cruesss WV. 2000. *Commercial Fruit and Vegetable Products*. Agrobios Publisher.
- Danthy ME. 1997. *Fruit and Vegetable Processing*. International Book Publisher.
- Simson. 2016. *Post-Harvest Technology of Horticultural crops*. AAP.
- Singh. 2018. *Advances in Post-Harvest Technologies of Vegetable Crops*. AAP.
- Srivastava RP and Kumar S. 1994. *Fruit and Vegetable Preservation*. Principles and Practices. International Book Distr.
- Thompson AK. 1996. *Post Harvest Technology of Fruits and Vegetables*. Blackwell.
- Verma LR and Joshi VK. 2000. *Post Harvest Technology of Fruits and Vegetables*. Vols. I-II. Indus Publisher.

I. Course Title : Storage Engineering and Handling of Agricultural Produce

II. Course Code : PFE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the safe storage of food materials, design of storage structures and the design of different material handling equipment used in the industries.

V. Theory

Unit I

Storage of grains, biochemical changes during storage, production, distribution and storage capacity estimate models, storage capacity models, ecology, storage factors affecting losses, storage requirements.

Unit II

Bag and bulk storage, godowns, bins and silos, rat proof godowns and rodent control, method of stacking, preventive method, bio-engineering properties of stored products, function, structural and thermal design of structures, aeration system.

Unit III

Grain markets, cold storage, controlled and modified atmosphere storage, effects of nitrogen, oxygen, and carbon dioxide on storage of durable and perishable commodities, irradiation, storage of dehydrated products, food spoilage and preservation, BIS standards.

Unit IV

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts; design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators,principles of fluidization, recent advances in handling of food materials.

VI. Practical

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts, design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators; principles of fluidization; recent advances in handling of food materials.

VII. Learning outcome

Student's capability to understand and undertake mechanical handling of food as per requirement of food industries as well as storage devices and systems for safe storage of food for longer period of time.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of storage, Types of losses, Principle of storage, Aeration of grains, Factors causing deterioration of grains, Sources of infestation	3
2.	Biochemical changes during storage, Grain storage capacity estimation models	2
3.	Factors affecting losses, Storage requirements	2
4.	Bag and bulk storage, godowns, bins and silos, Selection of storage type, Deep and shallow bins	3
5.	Rat proof godowns and rodent control, method of stacking, preventive method, bio-engineering properties of stored products	2
6.	Functional, structural and thermal design of structures, aeration system.	2
7.	Grain markets- Recent reforms, Continued constraints to grain market integration, Rice and wheat marketing channels in India, Import, export and food policy, Food grains management system	2
8.	Cold storage,Controlled and modified atmosphere storage, Effects of nitrogen, oxygen, and carbon dioxide on storage of durable and perishable commodities.	3
9.	Food irradiation, Storage of dehydrated products, Food spoilage and preservation, BIS standards.	2
10.	Physical factors influencing flow characteristics, Rolling resistance, Mechanics of bulk solids - Shear apparatus for determination of flow properties, Yield locus, Time yield locus and effective yield locus.	3
11.	Flow through hoppers, openings and ducts – Types of flow along bins or hopper wall, Flow function and Critical flow factor, Critical dimensions of hopper openings;	2
12.	Material handling equipment, Design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators.	4
13.	Principles of fluidization, recent advances in handling of food materials.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of angle of repose	1
2.	Determination of coefficient of internal friction	1
3.	Determination of coefficient of external friction	1
4.	Physical factors influencing flow characteristics	1

S. No	Topic	No. of Practicals
5.	Determination of flow properties using Shear apparatus	1
6.	Determination of Yield locus, Time yield locus and effective yield locus from Mohr's circle	1
7.	Flow through hoppers, openings and ducts	1
8.	Design of belt conveyors	1
9.	Design of chain conveyors	1
10.	Design of screw conveyors	1
11.	Design of bucket elevators	1
12.	Design of roller conveyors	1
13.	Design of pneumatic conveyors	1
14.	Principles of fluidization	1
15.	Recent advances in handling of food materials	2
	Total	16

X. Suggested Reading

- Boumans. 1985. *Grain Handling and Storage*. Elsevier.
- FAO. 1984. *Design and Operation of Cold Stores in Developing Countries*. FAO.
- Golob. 2002. *Crop Post-Harvest: Science and Technology*. Vol 1 Wiley-blackwell.
- Hall CW. 1970. *Handling and Storage of Food Grains in Tropical and Sub-Tropical Areas*. FAO Publisher Oxford & IBH.
- Henderson S and Perry SM. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Hodges 2004. *Crop Post-Harvest: Science and Technology*. Vol 2, Wiley-blackwell.
- Ripp BE. 1984. *Controlled Atmosphere and Fumigation in Grain Storage*. Elsevier.
- Shefelt RL and Prussi SE. 1992. *Post Harvest Handling – A System Approach*. Academic Press.
- Vijayaraghavan S 1993. *Grain Storage Engineering and Technology*. Batra Book Service.

I. Course Title : Food Package Engineering

II. Course Code : PFE 506

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with packaging methods, packaging materials, packaging machineries, modern packaging techniques etc.

V. Theory

Unit I

Introduction of packaging: Package, functions and design. Principle in the development of protective packaging. Deteriorative changes in foodstuff and packaging methods of prevention.

Unit II

Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fibre board boxes, textile and paper sacks, corrosion of containers (tin plate).Flexible packaging materials and their properties.Aluminum as packaging material.Evaluation of packaging material and package performance.

Unit III

Packaging equipment: Food packages, bags, types of pouches, wrappers, carton and other traditional package.Retortable pouches: Shelf life of packaged foodstuff.

Unit IV

Methods to extend shelf life.Packaging of perishables and processed foods. Special problems in packaging of food stuff.

Unit V

Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP. Biodegradable packaging: Recent advances in packaging, active packaging, smart packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, microencapsulation and nano encapsulation.

VI. Practical

Thickness, substance weight, water absorption capability of flexible packaging materials,strength properties of packaging materials,water vapour and gas transmission rate of flexible packaging materials,identification and chemical resistance of plastic films. Packaging of fruits/vegetables: Estimation of shelf-life of packaged food stuff, familiarization of types of packaging material.

VII. Learning outcome

Student's capability to develop packages for all kinds of food products as per requirement of food industries and thereby adding value to the food products.

VIII. Lectures Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to food packaging, Definition, importance, package, functions of packaging, design.	1
2.	Principle in the development of protective packaging	1
3.	Deteriorative changes in foodstuff, Factors affecting shelf life of foods during storage, interactions of spoilage agents with environmental factors (water, oxygen, light and pH), packaging methods of prevention	1
4.	Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fibre board boxes, textile and paper sacks, corrosion of containers (tin plate).	1
5.	Flexible packaging materials and their properties. Aluminum as packaging material.	1
6.	Evaluation of packaging material and package performance: Testing methods for flexible, rigid and semi rigid materials. Paper and paper board:thickness, bursting strength, breaking length, stiffness, tear resistance, folding endurance, ply bond and surface oil absorption, Plastic film and laminates: thickness, tensile strength, gloss, haze and burning test to identify polymer, aluminium foil: thickness and pin holes, Glass containers: visual defects, colour, dimensions and impact strength and metal containers: pressure test and product compatibility	3
7.	Packaging equipment for food packages, bags, types of pouches, wrappers, carton and other traditional packages	1
8.	Retortable pouches: Shelf life of packaged foodstuff.	1
9.	Methods to extend shelf life. Packaging of perishables and processed foods	1
10.	Special problems in packaging of food stuff	1
11.	Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP	2

S.No.	Topic	No. of Lectures
12.	Recent advances in packaging, active packaging, smart packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, microencapsulation and nano encapsulation	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization of types of packaging material	1
2.	Determination of thickness of different types of packaging materials	1
3.	To determinewater absorption capability of flexible packaging materials	1
4.	Determination of tensile strength of packaging material	1
5.	Determination of compressive strength of packaging material	1
6.	Determination of water vapour transmission rate of packaging material	1
7.	Determination of gas transmission rate of packaging material	1
8.	Identification of different types of plastic films	1
9.	Testing of chemical and grease resistance of packaging materials	1
10.	Determination of bursting strength of packages	1
11.	Drop test for food package strength	1
12.	Vacuum packaging of various food products	1
13.	Nitrogen packaging of food products	1
14.	To study the effect of shrink wrapping onshelf life of fruits and vegetables	1
15.	To study the effect of active modified atmosphere packaging onshelf life of fruits and vegetables	1
16.	Visit to relevant industries	1
	Total	**16**

X. Suggested Reading

- Crosby NT. 1981. *Food Packaging Materials*. Applied Science Publisher.
- Frank A. 1992. *A Handbook of Food Packaging*. Springer.
- Mahadeviah M and Gowramma RV. 1996. *Food Packaging Materials*. Tata McGraw
- Hill.Palling SJ. 1980. *Developments in Food Packaging*. Applied Science Publisher.
- Robertson GL. 2013. *Food Packaging - Principles and Practice*. 3rd Ed Taylor & Francis.
- Sacharow S and Grittin RC. 1980. *Principles of Food Packaging*. AVI Publisher.

I. Course Title : Instrumentation and Sensors in Food Processing

II. Course Code : PFE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with instrumentation and use of sensors in food processing operations.

V. Theory

Unit I

Basic instrumentation systems and transducer principles. Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers.

Unit II

Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring. Method of separation of force: Torque, power and energy measuring technique.

Unit III

Temperature measurement using bi-metals, thermisters, thermocouples, humidity measurement, manometers. Flow transducer, positive displacement, venturimeter, Rotameter, Drag force, hot wire anemometer.

Unit IV

Theory and classifications of chemical sensors, biosensors, fibre optic sensors, gas sensors etc. Biosensor: Concepts, types of biosensors, methods of immobilizing biosensors, application. Imaging methods: X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging. Spectroscopy and chemometrics: UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy.

VI. Practical

Identification of components of generalized measuring system: Calibration of instruments, experiment on LVDT, strain gauge transducer, force, torque, power and pressure, fluid flow rates, temperature, calorific value, vibration measurement.Use of data loggers and data storage devices, spectroscopy, imaging systems.

VII. Learning outcome

Student's capability to control the process operations through precise instrumentation and knowledge of sensors for precision analysis of food quality in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Basic instrumentation systems	1
2.	Transducer principles	1
3.	Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers.	3
4.	Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring.	3
5.	Different methods of separation of force: Torque, power and energy measuring technique	3
6.	Temperature measurement using bi-metals, thermistors, thermocouples, humidity measurement, manometers.	3
7.	Flow transducer, positive displacement, venturi meter, Rotameter, Drag force, hot wire anemometer.	2
8.	Theory and classification of chemical sensors, biosensors, fibre optic sensors, gas sensors etc.	4
9.	Biosensor: Concepts, types of biosensors, methods of immobilizing biosensors, application.	3
10.	Imaging methods for foods, Principles, equipment, food applications- X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging.	4
11.	Various methods of spectroscopy and chemometrics, principles, equipment, food applications- UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Identification of components of generalized measuring system for temperature, pressure, relative humidity, moisture etc.	1
2.	Calibration of moisture measuring equipment	1
3.	Calibration of temperature control and measuring devices	1
4.	To study the working of Bourdon Pressure Gauge and to check the calibration of the gauge in a deadweight pressure gauge calibration set up.	1
5.	To study various temperature measuring instruments e.g. Mercury-in-glass thermometer, Thermocouple, Electrical resistance thermometer, laser thermometer and to estimate their response times	1
6.	To determine the calorific value of different food products using a bomb calorimeter having temperature sensing device	1
7.	To study a Linear Variable Differential Transformer (LVDT) and use it in a simple experimental set up to measure a small displacement	1
8.	To measure torque of a rotating shaft using torsion meter/strain gauge torque transducer	1
9.	To measure the speed of a motor shaft with the help of non-contact type pick-ups (magnetic or photoelectric)	1
10.	To measure static/dynamic pressure of fluid in pipe/tube using pressure transducer/pressure cell	1
11.	To determine the hardness/firmness of food samples using a texture analyzer	1
12.	To study the effect of vibrations during transportation on the quality of food (damage/ bruising/ texture etc) using a simulated vibration test	1
13.	To study and use the data logging and data storage devices	1
14.	To study and understand the working principle of UV and visual spectroscopy for measurement of food properties	1
15.	To study and understand the working principle of NIR and FTIR spectroscopy for measurement of food properties	1
16.	To study the working principle of X-ray imaging, Computed tomography, MRI, Ultrasound and Hyperspectral imaging for measurement of food quality	1
	Total	**16**

X. Suggested Reading

- Doebelin EO. 1990. *Measurement Systems Applications and Design*. Tata McGraw Hill.
- Erika KR and Brimelow JB. 2001. *Instrumentation and Sensors for the Food Industry*. CRC Woodhead.
- Nakra BC and Chaudhary KK. 2004. *Instrumentation Measurement and Analysis*. Tata McGraw Hill.
- Mukhopadhyay. 2014. *Novel Sensors for Food Inspection: Modelling, Fabrication and Experimentation*. Springer.
- Mukhopadhyay SC. 2017. *Sensors for Everyday Life*. Springer.
- Paré JRJ and Bélanger JMR. 1997. *Instrumental Methods in Food Analysis*. Elsevier Academic Press.

I. Course Title : Application of Engineering Properties in Food Processing

II. Course Code : PFE 508

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with different techniques of measurement of engineering properties and their application in the design of processing equipment.

V. Theory

Unit I

Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size, volume and density, porosity, surface area. Rheology: ASTM standard, terms, physical states of materials, classical ideal material, rheological models and equations, viscoelasticity, creep-stress relaxation, non-Newtonian fluid and viscometry, rheological properties, force, deformation, stress, strain, elastic, plastic behaviour.

Unit II

Contact stresses between bodies, Hertz problems, firmness and hardness, mechanical damage, dead load and impact damage, vibration damage, friction, effect of load, sliding velocity, temperature, water film and surface roughness. Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose, flow of bulk granular materials, aero dynamics of agricultural products, drag coefficients, terminal velocity.

Unit III

Thermal properties: Specific heat, thermal conductivity, thermal diffusivity, methods of determination, steady state and transient heat flow. Electrical properties: Dielectric loss factor, loss tangent, A.C. conductivity and dielectric constant, method of determination, energy absorption from high frequency electric field.

Unit IV

Application of engineering properties in design and operation of agricultural equipment and structures.

VI. Practical

Experiments for the determination of physical properties like length, breadth, thickness, surface area, bulk density, porosity, true density, coefficient of friction, angle of repose and colour for various food grains, fruits, vegetables, spices and processed foods, aerodynamic properties like terminal velocity, lift and drag force for food grains, thermal properties like thermal conductivity, thermal diffusivity and specific heat. Rheological properties: firmness and hardness of grain, fruits and stalk, electrical properties like dielectric constant, dielectric loss factor, loss tangent and A.C. conductivity of various food materials.

VII. Learning outcome

Student’s capability to apply properties of food for design of equipment and structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size.	3
2.	Volume and density, porosity, surface area.	1
3.	Rheology: ASTM standard, terms, physical states of materials, classical ideal material.	2
4.	Rheological models and equations, visco elasticity.	2
5.	Creep-stress relaxation, non-Newtonian fluid and viscometry.	1
6.	Rheological properties, force, deformation, stress, strain, elastic, plastic behavior.	1
7.	Contact stresses between bodies, Hertz problems, firmness and hardness	1
8.	Mechanical damage, dead load and impact damage.	2
9.	Vibration damage, friction, effect of load, sliding velocity.	1
10.	Temperature, water film and surface roughness.	1
11.	Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose.	2
12.	Flow of bulk granular materials.	1
13.	Aero dynamics of agricultural products, drag coefficients, terminal velocity.	3
14.	Thermal properties: Specific heat, thermal conductivity, thermal diffusivity.	1
15.	Methods of determination, steady state and transient heat flow	1
16.	Electrical properties: Dielectric loss factor, loss tangent.	1
17.	A.C. conductivity and dielectric constant, method of determination.	2
18.	Energy absorption from high frequency electric field.	1
19.	Application of engineering properties in design and operation of agricultural equipment and structures.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To determine the size of grains, pulses, oil seeds, spices, fruits and vegetables.	1
2.	To determine the shape of various food grains and fruits and vegetables.	1
3.	To determine the bulk density of food grains and fruits and vegetables.	1
4.	To determine the particle density/true density and porosity of solid grains.	1
5.	To study the comparison pycnometer for finding the particle density of food grains.	1
6.	To determine the angle of repose of grains, oilseeds etc.	1
7.	To find the coefficient of external friction for different food grains.	1
8.	To determine the coefficient of internal friction of different food grains.	1
9.	To plot the normal stress vs. sheet stress curves for different food grains.	1
10.	To study the separating behaviour of a grain sample in a vertical wind tunnel (Aspirator column).	1
11.	To study the thermal properties (thermal conductivity, thermal diffusivity and specific heat) of food grains.	2

S.No.	Topic	No. of Practicals
12.	To determine the Rheological properties: firmness and hardness of grain, fruits, stalk and vegetables.	1
13.	To study the electrical properties (dielectric constant, dielectric loss factor) of various food materials.	1
14.	To study the electrical properties (loss tangent and A.C. conductivity) of various food materials.	1
	Total	**15**

X. Suggested Reading

- Ludger F and Teixeira AA. 2007. *Food Physics Physical Properties - Measurement and Application*. Springer.
- Mohesenin NN. 1980. *Thermal Properties of Foods and Agricultural Materials*. Gordon and Breach Science Publisher.
- Mohesenin NN. 1980. *Physical Properties of Plant and Animal Materials*. Gordon & Breach Science Publisher.
- Peleg M and Bagelay EB. 1983. *Physical Properties of Foods*. AVI Publisher.
- Peter B. 2007. *The Chemical Physics of Food*. Wiley-Blackwell.
- Rao MA and Rizvi SSH. 1986. *Engineering Properties of Foods*. Marcel Dekker.
- Singhal OP and Samuel DVK. 2003. *Engineering Properties of Biological Materials*. Saroj Prakasan.
- Sitkei. 1986. *Mechanics of Agricultural Materials*. Elsevier.

I. Course Title : Food Quality and Safety

II. Course Code : PFE 509

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the latest standards to maintain food quality and safety.

V. Theory

Unit I

Food safety:Need for quality control and safety, strategy and criteria, microbiological criteria for safety and quality, scope of food toxicology, toxic potential and food toxicants, biological and chemical contaminants.

Unit II

Food additives and derived substances, factors affecting toxicity, designing safety in products and processes, intrinsic factors, establishing a safe raw material supply, safe and achievable shelf life.

Unit III

Process equipment and machinery auditing, consideration of risk, environmental consideration, mechanical quality control.

Unit IV

Personnel hygienic standards, preventative pest control, cleaning and disinfesting system, biological factors underlying food safety.

Unit V

Preservation and stability, contaminants of processed foods, adulteration, prevention and control, FSSAI, ISO, Codex, GMP, BIS and HACCP.Practices, principles, standards, specifications, application establishment and implementation, HACCP and quality management system.Food Safety Management Systems (FSMS), Traceability.

VI. Practical

Microbiological examination of food, hazard analysis, premises design, HACCP project plan, CCP, CCP Decision tree, HACCP control chart. HACCP case studies: Survey, BIS, FPO, Codex standards and specifications. Visits to food industries to study the various quality and safety aspects adopted.

VII. Learning outcome:

Student's capability to measure food quality as well as ensure food safety in food supply chain.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Food safety: Need for quality control and safety, strategy and criteria.	2
2.	Microbiological criteria for safety and quality.	1
3.	Scope of food toxicology, toxic potential and food toxicants.	2
4.	Biological and chemical contaminants.	1
5.	Food additives and derived substances, factors affecting toxicity.	2
6.	Designing safety in products and processes, intrinsic factors.	2
7.	Establishing a safe raw material supply, safe and achievable shelf life.	2
8.	Process equipment and machinery auditing.	1
9.	Consideration of risk, environmental consideration. Biological factors underlying food safety.	2
10.	Personnel hygienic standards, preventative pest control. Cleaning and disinfesting system.	2
11.	Preservation and stability, contaminants of processed foods, adulteration, prevention and control	3
12.	FSSAI-Practices, principles, standards, specifications, application establishment and implementation	2
13.	ISO-Practices, principles, standards, specifications, application establishment and implementation.	2
14.	Codex, GMP and BIS - Practices, principles, standards, specifications, application establishment and implementation.	3
15.	HACCP and quality management system.	1
16.	Food Safety Management Systems (FSMS), Traceability.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To test microbiological contamination of food.	1
2.	To conduct hazard analysis.	2
3.	To study the premises design for food safety and quality.	2
4.	To study the HACCP project plan.	1
5.	To prepare CCP and CCP Decision tree.	2

S.No.	Topic	No. of Lectures
6.	To prepare HACCP control chart.	2
7.	To conduct the Survey and study BIS- standards and specifications.	2
8.	To study the FPO standards and specifications.	1
9.	To study the codex standards and specifications.	1
10.	Visits to food industries to study the various quality and safety aspects adopted.	2
	Total	**15**

X. Suggested Reading

- Herschdoerfer, SM. 1984. *Quality Control in the Food Industry*. Vol. 1 Academic Press.
- Herschdoerfer SM. 2012. *Quality Control in the Food Industry*. Vol. 2 Elsevier Science.
- Hubbard MR. 2003. *Statistical Quality Control for the Food Iindustry*. Springer.
- Mahadeviah M and Gowramma R V. 1996. *Food Packaging Materials*. Tata McGraw Hill.
- Mehmet M. 2011. *Biosensors in Food Processing, Safety, and Quality Control*. CRC Press.
- Palling SJ. 1980. *Developments in Food Packaging*. Applied Science Publisher.
- Sacharow S and Grittin RC. 1980. *Principles of Food Packaging*. AVI Publisher.
- Yanbo H, Whittaker AD and Lacey RE. 2001. *Automation for Food Engineering*. Food Quality Quantization and Process Control-CRC Press.

I. Course Title : Food Processing Technologies

II. Course Code : PFE 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with different unit operations to be performed in food industries and related equipment.

V. Theory

Unit I

Mixing and homogenization; Principles of solid and liquid mixing, types of mixers for solids, liquid and pastes homogenization. Emulsification: Principles and equipments.

Unit II

Novel dehydration technologies; Osmotic dehydration, foam mat drying, puff drying, freeze drying, microwave drying, dehumidified air drying. Extrusion: Theory, equipment, applications.

Unit III

Non-thermal processing; Principles and equipment involved in ohmic heating, pulsed electric field preservation, hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology, irradiation, quality changes and effects on microorganisms, nanotechnology in food processing.

Unit IV

Distillation, leaching and extraction: Principles and equipment for distillation, crystallization, phase equilibria, multistage calculations, leaching principles and equipment, solvent extraction, super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and industrial application, advanced methods for extraction of food components and aroma recovery.

Unit V

Food plant hygiene; Cleaning, sterilizing, waste disposal methods, Food processing plant utilities, steam requirements in food processing, HACCP in food processing industries.

VI. Practical

Conducting experiments and solving problems on mixing and mixing indices, homogenization, distillation, crystallisation, extraction, leaching, membrane separation, reverse osmosis and ultrafiltration, design of plate and packed tower, visit to related food industry.

VII. Learning outcome

Student's capability to develop food products using recent techniques as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Mixing and homogenization: Principles of solid and liquid mixing.	1
2.	Types of mixers for solids, liquid and pastes homogenization.	2
3.	Emulsification: Principles and equipments.	1
4.	Novel dehydration technologies: Osmotic dehydration, foam mat drying, puff drying.	2
5.	Freeze drying, microwave drying, and dehumidified air drying.	2
6.	Extrusion: Theory, equipment, applications.	2
7.	Non-thermal processing: Principles and equipment involved in ohmic heating, pulsed electric field preservation.	2
8.	Hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology.	2
9.	Irradiation, quality changes and effects on microorganisms, nanotechnology in food processing.	2
10.	Distillation; Principles and equipment for distillation.	2
11.	Leaching; Principles and equipment.	2
12.	Extraction; Solvent extraction, crystallization, phase equilibria, multistage calculations.	3
13.	Super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and industrial application.	3
14.	Advanced methods for extraction of food components and aroma recovery.	1
15.	Food plant hygiene; Cleaning, sterilizing, waste disposal methods. Food processing plant utilities, steam requirements in food processing.	2
16.	HACCP in food processing industries.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Conducting experiments and solving problems on mixing and mixing indices.	2
2.	To conduct the experiment on homogenization.	2
3.	To study the process of crystallization.	1
4.	To conduct the experiment on extraction.	2
5.	Experimentation on leaching process.	1
6.	To study the membrane separation process.	1
7.	To conduct the experiment on reverse osmosis technique.	1
8.	To conduct the experiment on ultrafilteraion process.	1
9.	Design of plate and packed tower.	2
10.	Visit to related food industry.	2
	Total	**15**

X. Suggested Reading

- Brennan JG, Butters JR, Cowell ND and Lilly AEI 1990. *Food Engineering Operations*. Elsevier.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publisher.
- Geankoplis JC. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.
- Gould GW. 1996. *New Methods of Food Preservation*. Blackie Academic & Professional.
- Heldman DR and Lund BD. 1992. *Hand Book of Food Engineering*. Marcel Dekker.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
- Singh RP 1991. *Fundamentals of Food Process Engineering*. AVI Publisher.
- Singh RP and Heldman DR 1993. *Introduction to Food Engineering*. Academic Press.

I. Course Title : Food Processing Equipment and Plant Design

II. Course Code : PFE 511

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with the design features of different food processing equipment being used in the industries along with the layout, planning of different food processing plants.

V. Theory

Unit I

Design considerations of processing agricultural and food products.

Unit II

Design of machinery for drying, milling, separation, grinding, mixing, evaporation, condensation, membrane separation.

Unit III

Human factors in design, selection of materials of construction and standard component, design standards and testing standards. Plant design concepts and general design considerations: Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.

Unit IV

Feasibility analysis and preparation of feasibility report; Plant size, factors affecting plant size and their interactions, estimation of break-even and economic plant size. Product and process design, process selection, process flow charts, computer aided development of flow charts.

Unit V

Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials, estimation of capital investment, analysis of plant costs and profitability's, management techniques in plant design including applications of network analysis, preparation of project report and its appraisal.

VI. Practical

Detailed design and drawing of mechanical dryers, milling equipment, separators, evaporators, mixers and separators. Each individual student will be asked to select a food processing plant system and develop a plant design report which shall include product identification and selection, site selection, estimation of plant size, process and equipment selection, process flow-sheeting, plant layout, and its evaluation and profitability analysis.

VII. Learning outcome

Student's capability to deal with food processing equipment and plant, techno-economic feasibility analysis of the project as needed in food industries.

VIII. Lecture Schedule

S.No.	Toic	No. of Lectures
1.	Design considerations of processing agricultural and food products. Plant design concepts - situations giving rise to plant design problems.	2
2.	General design considerations, Food Processing Unit Operations, Design of machinery for drying, milling and grinding	2
3.	Design principles of separation, mixing machines	1
4.	Design of evaporation, condensation, membrane separation machines	2
5.	Human factors in design, selection of materials of construction and standard component	1
6.	Design standards and testing standards	1
7.	Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.	2
8.	Pre Selection/ Pre feasibility stage, Analysis Stage: Market Analysis, Situational analysis related to market	1
9.	Technical analysis, Financial Analysis, Sensitivity and risk analysis, Feasibility cost estimates	1
10.	Break Even Analysis: Introduction, Break-Even Chart, Fixed Costs, Variable costs, Breakeven point calculation	1
11.	Product and process design, process selection, process flow charts, computer aided development of flow charts.	1
12.	Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials	1
13.	Estimation of capital investment, analysis of plant costs and profitability's. Management techniques in plant design including applications of network analysis. Project report and its appraisal.	2
	Total	**18**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Detailed design and drawing of mechanical dryers	2
2.	Detailed design and drawing of milling equipment	2
3.	Design of separators	2
4.	Design of evaporators	2
5.	Design of mixers and separators	2
6.	Project report preparation by students. (Individual student will select a processing plant, develop design report include product identification, site selection, estimation of plant size, process and equipment, process flow-sheeting, plant layout, its evaluation and profitability analysis	5
	Total	**15**

X. Suggested Reading

- Antonio LG and Gustavo VBC. 2005. *Food Plant Design*. CRC Press.
- Couper. 2012. *Chemical Process Equipment*. Selection and Design Elsevier.
- George S and Athanasios EK. 2015. *Handbook of Food Processing Equipment*. Springer.
- Lloyd EB and Edwin HY. 1959. *Process Equipment Design*. Wiley-Interscience.
- Michael MC. 2013. *Food Plant Sanitation: Design, Maintenance, and Good Manufacturing Practices*. CRC Press.

I. Course Title : Seed Process Engineering

II. Course Code : PFE 512

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with seed processing along with the design features of the equipment used in their processing.

V. Theory

Unit I

Processing of different seeds and their engineering properties, principles and importance of seed processing.

Unit II

Performance characteristics of different unit operations such as precleaning, grading, conveying, elevating, drying, treating, blending, packaging and storage, seed processing machines like scalper, debreader, huller, velvet separator, spiral separator, cleaner-cum-grader, specific gravity separator, indent cylinder, disc separator, and colour sorter, seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity, seed quality maintenance during processing, plant design and layout, economy and safety consideration in plant design.

Unit III

Seed drying principles and methods, theory of seed drying, introduction to different types of heated air dryers, significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance.

Unit IV

Importance of scientific seed storage, types of storage structures to reduce temperature and humidity, management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging, seed treatment methods and machines used, method of stacking and their impact, design features of medium and long term seed storage building.

VI. Practical

Study of various seed processing equipments such as pre-cleaners, scalpers, air screen cleaners, graders, spiral and pneumatic separators, seed treating equipment, bag closures, scale etc. and their performance evaluation, design and layout of seed processing plant and its economics, analysis of cost of operation and unit cost of processed product, effect of drying temperature and duration of seed germination and storability.

VII. Learning outcome

Student's capability to understand processing and storage requirement of seed maintaining its vigor and viability, suitable equipment for seed processing as per requirement of seed industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Processing of different seeds and their engineering properties.	1
2.	Principles and importance of seed processing.	1
3.	Performance characteristics of different unit operations such as pre-cleaning, grading, conveying, elevating, drying.	1
4.	Treating, blending, packaging and storage, seed processing machines like scalper, de-breeder, huller.	1
5.	Velvet separator, spiral separator, cleaner-cum-grader, specific gravity separator, indent cylinder, disc separator, and colour sorter.	1
6.	Seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity.	1
7.	Seed quality maintenance during processing.	1
8.	Plant design and layout, economy and safety consideration in plant design.	2
9.	Seed drying principles and methods, theory of seed drying.	1
10.	Introduction to different types of heated air dryers.	1
11.	Significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance.	1
12.	Importance of scientific seed storage, types of storage structures to reduce temperature and humidity.	1
13.	Management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging.	1
14.	Seed treatment methods and machines used, method of stacking and their impact.	1
15.	Design features of medium and long term seed storage building.	1
	Total	**16**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	To study seed processing equipment such as pre-cleaners, scalpers and their performance evaluation.	2
2.	To study graders and their performance evaluation.	2
3.	To study air screen cleaners and their performance evaluation.	1
4.	To study spiral and pneumatic separators and their performance evaluation.	2
5.	To study seed treating equipment, bag closures, scale and their performance evaluation.	2
6.	To study design and layout of seed processing plant and its economics.	2
7.	To analyze the cost of operation and unit cost of processed product.	2
8.	To study the effect of drying temperature and duration of seed germination and storability.	2
	Total	**15**

X. Suggested Reading

- Babasaheb. 2004. *Seeds Handbook: Processing and Storage.* CRC.
- Gregg *et al.* 1970. *Seed Processing*. NSC.
- Guar. 2012. *A Handbook of Seed Processing and Marketing* Agrobios.
- Henderson S and Perry S M. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Mathad. 2017. *Seed Processing: A Practical Approach.* NIPA.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publisher House.
- Vaugha. 1968. *Seed Processing and Handling*.https://www.mcia.msstate.edu/pdf/seed-processing-and-handling_1.pdf.

I. Course Title : Agri-Project Planning and Management

II. Course Code : PFE 513

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the techniques of project development and evaluation along with different standards.

V. Theory

Unit I

Project development, market survey and time motion analysis.

Unit II

Selection of equipment, technology option, techno-economic feasibility and processing in production catchment.

Unit III

Product and process design, PERT, CPM, transport model, simplex, linear and dynamic programming, operation log book. Material balance and efficiency analysis, performance testing, performance indices, energy requirement and consumption. Marketing of agricultural products, market positioning.

Unit IV

BIS/FSSAI/ISO standards/ guidelines on best practices, equipment and their design and operation for handling, processing and storage of food/feed.

VI. Practical

Preparation of project and feasibility report. Salient features, design and layout of different food processing units; MSME, large processing unit. Record keeping related to production, finance and marketing. Techno-economic feasibility and SWOT analysis for Start-ups.

VII. Learning outcome

Student's capability to plan, scheduling of activities and manage a food related project as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Project development.	2
2.	Market survey and time motion analysis.	2
3.	Selection of equipment for agro project planning.	2
4.	Technology option.	2
5.	Techno-economic feasibility and processing in production catchment.	2
6.	Product and process design.	2
7.	PERT, CPM.	2
8.	Transport model, simplex, linear and dynamic programming, operation log book.	3
9.	Material balance and efficiency analysis.	3
10.	Performance testing, performance indices, energy requirement and consumption.	3
11.	Marketing of agricultural products, market positioning.	2
12.	BIS/FSSAI/ISO standards/ guidelines on best practices.	2
13.	Equipment and their design and operation for handling, processing and storage of food/feed.	3
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To study the preparation of project and feasibility report.	2
2.	To design salient features, design and layout of MSME.	2
3.	Design and layout of different food processing units: MSME, large processing unit.	2
4.	To study record keeping related to production.	2
5.	To study record keeping related to finance and marketing.	2
6.	To conduct experiment on agro project management and design techno-economic feasibility.	2
7.	To conduct SWOT analysis for different Start-ups.	3
	Total	**15**

X. Suggested Reading

- Ahmed T. 1997. *Dairy Plant Engineering and Management*. 4th Ed. Kitab Mahal.
- Albert L. 2017. *Project Management, Planning and Control*.
- Anandajayasekeram P. 2004. *Agricultural Project Planning and Analysis.*

I. Course Title : Farm Structures and Environmental Control

II. Course Code : PFE 514

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the different types of farm structures and techniques, to control atmospheric parameters and to create favourable environment in the agricultural structures.

V. Theory

Unit I

Farmstead planning, survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal. Project development; Time, motion and input analysis, flow charts and drawings andcase studies.

Unit II

Farm structures (farmstead, livestock, poultry, storage godowns, farm machinery storage, biogas, green house, net house etc), their design, constructional details and design of low cost structures. Heating, ventilating and exhaust systems, air distribution and air cleaning, combustion of fuels and equipment.

Unit III

Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices. Rural electrification, households electric wiring, rural water supply and sanitation.

Unit IV

Instruments and measurements:Codes and standards.

VI. Practical

Calculation of heating and cooling load,design calculation of moisture condensation in agricultural buildings, study of moisture migration behaviour in storage bins, design aspect of green house, net house, septic tank, grain storage structures, cold storage.

VII. Learning outcome

Student's capability to design new farm structures and create suitable atmosphere within it.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Farmstead Planning, types and objectives. Planning principles and layout, design and construction of farmstead.	2
2.	Survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal.	2
3.	Project development: Time, motion and input analysis, flow charts and drawings and case studies.	2
4.	Farm structure, layout and structural design of shelters for dairy animals (cow, buffaloes, calves, bulls etc).	3
5.	Layout and structure design of modern poultry houses (cage type) along with other associated structures.	2

S.No.	Topic	No. of Lectures
6.	Familiarization with various rural grain storage structures. Layout, design and constructional detail of grain and feed storage structures like bins and silos.	3
7.	Layout and structural design of storage structures for farm inputs like farm machinery, seeds, weedicides, insecticides and fertilizers.	1
8.	Ventilation utility in farm buildings; principles of natural ventilation; psychometric processes; heat and mass balance equation for ventilation; ventilation rates for temperature moisture and odour control.	3
9.	Rural electrification, households electric wiring, rural water supply and sanitation.	2
10.	General design considerations, operational and maintenance of biogas plant.	2
11.	Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices.	3
12.	Environmental indices like THI; wet bulb depression, daily range, degree days, effective temperature, black globe temperature; mean radiant temperature, etc. Basic solar-earth angles and sol-air temperature.	3
13.	Instruments and measurements; Codes and standards.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Planning and layout of a farmstead.	1
2.	Instruments for measurements of environmental parameters.	1
3.	Design of a farm fencing system.	1
4.	Study of moisture migration behaviour in storage bins.	1
5.	Design aspect of Septic tank.	1
6.	Design aspect of Net house.	1
7.	Design aspect of Grain storage structures.	1
8.	Design aspect of Green house.	1
9.	Design aspect of Cold storage.	1
10.	Design of a feed/fodder storage structures.	1
11.	Design of a biogas plant.	1
12.	Calculation of heating and cooling load.	1
13.	Design calculation of moisture condensation in agricultural buildings.	1
14.	Design of ventilation system for dairy and poultry house.	1
15.	Visit to Green/ Net house and cold storage.	2
	Total	**16**

X. Suggested Reading

- Albright LD. 1990. *Environmental Control for Animals and Plants*. ASAE Textbooks.
- Esmay ML and Dixon JE. 1986. *Environmental Control for Agricultural Buildings*. The AVI Corp.
- Gaudy AF and Gaudy ET. 1988. *Elements of Bioenvironmental Engineering*. Engineering Press.
- Moore FF. 1994. *Environmental Control Systems: Heating, Cooling, Lighting*. Chapman and Hall.
- Threlkeld JL. 1970. *Thermal Environmental Engineering*. Prentice Hall.

I. Course Title : Dairy Product Processing

II. Course Code : PFE 515

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the various dairy products, processing methods and related equipment.

V. Theory

Unit I

Procurement, transportation and processing of market milk, cleaning and sanitization of dairy equipment. Special milks such as flavoured, sterilized, recombined and reconstituted toned and double toned.

Unit II

Condensed milk: Methods of manufacture and related equipment, evaluation of condensed and evaporated milk. Dried milk: Definition, methods of manufacture of skim and whole milk powder, instantiation, physiochemical properties, evaluation, defects in dried milk powder. Cream: Cream separation, neutralization, sterilization, pasteurization and cooling of cream, defects in cream, Butter: methods of manufacture, defects in butter.

Unit III

Ice cream: Methods of manufacture and related equipment, defects in ice cream, technology of softy manufacture. Cheese: Methods of manufacture, cheddar, Gouda, cottage and processed cheese, defects in cheese.

Unit IV

Indigenous milk products: Method of manufacture of *yoghurt, dahi, khoa, burfi, kalakand, gulabjamun, rosogolla, srikhand, chhana, paneer, ghee, lassi*etc.Probiotic milk product.

VI. Practical

Estimation and fat and SNF in milk.Operation of LTLT and HTST Pasteurization. Preparation of special milks.Cream separation and standardization of milk. Preparation and evaluation of table butter, ice-cream, cheese and indigenous milk product such as *khoa, chhana, paneer, ghee, rosogolla, gulabjamun, shrikhand, lassi, burfi,* etc. Visit to dairy plants.

VII. Learning outcome

Student's capability to mechanize processing operations in dairy industries for manufacturing of dairy products.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Collection and transportation of milk; Practices for collection of milk, preservation at farm, refrigeration, natural microbial inhibitors, lactoperoxidase system.	1
2.	Reception and treatment of milk: Reception, chilling, clarification and storage. General practices. Homogenization: pretreatments, theories, synchronization of homogenizer with operation of pasteurizer (HTST),	

S.No.	Topic	No. of Practicals
	effect of homogenization on physical properties of milk. Bactofugation: Theory and microbiology.	**3**
3.	Principles of thermal processing; kinetics of microbial destruction, thermal death curve, arrhenius equation, D value, Z value, F0 value, Q10 value. Factors affecting thermal destruction of micro organisms. Definition and description of processes; Pasteurization, thermisation, sterilization, UHT Processing.	**2**
4.	Cleaning and sanitization of dairy equipment	**1**
5.	Manufacture of special milks: flavoured, sterilized milk, recombined and reconstituted toned and doubled toned.	**2**
6.	Condensed milk, sweetened condensed milk and evaporated milk. Manufacture of evaporated milk, sweetened condensed milk and Recombined sweetened condensed milk and related equipment	**2**
7.	Physico chemical changes taking place during manufacture of condensed milk, Heat stability of milk and condensed milk, Physico chemical properties of condensed milk, Chemical defects in condensed milk, their causes and prevention.	**2**
8.	Dried Milks; Definition, grading and quality of raw milk for dried milks, Manufacture of skim milk powder (SMP), whole milk powders and heat classified powders,	**2**
9.	Physico chemical changes taking place during manufacture of dried milks, Physical properties of dried milks, Defects in dried milk during manufacture and storage, their causes and prevention.	**2**
10.	Cream: Definition, Efficiency of cream separation and factors affecting it; Neutralization, standardization, pasteurization and cooling of cream; Defects in cream	**2**
11.	Butter; Definition, Introduction to the butter making process; theory of churning, Technology of Butter manufacture, Batch and continuous methods, Defects in butter.	**2**
12.	History of ice cream industry, composition of ice cream, stabilizers and emulsifiers, properties and role in quality of ice cream Ice cream:	**1**
13.	Manufacturing, Ice cream plant components, Types of freezers, refrigeration control/ instrumentation, Technology of softy manufacture.	**2**
14.	Defects in ice cream, their causes and prevention	**1**
15.	Cheese; Manufacture of different varieties of cheese; Cheddar, Gouda, Cottage and processed cheese. Microbiological defects in cheese; their causes and prevention.	**3**
17.	Indigenous milk products: Product description, methods of manufacture of *yoghurt, dahi, khoa, burfi, kalakand, gulabjamun, rosogolla, srikhand, chhana, paneer, ghee, lassi*etc. Probiotic milk product.	**2**
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of fat and SNF in milk.	1
2.	Operation of LTLT and HTST Pasteurizer.	1
3.	Standardization of milk.	1
4.	Preparation of special milks.	1
5.	Cream separation: parts of separator and the process.	1
6.	Preparation of table butter using the power driven churn.	1
7.	Preparation of plain and fruit flavoured ice cream.	1

S.No.	Topic	No. of Practicals
8.	Preparation and analysis of *khoa* from cow and buffalo milk.	1
9.	Preparation and analysis of *chhana* from cow and buffalo milk.	1
10.	Preparation and analysis of *paneer* from cow and buffalo milk.	1
11.	Preparation and analysis of*lassi*from cow and buffalo milk.	1
12.	Preparation of *ghee* from cream and butter.	1
13.	Preparation of *rosogolla* and *gulabjamun*.	1
14.	Preparation of srikhand and burfi.	1
15.	Visit to dairy plant.	1
	Total	**15**

X. Suggested Reading

- Adnan T. 2009. *Dairy Powders and Concentrated Products* (*Society of Dairy Technology*). Wiley-Blackwell.
- Adnan T. 2006. *Probiotic Dairy Products* (*Society of Dairy Technology series*). Wiley-Blackwell.
- Britz. 2008. *Advanced Dairy Science and Technology*. Blackwell Publisher: Blackwell Publisher Professional.
- De. 2001. *Outlines of Diary Technology*. Oxford.
- Hui YH. 1992. *Dairy Science and Technology Handbook*. Vol. I, II and III Wiley.
- Spreer E. 2017. *Milk and Dairy Product Technology*. Taylor and Francis.
- Walstra P, Jan TM, Wouters and Geurts TJ. 2006. *Dairy Science and Technology*. CRC, Taylor and Francis.

I. Course Title : Processing of Meat, Poultry and Fish

II. Course Code : PFE 516

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with processing of meat, fish and poultry and the design features of the equipment used for their processing.

V. Theory

Unit I

Meat: Genetic engineering of farm animals for better meat quality, automation for the modern slaughterhouse, hot-boning of meat, new spectroscopic techniques for online monitoring of meat quality, real-time PCR for the detection of pathogens in meat, new developments in decontaminating raw meat, automated meat processing, developments in chilling and freezing of meat, high pressure processing of meat, approaches for the development of functional meat products, new techniques for analyzing raw meat, modified atmosphere packaging, perspectives for the active packaging of meat products.

Unit II

Poultry: Breeding and quality of poultry, stunning and slaughter of poultry, processing and packaging of poultry, new techniques of preservation of poultry, production of turkeys, geese, ducks and game birds, microbial hazards in poultry production and processing, latest trends in measuring quality of poultry and poultry products, treatment and disposal of poultry processing waste.

Unit III

Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging of seafoods, fish odours and flavours, assessment of freshness of fish and seafoods, traditional dried and salted fish products, proteolysed fish products, minced fish technology, retort pouch processing technology, irradiation and microwave in fish handling and processing, advanced freezing technology for fish storage, high pressure processing of seafoods, value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing and quality control, toxins, pollutants and contaminants in fish and seafoods.

Unit IV

Milk: Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk. Flavour generation in dairy products, controlling texture of fermented dairy products, functional dairy products, on-line measurement of product quality in dairy processing, high pressure processing of milk products, novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products, genetic engineering of milk proteins, production and utilization of functional milk proteins, methods of improving nutritional quality of milk, significance of milk fat in dairy products, chromatographic, spectrometric, ultrasound and other techniques for analysis of milk lipids.

VI. Practical

Analysis of fresh and processed meat, fish, poultry and milk products, preservation of fresh meat and fish, processing and production of different products from fresh meat, fish and milk, shelflife studies on different meat, fish and milk products. Visit to processing plants.

VII. Learning outcome

Student's capability to process meat, fish and poultry and manufacture value added products as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Genetic engineering of farm animals for better meat quality.	1
2.	Developments in automation of the modern slaughterhouse, hot-boning process of meat, benefits of hot boning.	1
3.	New spectroscopic techniques for online monitoring of meat quality, Real-time PCR for the detection of pathogens in meat.	2
4.	Automated meat processing, developments in chilling and freezing of meat, High pressure processing of meat, approaches for the development of functional meat products.	3
5.	New techniques for analyzing raw meat, modified atmosphere and active packaging of meat products.	2
6.	Breeding and quality of poultry, Stunning and slaughter of poultry, Processing and packaging and new techniques of preservation of poultry.	2
7.	Production of turkeys, geese, ducks and game birds.	1
8.	Microbial hazards in poultry production and processing, treatment and disposal of poultry processing waste, Latest trends in measuring quality of poultry and poultry products. Treatment and disposal of poultry processing waste.	3

S No	Topic	No. of Lectures
9.	Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging, Assessment of freshness of fish and seafoods, different traditional and proteolysed fish products, minced fish technology.	3
10.	Retort pouch processing technology, irradiation and microwave in fish processing, Advanced freezing technology for fish storage, Value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing.	3
11.	Quality control: toxins, pollutants and contaminants in fish and sea foods.	1
12.	Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk.	2
13.	Flavour generation in dairy products, controlling of texture in fermented dairy products.	1
14.	Functional dairy products, on-line measurement of product quality, high pressure processing, Novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products.	2
15.	Genetic engineering of milk proteins, production and utilization of functional milk proteins.	1
16.	Methods of improving nutritional quality of milk, significance of milk fat in dairy products and different techniques for analysis of milk lipids.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Analysis of fresh and processed meat products	1
2.	Analysis of fresh and processed fish products	1
3.	Analysis of fresh and processed poultry products	1
4.	Analysis of fresh and processed milk products	1
5.	Preservation of fresh meat and fish	1
6.	Processing and production of different products from fresh meat	2
7.	Processing and production of different products from fresh fish	2
8.	Processing and production of different products from fresh poultry	2
9.	Processing and production of different products from fresh milk	1
10.	Shelf life studies on different meat, fish and milk products	2
11.	Visit to processing plants	1
	Total	**15**

X. Suggested Reading

- Chooksey MK. 2003. *Fish Processing and Product Development*. CIFE, Kochi.
- Chooksey MK and Basu S. 2003. *Practical Manual on Fish Processing and Quality Control*. CIFE, Kochi.
- Hall GM. 1997. *Fish Processing Technology*. Blabie Academic and Professional.
- Lawrie RS. 1985. *Developments in Meat Sciences*. Vol III Applied Science Publishers.
- Mead GC. 1989. *Processing of Poultry*. Elsevier.
- Pearson AM and Tauber FW. 1984. *Processed Meats*. AVI Publishers.
- Stadelman WJ and Cotterill OJ. 1980. *Egg Science and Technology*. AVI Publishers.

I. Course Title : Design of Aquacultural Structures

II. Course Code : PFE 517

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with aquaculture structures and their design features.

V. Theory

Unit I

Inland fish farming and associated considerations.

Unit II

Fish physiology and micro-climatic considerations.Site selection for aquaculture structures.

Unit III

Design of dykes, sluice, channels etc. Aeration and feeding systems: Design of fish rearing structures, hatcheries, containers for live fish, fingerlings, fish seeds.

Unit IV

Aquaculture in recirculatory systems, oxygen and aeration, sterilization and disinfection. Recirculation of water:Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures and water treatment plants.

VI. Practical

Aeration and feeding systems of fish ponds, fish farming structures, water treatment plants, containers for live fish.Design of re-use systems.Inlet and outlet structures.

VII. Learning outcome

Student's capability to design suitable aquaculture structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Inland fish farming.	1
2.	Considerations in site selection for designing inland fish farms.	2
3.	Preparatory work for designing inland fish farms: technological requirements, general technical, hydrological and meteorological data.	3
4.	Fish physiology.	2
5.	Micro-climatic considerations for fish farms.	1
6.	Design of dykes, sluice, channels etc.	3
7.	Aeration and feeding systems.	1
8.	Design of fish rearing structures.	1
9.	Hatcheries.	2
10.	Containers for live fish, fingerlings, fish seeds.	1
11.	Fish pond arrangements: Barrage Ponds, Contour Ponds, Paddy Ponds.	2
12.	Earth structures in fish farms: Dams and Dikes, Feeder Canals, Drainage canals, Drain Ditch, Internal Pond Drains, Borrow Pits and Internal Harvesting Pits.	3
13.	Aquaculture in recirculatory systems.	2
14.	Oxygen and aeration in fish farms. Sterilization and disinfection in fish farms.	2

S.No.	Topic	No. of Lectures
15.	Recirculation of water; Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures.	3
16.	Water treatment plants in fish farms.	1
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of aeration systems of fish ponds.	1
2.	Study of feeding systems of fish ponds.	1
3.	Design of dykes in fish farming structures.	1
4.	Design of feeder canals in fish farming structures.	2
5.	Design of drainage canals in fish farming structures.	1
6.	Design of drain ditch in fish farming structures.	1
7.	Design of internal pond drains in fish farming structures.	1
8.	Design of borrow pits in fish farming structures.	1
9.	Design of internal harvesting pits in fish farming structures.	1
10.	Study of waste water management through aquaculture.	1
11.	Design of recirculatory ponds for waste water treatment in fish farms.	1
12.	Different types of containers for live fish.	1
13.	Design of re-use systems in fish farms.	1
14.	Different types of inlet and outlet structures in fish farms.	1
	Total	**15**

X. Suggested Reading

- FAO. 1983. *Inland Aquaculture Engineering*. ISBN 92-5-102168-6.

I. Course Title : Thermal Environmental Engineering for Agricultural Processing

II. Course Code : PFE 518

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint and equip the students with the concept of thermodynamic properties of air and its application in food processing.

V. Theory

Unit I

Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc.

Unit II

Thermodynamic properties of moist air, psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer, direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials. Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.

Unit III

Design of air conditioning systems, air distribution and duct design, air flow pattern and control, equipment, components and controls.Instruments for measurement and control of temperature and moisture.

Unit IV

Thermal insulation materials for environmental control systems, applications of environmental control in green house, dairy industry, potato storage etc.

VI. Learning outcome

Student's capability to design environmental control systems related to different unit operation in food processing industry.

VII. Schedule of Lectures

S.No.	Topic	No. of Lectures
1.	Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc. Various thermal indices.	5
2.	To study the different temperature, moisture and relative humidity measuring instruments.	3
3.	Thermodynamic properties of moist air.	3
4.	Psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer.	5
5.	Direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials.	4
6.	Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.	5
7.	Introduction to air conditioning systems and design considerations.	4
8.	air distribution and duct design, air flow pattern and control, equipment, components and controls. Instruments for measurement and control of temperature and moisture.	4
9.	Thermal insulation materials for environmental control systems. Comparative performance of these materials.	4
10.	Applications of environmental control in farm buildings, farmstead, green house, dairy industry, poultry shed, potato storage etc.	5
	Total	**42**

VIII. Suggested Reading

- *Perry's Chemical Engineers' Handbook*, Section 12. (2007).
- Threlkald JL. *Thermal Environmental Engineering*, Pearson.

Course Title with Credit Load
Ph.D. in Processing and Food Engineering

Major Courses

Course Code	Course Title	Credit Hours
*PFE 601	Advances in Food Process Engineering	2+1
*PFE 602	Drying and Dehydration of Food Materials	2+1
PFE 603	Textural and Rheological Characteristics of Food Materials	2+1
PFE 604	Agricultural Waste and By-Products Utilization	2+1
PFE 605	Mathematical Modeling in Food Processing	3+0
PFE 606	Bioprocess Engineering	2+1
	Total	**13+5**

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
CSE 506	Digital Image Processing	2+1
CSE 507	Process Control System	2+1
REE 616	Renewable Energy for Industrial Application	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
CE 501	Dimensional Analysis and Similitude	1+1
	Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
STAT 502	Theory of Designs and Analysis of Experiments	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

List of Other Essential Requirements

Course Code	Course Title	Credits
PFE 691	Seminar-I	0+1
PFE 692	Seminar-II	0+1
PFE 699	Thesis Research	0+75

Course Contents
Ph.D. in Processing and Food Engineering

I. Course Title : Advances in Food Process Engineering

II. Course Code : PFE 601

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the modern andlatest techniques offood engineering.

V. Theory

Unit I

Preservation of foods: Physical and chemical methods, microbiological aspects, thermo bacteriology, process calculation and selection. Thermal processing of canned foods: Introduction, commercial sterilization systems, thermal inactivation, kinetics of bacterial spores, heat transfer in canned foods, process calculations, numerical computer simulation of heat transfer, aseptic processing.

Unit II

Low temperature preservation; Cooling and cold storage. Hurdle technology: Principles and applications. Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods. Microwave processing: Interaction with food materials, microwave equipment. Hydrostatic pressure treatment of food: Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermodynamic principles.Applications of HP to foods.Commercial high pressure equipment and applications. Membrane concentration of liquid foods: Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models.

Unit III

Application of heat energy and ultrasound; Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation. Electrical resistance heating of food: Heat generation. Ohmic heating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models. Pulsed electric field preservation: Principles and application, microbial inactivation mechanism, determinant factors in PFE technology, influence on food ingredients, pulsed electric field treatment unit, modeling PFE microbial inactivation, alternative applications of PFE technology, decontamination of microorganisms by surface treatment.

Unit IV

Extrusion cooking: Rheology of extrudates, newtonian models of single-screw extruder performance, non-newtonian models of single-screw extruder performance, single-screw extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, feed zone, behavior of more complex single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence-time distributions, recent developments, methods, equipment, design criteria of extruders.

VI. Practical

Thermal processing of foods, sterilization, irradiation, membrane concentration, ultrasound, ohmic heating, pulsed electric field preservation, extrusion cooking, product quality determination. Visit of related food industries.

VII. Learning outcome

Student's capability to process and preserve food products using advance techniques as per requirement of food industries.

VIII. Lecture Schedule

S.No.	Toic	No. of Lectures
1.	Preservation of foods; Physical and chemical methods, microbiological aspects, thermo bacteriology, process calculation and selection.	3
2.	Thermal processing of canned foods: Introduction, commercial sterilization systems, thermal inactivation, kinetics of bacterial spores, heat transfer in canned foods, process calculations, Numerical computer simulation of heat transfer, aseptic processing.	4
3.	Low temperature preservation: Cooling, cold storage and CA storage.	3
4.	Hurdle technology; Principles and applications.	2
5.	Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods.	2
6.	Microwave processing; Interaction with food materials, microwave equipment.	2
7.	Hydrostatic pressure treatment of food; Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermodynamic principles. Applications of HP to foods. Commercial high pressure equipment and applications.	2
8.	Membrane concentration of liquid foods; Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models.	2
9.	Application of heat energy and ultrasound; Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation	2
10.	Electrical resistance heating of food: Heat generation. Ohmic heating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models.	2

S.No.	Topic	No. of Lectures
11.	Pulsed electric field preservation; Principles and application, microbial inactivation mechanism, determinant factors in PFE technology, influence on food ingredients, pulsed electric field treatment unit, modeling PFE microbial inactivation, alternative applications of PEF technology, decontamination of microorganisms by surface treatment.	2
12.	Extrusion cooking; Rheology of extrudates, Newtonian and non-Newtonian models of single-screw extruder performance, extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence-time distributions, recent developments, design criteria of extruders.	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of thermal processing of foods and equipment, viz. pasteurization and sterilization and tutorials.	2
2.	Study of different irradiation processes and equipments.	1
3.	Study of different membrane separation processes and equipments.	1
4.	Study of different ultrasound processes and equipments	1
5.	Study of different ohmic heating method and equipments.	1
6.	Study of different pulsed electric field preservation processes and equipments.	1
7.	Study of different extrusion cooking method and equipments.	2
8.	Product quality determination	2
9.	Visit of various food industries.	3
10.	Development of experimental setup by students	1
	Total	**15**

X. Suggested Reading

- Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier Publications.
- Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publications.
- Geankoplis J Christie. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.
- Henderson S and Perry SM. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publishing Company.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. VikasPublishing House Pvt Ltd.
- Singh RP and Heldman DR. 1993. *Introduction to Food Engineering*. Academic Press.
- Singh RP. 1991. *Fundamentals of Food Process Engineering*. AVI Publishing Company.

I. Course Title : Drying and Dehydration of Food Materials

II. Course Code : PFE 602

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the latest technologies of dehydration of food products and the design features of different dryers.

V. Theory

Unit I

Importance of drying, principles of drying, moisture determination, equilibrium moisture content, determination of EMC, methods and isotherm models. Psychrometry; Psychrometric terms, construction and use of psychrometric charts.

Unit II

Air flow and resistance, principles and equipment for air movement and heating, drying methods and theory of drying, dryers, classification and other allied equipment, thin layer drying of cereal grains, deep bed and continuous flow drying, drying models.

Unit III

Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration, operation of dryers and their controls, selection of dryers, performance testing of grain dryers, drying characteristics of cereals, pulses and oilseeds, microwave drying, radio frequency drying and tunnel drying, principles and equipment.

Unit IV

Drying of liquid foods, spray drying, drum drying, freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying osmotic dehydration. Principles, methods, construction and adjustments,selection of dryers, heat utilization factor and thermal efficiency.

VI. Practical

Experiments on batch type thin layer dryer, fluidized bed dryer, continuous flow mixing type dryer, continuous flow non mixing type dryer, sand medium dryer (conduction type drying), agricultural waste fired furnace dryer, spray dryer, drum dryer, foam mat drying and osmotic dehydration to evaluate the thermal efficiency and heat utilization factor.

VII. Learning outcome

Student's capability to develop dehydrated food products with higher retention of nutrients using different drying techniques and equipments.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Importance of drying, principles of drying, moisture content determination, equilibrium moisture content, determination of EMC.	2
2.	Basic concepts associated with drying – Intermolecular forces, Water activity, Molecular mobility, Glass transition temperature, Isotherm models – Langmuir, BET Isotherm	3
3.	Psychrometry; Psychrometric terms, construction and use of psychrometric charts.	3
4.	Air flow and resistance, principles and equipment for air movement and heating	3
5.	Theory of drying, Dryers, Classification and other allied equipment,	2
6.	Thin layer drying of cereal grains, deep bed and continuous flow drying, drying models.	3
7.	Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration.	3

S.No.	Topic	No. of Lectures
8.	Operation of dryers and their controls, selection of dryers, performance testing of grain dryers Drying characteristics of cereals, pulses and oilseeds,	3
9.	Microwave drying, radio frequency drying and tunnel drying, principles and equipment.	2
10.	Drying of liquid foods, spray drying, drum drying. Principles, methods, construction and adjustments.	2
11.	Freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying, and osmotic dehydration. Principles, methods, construction and adjustments.	3
12.	Selection of dryers, heat utilization factor and thermal efficiency.	1
	Total	30

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of moisture content with Oven method.	1
2.	Determination of moisture content (w.b.) with Universal/Digital moisture meter.	1
3.	Determination of moisture content (w b) with Infrared moisture meter.	1
4.	Determination of Equilibrium moisture content of grains.	1
5.	Drying of grains in a batch type thin layer dryer to evaluate the thermal efficiency and heat utilization factor.	1
6.	To evaluate the performance of fluidized bed dryer in terms of thermal efficiency and heat utilization factor.	1
7.	To draw a drying rate curve for wet grains in Satake test dryer i.e. Compartment type dryer.	1
8.	Drying of food materials in a solar assisted mechanical tray drying system.	1
9.	To dry grains in continuous flow mixing type dryer.	1
10.	To evaluate the performance of conduction type dryer.	1
11.	To determine the drying efficiency of agricultural waste fired furnace dryer.	1
12.	Drying of liquid food material in a spray dryer and evaluate its thermal efficiency and heat utilization factor.	1
13.	To evaluate the performance of a drum dryer.	1
14.	Experimentation on foam mat drying process.	1
15.	Experiment on osmotic dehydration of grapes.	1
	Total	**15**

X. Suggested Reading

- Bala BK. 1998. *Drying and Storage of Cereal Grains*. Oxford and IBH.
- Brooker DB, Bakker Arkema FW and Hall CW. 1974. *Drying Cereal Grains*. The AVI Publishing Company.
- Chakraverty A and De DS. 1999. *Post-Harvest Technology of Cereals, Pulses and Oilseeds*. Oxford & IBH.
- Hall CW. 1970. *DryingFarm Crops*. Lyall Book Depot.
- Kudra and Mujumdar. 2009. *Advanced Drying Technologies*. CRC press.

I. Course Title : Textural and Rheological Characteristics of Food Materials

II. Course Code : PFE 603

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with advances in measurement of textural and rheological characteristics affecting the food quality.

V. Theory

Unit I

Rheological properties of foods; Food rheology, physical states of materials, classical ideal material, rheological models, elements in the models, electrical equivalence, maxwell model, Kelvin model and four element burger's model, stress-strain behavior. Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation.

Unit II

Viscometry; Capillary viscometry, casson model, flow rate equation, friction losses in pumping, turbulent flow, newtonian fluid, power law fluid, cone and plate viscometry, parallel plate viscometry, mixer viscometry. Flow through a converging die, cogswell's equations, gibson's equations, empirical method. Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances.

Unit III

Objective and subjective measurements of texture; Texture classification, relation of food texture with structure and rheology, principles and practices of objective or instrumental texture measurements, fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation. Imitative and empirical measurements of texture; Tenderometer, brabenderfarinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement.

Unit IV

Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids. Recent advances in textural, rheological and viscoelastic characteristics of foods and their associated mathematical models.

VI. Practical

Determination of viscosity of liquid foods, gumminess, chewiness, springiness and hardness of various fruits, vegetables and processed foods using texture profile analysis.Determination of force-distance relationship.Sensory evaluation/ subjective measurement and correlation between subjective and objective measurements of foods.

VII. Learning outcome

Student's capability to determine textural and rheological properties of food materials and their application in control of food processing operations.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Objective and subjective measurements of texture: Texture classification, relation of food texture with structure and rheology.	3
2.	Principles of Objective Texture Measurement.	2
3.	Practices of objective or instrumental texture measurements.	2
4.	Fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation.	2
5.	Imitative and empirical measurements of texture: Tenderometer, brabender farinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement.	2
6.	Rheological properties of foods: Food rheology, physical states of materials, classical ideal material.	2
7.	Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation.	2
8.	Rheological models, elements in the models, electrical equivalence, maxwell model, Kelvin model and four element burger's model, stress-strain behavior.	2
9.	Viscometry; Capillary viscometry, casson model, flow rate equation, friction losses in pumping, turbulent flow, newtonian fluid, power law fluid, cone and plate viscometry, parallel plate viscometry, mixer viscometry.	2
10.	Flow through a converging die, cogswell's equations, gibson's equations, and empirical method.	2
11.	Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances.	2
12.	Correlation between physical measurements and sensory assessments of texture and viscosity.	2
13.	Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids.	2
14.	Recent advances in textural, rheological and viscoelastic characteristics of foods and their associated mathematical models.	2
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Introduction to Texture analyzer	1
2.	Study of different attachments of texture analyzer used in texture analysis of various agricultural commodities.	1
3.	To study the texture profile curve for food material	1
4.	To study the textural profile kinetics of various fruits	2
5.	To study the textural profile kinetics of various vegetables	2
6.	To study the textural profile kinetics of various processed foods	2
7.	To study the textural properties of liquid food	1
8.	To study the Compression, puncture, elongation and bending tests for food materials	3
9.	Introduction to Rapid Visco analyser	2
10.	Subjective measurement and correlation between subjective and objective measurements of foods.	1
	Total	**16**

X. Suggested Reading

- Bourne MC. 2002. *Food Texture and Viscosity: Concept and Measurement*. Academic Press.
- Deman JM. 1976. *Rheology and Texture in Food Quality*. AVI Publications.
- Mohsanin NN. 1989. *Physical Properties of Plant and Animal Material.* Vol. I, II. Gordon and Breach Science Publications.
- Steffe JF. 1992. *Rheology and Texture in Food Quality*. AVI Publications.

I. Course Title : Agricultural Waste and By-Products Utilization

II. Course Code : PFE 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the techniques of utilization of agricultural waste and by-products and also about development of value added products from wastes.

V. Theory

Unit I

Conversion processes: Thermo-chemical conversions, densification, combustion and gasification, extraction, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process. Agricultural wastes as paper, boards and fuel.

Unit II

Briquetting: Briquetted fuel from husk, hull and other wastes selection, design of briquetting machines. Utilization of shell, stem and stalk:Production of activated carbon. By-products of agro-industries:Rice mill, oil mill, cattle feed mill, valuable constituents and composition. Utilization of rice husk: Production of silica and cement from rice husk.Stabilization and storage of rice bran, extraction of rice bran oil.

Unit III

By-products of oil refining: Fatty acids/soap stock, wax and gum, characteristics and utilization. Rice germ and broken rice. Production of starch and infant food, industrial uses of starch. By-products of oil milling:Oil cake and defatted oil cake, cattle feed and industrial uses. Utilization of starch and other industrial wastes: Microcrystalline cellulose, production of ethanol, wastes of tapioca starch industries,thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes.

Unit IV

By-products of sugar industry: Sugarcane tops, bagasse, molasses and pressmud, utilization as animal feed. By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste.

VI. Practical

Exercises on stepped grate and fixed grate rice husk furnaces, waste fired furnace, briquette machine, production of alcohol from waste materials, production and testing of paperboards and particleboards from agricultural wastes.

VII. Learning outcome

Student's capability to develop processes for effective utilization of wastes generated through milling and processing of food materials.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to by-products and waste generation in agricultural production and processing system. Generation of agricultural and agro industrial by-products/ wastes, their properties, on site handling, storage and processing.	2
2.	Thermo-chemical conversions, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process.	3
3.	Combustion and its types, theory, basic requirements for combustion, extraction.	2
4.	Gasification process, gasifiers- types and their functioning, factors affecting gasification process.	2
5.	Densification process, methods to densify mateials, factors to be considered.	1
6.	Utilization of wastes for paper production, production of particle board.	1
7.	Briquetting process, methods, design of machinery used for briquette formation, basic requirements, factors affecting briquetting from husk, hull and other wastes selection.	2
8.	Utilization of rice husk: Production of silica and cement from rice husk, Stabilization and storage of rice bran, extraction of rice bran oil.	2
9.	Utilization of shell, stem and stalk: Production of activated carbon.	1
10.	By-products from rice milling operations, rice husk, rice bran, utilization in different materials.	3
11.	Waste from oil mill, cattle feed mill, their valuable constituents and composition, utilization.	2
12.	By-products of oil refining: Fatty acids/soap stock, wax and gum, characteristics and utilization.	1
13.	Rice germ and broken rice. Production of starch and infant food, industrial uses of starch.	1
14.	By-products of oil milling: Oil cake and defatted oil cake, cattle feed and industrial uses.	1
15.	Utilization of starch and other industrial wastes: Microcrystalline cellulose, production of ethanol, wastes of tapioca starch industries.	2
16.	Thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes.	2
17.	By-products of sugar industry: Sugarcane tops, bagasse, molasses and press mud, utilization as animal feed.	2
18.	By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste.	2
	Total	32

IX. List of Practicals

S.No.	Experiment	No. of Practicals
1.	To Determine of moisture content of biomass.	1
2.	To Determine of ash content of biomass.	1
3.	To determine Proximate analysis of biomass/waste/residue.	2
4.	Exercises on stepped grate and fixed grate rice husk furnaces.	2
5.	Exercises on waste fired furnaces.	1
6.	Exercises on combustion calculation.	1
7.	To study the briquetting machine.	1

S.No.	Topic	No. of Lectures
8.	To study the various quality parameters of briquettes.	1
9.	To study the production of alcohol from waste materials.	1
10.	To study the production of paper boards and particle boards from agricultural wastes.	2
11.	To determine the properties of paper boards and particle boards from agricultural wastes.	2
	Total	**15**

X. Suggested Reading

- ASAE Standards. 1984. *Manure Production and Characteristics.*
- Bor SL. (Ed.). 1980. *Rice: Production and Utilization*. AVI Publ.
- Chahal DS. 1991. *Food, Feed and Fuel from Biomass*. Oxford & IBH.
- Chakraverty A. 1989. *Biotechnology and other Alternative Technologies for Utilisation of Biomass/Agricultural Wastes*. Oxford & IBH.
- Donald LK and Emert HG. 1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. *Biomass Briquetting and Utilization*. Jain Bros.
- USDA. 1992. *Agricultural Waste Management Field Handbook*. USDA.

I. Course Title : Mathematical Modeling in Food Processing

II. Course Code : PFE 605

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint and equip the students with the mathematical modeling techniques and their applications in food processing

V. Theory

Unit I

An overview of the modeling process.Introduction to mathematical, correlative and explanatory models.Formulation, idealization and simplification of the problems.

Unit II

Probability models, series and linear mathematical approximation, dynamic and interacting dynamic processes.

Unit III

Applications of mathematical modelling techniques to food processing operations like parboiling, convective drying, pasteurization, dehydration, shelf-life prediction, fermentaiton, aseptic processing, moisture diffusion, deep fat drying, microwave processing, infrared heating and ohmic heating.

Unit IV

Stochastic finite element analysis of thermal food processes. Neural networks approach to modelling food processing operations.

VI. Learning outcome

Student's capability to develop models for food processing operations for prediction and control of operations.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	An overview of the modeling process.	2
2.	Introduction to mathematical, correlative and explanatory models. Formulation, idealization and simplification of the problems.	3
3.	Probability models, series and linear mathematical approximation	3
4.	Dynamic Mathematical Model, Analysis of Dynamic Mathematical Models, dynamic and interacting dynamic processes.	3
5.	Basic Concepts of Systems Analysis and Simulation.	2
6.	Common Heat and Mass Transfer Models Dimensional Analysis.	3
7.	Model-based techniques in food processing.	2
8.	Applications of mathematical modelling techniques to parboiling of rice, convective drying/ dehydration, deep fat drying etc.	4
9.	Applications of mathematical modelling techniques to pasteurization of milk and juices.	4
10.	Applications of mathematical modelling techniques to fermentation, aseptic processing, moisture diffusion.	4
11.	Applications of mathematical modelling techniques in shelf-life prediction of agricultural commodities.	3
12.	Applications of mathematical modelling techniques to microwave heating, infrared heating and ohmic heating.	3
13.	Stochastic finite element analysis of thermal food processes.	3
14.	Probability models, series and linear mathematical approximation	3
15.	Neural networks approach to modelling food processing operations.	3
	Total	**45**

VIII. Suggested Reading

- Fischer M, Scholten HJ and Unwin D. 1996. *Spatial Analytical Perspectives on GIS*. Taylor & Francis.
- Fish NM and Fox RI. 1989. *Computer Application in Fermentation Technology: Modelling and Control of Biotechnological Processes*. Elsevier.
- Gold HJ. 1977. *Mathematical Modelling of Biological Systems - An Introductory Guidebook*. John Wiley & Sons.
- Hunt DR. 1986. *Engineering Models for Agricultural Production*. The AVI Publ.
- Koeing HE, Tokad Y, Kesacan HK and Hedgers HG. 1967. *Analysis of Discrete Physical Systems*. McGraw Hill.
- Meyer JW. 2004. *Concepts of Mathematical Modeling*. McGraw Hill.
- Peart RM and Curry RB. 1998. *Agricultural Systems, Modelling and Simulation*. Marcel Dekker.
- Tijms HC. 1984. *Modelling and Analysis. A Congrtational Approach*. Wiley Publ.

I. Course Title : Bioprocess Engineering

II. Course Code : PFE 606

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip the students with the basic principles of biochemical process engineering.

V. Theory

Unit I

Applications of engineering principles: Mass and energy balance, fluid flow principles, Unit operations of process engineering.

Unit II

Fundamentals of growth kinetics, maintenance energy and yield concepts, principles of media sterilization, media formulations of industrial fermentation.

Unit III

Aerobic and agitated rheology of fermentative fluids, design and scale-up of bioreactors, enzyme reactors.

Unit IV

Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon.

VI. Practical

Kinetics of one substitute reactions, kinetics of growth in batch cultures, design consideration for bioreactors, media preparation and sterilization, microprocessor based monitoring of bioprocess parameters.

VII. Learning outcome

Student's capability to calculate the mass and energy balances in ant process operations, understanding growth kinetics and design bioreactors as per requirement of food industries.

VIII. Lectures Schedule

S.No.	Topic	No. of Lectures
1.	Basic engineering principles and their applications. Use of units and dimensions.	3
2.	Mass balance: steady and unsteady. Problem solving involving blending, separation, drying, growth, recycling etc.	3
3.	Energy balance in food processing operations. Use of steam tables in calculation of heat requirements etc.	3
4.	Fluid flow principles: Static and dynamic. Concept of viscosity. Types of flow. Flow through pipes. Mass and energy balance in fluid flow. Calculation of pressure drop in pipes.	4
5.	Fundamentals of growth kinetics, maintenance energy and yield concepts.	3
6.	Principles of media sterilization, media formulations of industrial fermentation.	3
7.	Aerobic and agitated rheology of fermentative fluids.	3
8.	Design and scale-up of bioreactors, enzyme reactors.	3
9.	Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon.	5
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To study the instruments used for measurement of temperature, relative humidity, flow rate, pressure, wind velocity, solar radiation etc.	1
2.	Use of units, dimensions and basic mathematical applications.	1
3.	To judge the students ability for solving mass balance problems.	2
4.	To judge the students ability for solving Energy balance problems.	2
5.	To study the kinetics of one substitute reactions.	1

S.No.	Topic	No. of Practicals
6.	To assess the kinetics of growth in batch cultures.	1
7.	To study the order of reactions involving single/multiple reactants/products.	1
8.	To study the various thermal and structural parameters affecting the design of bioreactors.	1
9.	To assess the student's ability for design of bioreactors by solving related numerical problems.	2
10.	To prepare various media cultures and assess their effectiveness with time.	1
11.	To study the mechanism of sterilization of cultures.	1
12.	To study the various electronic gadgets for continuous monitoring of bioprocess parameters.	1
	Total	**15**

X. Suggested Reading

- Brennan JG, Butters JR, Cavell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier.
- Coulson JM and Richadson JF. 1999. *Chemical Engineering*. Vols. II, IV. The Pergamon Press.
- Greanoplis JC. 1999. *Transport Process and Unit Operation*. Allyn & Bacon
- Treybal RE. 1981. *Mass Transfer Operations*. 3rd Ed. Harper & Row.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Irrigation and Drainage Engineering

Preamble

(Irrigation and Drainage Engineering)

Course curricula and course outlines in Irrigation and Drainage Engineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Soil Science, Agronomy and Agricultural Meteorology.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector.

All courses are designed to cover all basic topics and have been designed by taking into consideration demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students. The emphasis has been given on precision irrigation and modeling management and accordingly new courses “Water and nutrient management under protected cultivation, Waste water management and utilization in agriculture, Sensing and automation in irrigation systems, Climate change and water resources, Multi criteria decision making system” are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Irrigation and Drainage Engineering. The revised courses cover the areas: Design of farm drainage systems, Command area management, Design of surface irrigation systems, Design of drip and sprinkler irrigation systems, Ground water engineering, Remote sensing and GIS for land and water resource management, Water conveyance and distribution, Minor irrigation, Design of pumps for irrigation and drainage, Water resources systems engineering, Irrigation economics, Planning and management, Watershed management and modeling, Flow through porous media, Dryland water management technologies, Recent developments in irrigation engineering, Advances in drainage engineering, Hydro-Mechanics and ground water modeling, Soil-Water-Plant-Atmospheric modeling, Plant growth modeling and simulation, Applied watershed hydrology, Reservoir operation and river basin modeling and Modeling soil erosion processes and sedimentation.

The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech. in Irrigation and Drainage Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credits
IDE 501	Design of Surface Irrigation Systems	1+1
*IDE 502	Design of Farm Drainage Systems	2+1
IDE 503	Command Area Management	2+1
IDE 504	Water and Nutrient Management Under Protected Cultivation	2+1
*IDE 505	Design of Drip and Sprinkler Irrigation Systems	2+1
*IDE 506	Ground Water Engineering	2+1
SWCE 507/IDE 507	Remote Sensing and GIS for Land and Water Resource Management	2+1
IDE 508	Waste Water Management and Utilization in Agriculture	2+1
IDE 509	Water Conveyance and Distribution	2+1
IDE 510	Minor Irrigation	2+1
IDE 511	Design of Pumps for Irrigation and Drainage	2+0
IDE 512	Crop Environmental Engineering	2+0
IDE 513	Water Resources Systems Engineering	2+1
IDE 514	Irrigation Economics, Planning and Management	2+0
IDE 515	Sensing and Automation in Irrigation Systems	3+0
	Total	30+11

*Compulsory course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credits
SWCE 505	Watershed Management and Modeling	2+1
SWCE 506	Flow Through Porous Media	2+0
SWCE 508	Climate Change and Water Resources	3+0
SWCE 510	Dryland Water Management Technologies	2+0
FMPE 517	Machinery for Precision Agriculture	2+1
REE 513	Energy, Ecology and Environment	3+0
CE 501	Dimensional Analysis and Similitude	2+0
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
CSE 504	Soft Computing Techniques in Engineering	2+1

Course Code	Course Title	Credits
MATH 501	Finite Element Methods	2+0
MATH 502	Numerical Methods for Engineers	2+0
ME 501	Mechatronics and Robotics in Agriculture	2+0
	Any other course(s) of other department can be taken as per recommendationsof the student’s advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credits
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student’s advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credits
*PGS 501	Library and Information Services	1+0
*PGS 502	Technical Writing and Communication Skills	1+0
*PGS 503	Intellectual Property and its management in Agriculture	1+0
*PGS 504	Basic Concepts in Laboratory Techniques	1+0
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Course Code	Course Title	Credits
IDE 591	Seminar	0+1
IDE 599	Thesis Research	0+30

Course Contents
M.Tech. in Irrigation and Drainage Engineering

I. Course Title : Design of Surface Irrigation Systems

II. Course Code : IDE 501

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint students for design and evaluation of various surface irrigation methods, design optimum layout, conveyance network for efficient use of water in surface irrigation system.

V. Theory

Unit I

Climate and irrigation water requirement. Irrigation principles, losses, conveyance, distribution, application and water budgeting. Estimation techniques of effective rainfall. Irrigation softwares: CROPWAT, AQUACROP.

Unit II

Farm irrigation systems. Irrigation efficiencies. Economic feasibility. Irrigation water quality and salinity management techniques. Design of water conveyance, control and distribution systems.

Unit III

Hydraulics: Design and operation of border, check basin, furrow, sprinkler and trickle irrigation systems. Flow dynamics, drop size distribution and spray losses in sprinklers. Cablegation, surge and bubbler irrigation. Automation of irrigation system.

Unit IV

Basic water management concepts and objectives. Alternative irrigation scheduling techniques. Integrated approach to irrigation water management.

VI. Practical

Design and evaluation of border, furrow, check basin, sprinkler and micro-irrigation. Computation of frictional losses. Design of underground water conveyance systems. Economics of irrigation methods. Visit to mechanized farms.

VII. Learning outcome

The students will be able to plan and design various surface irrigation systems and irrigation scheduling techniques for efficient use of water. They will also be exposed to irrigation softwares used for design purpose.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Climate and irrigation water requirement	1
2.	Irrigation principles, losses, conveyance, distribution, application and water budgeting	2

S.No.	Topic	No. of Lectures
3.	Estimation techniques of effective rainfall	2
4.	Irrigation softwares; CROPWAT, AQUACROP	2
5.	Farm irrigation systems. Irrigation efficiencies, Economic feasibility	2
6.	Irrigation water quality and salinity management techniques	2
7.	Design of water conveyance, control and distribution systems	2
8.	Hydraulics; Design and operation of border, check basin and furrow irrigation systems.	5
9.	Hydraulics: Design and operation of sprinkler and trickle irrigation systems	4
10.	Flow dynamics, drop size distribution and spray losses in sprinklers	2
11.	Cablegation, surge and bubbler irrigation	3
12.	Automation of irrigation system	2
13.	Basic water management concepts and objectives	2
14.	Alternative irrigation scheduling techniques	1
15.	Integrated approach to irrigation water management	2
	Total	**34**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of different techniques of effective rainfall	1
2.	Design of irrigation methods using irrigation software's: CROPWAT, AQUACROP	3
3.	Design of water conveyance, control and distribution systems.	1
4.	Design and evaluation of border irrigation method	1
5.	Design and evaluation of furrow irrigation method	1
6.	Design and evaluation of check basin method	1
7.	Design and evaluation of sprinkler irrigation method	1
8.	Design and evaluation of trickle irrigation method	1
9.	Study of automation of irrigation system	1
10.	Design of underground water conveyance systems	1
11.	Study of economics of irrigation methods	2
12.	Visit to mechanized farms	1
	Total	**15**

X. Suggested Reading

- Finkel HJ. 1983. *Handbook of Irrigation Technology*. Vols. I-II, CRC Press.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.
- Karmeli D, Peri G and Todes M. 1985. *Irrigation Systems: Design and Operation*. Oxford University Press.
- Michael AM. 2008. *Irrigation Theory and Practices*. Vikas Publishing House Pvt. Ltd, New Delhi.
- Pillsbury AF. 1972. *Sprinkler Irrigation*. FAO Agricultural Development Paper No. 88, FAO.
- Rydzewski. 1987. *Irrigation Development Planning*. John Wiley and Sons.
- Sivanappan RK 1987. *Sprinkler Irrigation*. Oxford and IBH.
- Sivanappan RK, Padmakumari O and Kumar V. 1987. *Drip Irrigation*. Keerthy Publ, House.

I. Course Title : Design of Farm Drainage Systems

II. Course Code : IDE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge of water logging and salt affected areas, surface and sub-surface drainage systems, design and reclamation of salt affected waterlogged areas.

V. Theory

Unit I

Salt affected waterlogged areas in India. Water quality criteria and brackish water use for agriculture. Drainage requirements and crop growth under salt affected waterlogged soil.

Unit II

Concept of critical water table depth for waterlogged soil and crop growth. Drainage investigations and drainage characteristics of various soils. Methods of drainage system and drainage coefficient.

Unit III

Theories and applications of surface and subsurface drainage. Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils. Theories and design of vertical drainage, horizontal subsurface drainage and multiple well point system. Drainage materials.

Unit IV

Steady and unsteady state drainage equations for layered and non-layered soils. Principle and applications of Hooghoudt, Kirkham, Earnst, Glover Dumm, Kraijenhoff-van-de-leur equations. Drainage for salinity control.

Unit V

Salt balance, leaching requirement and management practices under drained conditions. Disposal of drainage effluents. Case study for reclamation of salt affected waterlogged areas.

VI. Practical

Measurement of in-situ hydraulic conductivity. Estimation of drainage coefficient and leaching requirements. Delineation of waterlogged areas through isobar, isobath and topographic maps. Design of surface and subsurface drainage systems. Design of filter and envelop materials.

VII. Learning outcome

The students will able to develop surface as well as subsurface drainage network in the agriculture field, install and laying of the drainage pipe with fitting of all accessories at their place and derive equation for different flow in drainage system and their approaches.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Waterlogging, causes of waterlogging, salt built up in waterlogged soil, solute transport in salt affected soil. Recent salt affected areas in different states and country as whole	2

S.No.	Topic	No. of Lectures
2.	Technology and approach for reclamation of salt affect waterlogged areas	2
3.	Drainage requirement and crop growth under salt affected waterlogged soil. Drainage water/ brackish water quality and it's criteria for use in agriculture	2
4.	Concept of critical water table depth for waterlogged soil and crop growth	1
5.	Drainage investigations and drainage characteristics of various soils.	2
6.	Methods of drainage system: surface, sub surface, well drainage and bio-drainage and drainage coefficient	1
7.	Theories and applications of surface and sub surface drainage	3
8.	Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils	3
9.	Theories of vertical and horizontal subsurface drainage systems	2
10.	Theory, design and application of multiple well point system	1
11.	Drainage materials. Design of filter and envelop for drainage system with different materials	2
12.	Steady state drainage equations for layered and non layer soils	2
13.	Unsteady state drainage equations for layered and non layer soils	3
14.	Principle and application, Hooghoudt and Khirkham equation	3
15.	Principles and application of Ernst, Glover Dumm, Karigenth off–van-de-law eaquation	2
16.	Drainage for salinity control, salt balance equation, leaching requirement and management practices under drained conditions, Disposal of drainage effluents	3
17.	Case study: Integrated planning, design and installation of drainage system for reclamation of salt affected waterlogged areas	2
	Total	**36**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of waterlogged areas through isobar, isobath and topographic maps	3
2.	Measurement of in-situ hydraulic conductivity	1
3.	Estimation of drainage coefficient from rainfall data	2
4.	Determination of leaching requirements for reclamation of salt affected land	2
5.	Design of surface drainage systems	2
6.	Design of subsurface drainage systems	2
7.	Design of filter and envelop materials	2
8.	Visit to drainage installation site/Institute	2
	Total	**16**

X. Suggested Reading

- Bhattacharaya AK and Michael AM. 2003. *Land Drainage*. Vikas Publ.
- Clande Ayres and Daniel Scoates AE. 1989. *Level Drainage and Reclamation*. Mc.Graw Hill.
- Luthin JN. 1978. *Drainage Engineering*. Wiley Eastern.
- Ritzema HP (Ed.) 1994. *Drainage Principles and Applications*. ILRI
- Roe CE. 1966. *Engineering for Agricultural Drainage*. McGraw Hill.
- Schilfgaarde Jan Van (Editor). 1974. *Drainage for Agriculture*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

I. Course Title : Command Area Management

II. Course Code : IDE 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concept of command area management, assessment and appraisal of water availability in command areas, water management problems in command areas and their possible remedies including socio-economic aspects of irrigation command.

V. Theory

Unit I

Concept of command area development as an integrated approach. Command area project formulation, major, medium and minor projects. Command areas in India, command area activities and their prioritization. Source of budget for CAD works. Structure of command area development, organization, role and responsibilities of CADA.

Unit II

Laser based land grading survey and levelling in command areas. Design of lined and unlined canals. Diversion head works and canal head regulators, cross drainage works, canal falls, canal breaches. Design of On Farm Water Distribution Network, operation and maintenance of canal.

Unit III

Assessment and appraisal of water availability in command areas. Water management problems in command areas and their possible remedies. Duty of water, its determination and factors affecting it. Methods of improving duty of canal water. Feasibility of drip irrigation in irrigated command areas.

Unit IV

Single and multi-objective command area planning for the better management and allocation of irrigation water. Conjunctive use of canal water and groundwater. Real time canal irrigation scheduling.

Unit IV

Canal performance indices. Diagnostic analysis and perform appraisal of command area projects. Water user's association–functions, problems encountered during formation of WUA and strategy and overcome the problems. Participatory irrigation management efforts and strategy for preparing PIM. Socio economic aspects of irrigation management in command areas.

VI. Practical

Study of canal, tank and tube well in a command area. Study of design and operational parameters of a command area. Study of water balance in a command. Study the impact of command area project on crop yield and environment. Conflict resolution through PRA exercise. Diagnostic analysis of the problems of command area through PRA and field observations. Analysis of equity in water distribution. Considerations for preparation of roistering schedules. Study of the functioning of irrigation cooperatives/water user's associations. Preparation of command area development plan.

VII. Learning outcome

The students will be able to understand the concept of command area and its management, to analyze problem diagnostics and remedies of command area and able to understand the performance evaluation procedure of command area.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of command area development as an integrated approach	1
2.	Command area project formulation, major, medium and minor projects	2
3.	Command areas in India	1
4.	Command area activities and their prioritization	1
5.	Source of budget for CAD works	1
6.	Structure of command area development	1
7.	Organization, role and responsibilities of CADA	1
8.	Laser based land grading survey and levelling in command areas	1
9.	Design of lined and unlined canals	2
10.	Diversion head works and canal head regulators, cross drainage works, canal falls, canal breaches	2
11.	Design of On Farm Water Distribution	1
12.	Network, operation and maintenance of canal	1
13.	Assessment and appraisal of water availability in command areas	1
14.	Water management problems in command areas and their possible remedies	2
15.	Duty of water, its determination and factors affecting it. Methods of improving duty of canal water	2
16.	Feasibility of drip irrigation in irrigated command areas	1
17.	Single and multi-objective command area planning for the better management and allocation of irrigation water	1
18.	Conjunctive use of canal water and groundwater	1
19.	Real time canal irrigation scheduling	1
20.	Canal performance indices	1
21.	Diagnostic analysis and perform appraisal of command area projects	1
22.	Water user's association–functions, problems encountered during formation of WUA and strategy and overcome the problems	2
23.	Participatory irrigation management efforts and strategy for preparing PIM	2
24.	Socio economic aspects of irrigation management in command areas	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of canal, tank and tube well in a command area	1
2.	Study of design and operational parameters of a command area	2
3.	Study of water balance in a command	1
4.	Study the impact of command area project on crop yield and environment	2
5.	Study about conflict resolution through PRA exercise	2
6.	Diagnostic analysis of the problems of command area through PRA and field observations	2
7.	Analysis of equity in water distribution	1

S.No.	Topic	No. of Lectures
8.	Considerations for preparation of roistering schedules	1
9.	Study of the functioning of irrigation cooperatives/water user's associations	2
10.	Preparation of command area development plan	2
	Total	**16**

X. Suggested Reading

- Jos´eLiria Montanes. 2006. *Design, Construction, Regulation and Maintenance*. Taylor and Francis Publication.
- Modi PN. *Irrigation Water Resources and Water Power Engineering*. Standard Publishers.
- Singh VP. 2014. *Entropy Theory in Hydraulic Engineering: An Introduction*. ASCE Press.
- Sharma SK. *Irrigation Water Resources and Water Power Engineering*. Standard Publishers.
- Swamee PK and Chahar BR. *Design of Canals*. Springer Publications.

I. Course Title : Water and Nutrient Management under Protected Cultivation

II. Course Code : IDE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concept of soilless culture in agriculture, water and nutrient management, water potential in soilless media and automation for climate control under protected cultivation.

V. Theory

Unit I

Significance of soilless culture in agriculture. Functions of the root system. Response of root growth to local nutrient concentrations. Interactions between environmental conditions and form of N nutrition.

Unit II

Roots as source and sink for organic compounds and plant hormones. Physical and chemical properties of soilless media.

Unit III

Water content and water potential in soilless media. Water movement in soilless media. Uptake of water by plants in soilless media and water availability.

Unit IV

Production technology for vegetables under protected conditions in soil and soilless media. Automation for climate control in protected structures. Thermal modeling of greenhouse environment for protected cultivation.

VI. Practical

Filter types and its selection criteria. Design and installation of drip irrigation system for vegetables and orchards. Irrigation and fertigation scheduling for vegetables and horticultural. Study of different types of sensors, relay and control mechanism for controlled irrigation and fertigation. Design of automated system for irrigation and fertigation. Design and installation of different protected structures as per the guidelines of NHM. Design and fabrication of soilless medium for crop/flower production. Economical evaluation of automated irrigation system and soilless medium for crop/flower production.

VII. Learning outcome

The students will able to understand the concept of soilless farming including nutrient management, water content and water potential in soilless media along with automation for climate control under protected cultivation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Significance of soilless culture in agriculture	1
2.	Functions of the root systems	1
3.	Response of root growth to local nutrient concentrations	2
4.	Interactions between environmental conditions and form of N nutrition	2
5.	Roots as source and sink for organic compounds and plant hormones	2
6.	Physical and chemical properties of soilless media	2
7.	Water content and water potential in soilless media	2
8.	Water movement in soilless media: water retained, drainage, plant use, etc	2
9.	Uptake of water by plants in soilless media and water availability	3
10.	Production technology for vegetables under protected conditions in soil and soilless media	4
11.	Automation for climate control in protected structures	3
12.	Thermal modeling of greenhouse environment using multiple regressions	2
13.	Thermal modeling of greenhouse environment using energy and mass balance approaches	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To study the filter types and their selection criteria	1
2.	Design and installation of drip irrigation system for vegetables	1
3.	Design and installation of drip irrigation system for orchards	1
4.	Irrigation and fertigation scheduling for vegetables and horticultural crops	1
5.	Study of different types of sensors, relay and control mechanism for controlled irrigation and fertigation	1
6.	Design of automated system for irrigation and fertigation	1
7.	Design and installation of different protected structures as per guidelines of NHM	6
8.	Design and fabrication of soilless medium for vegetable crops	1
9.	Design and fabrication of soilless medium for flower production	1
10.	Economical evaluation of automated irrigation system and soilless medium for crop/flower production	1
	Total	**15**

X. Suggested Reading

- Howard M Resh. *Hydroponic Food Production*. CRC Press, New York.
- Michael Raviv and Heinrich J Lieth 2014. *Soilless Culture*. CRC Press.
- Meier Schwarz. *Soilless Culture Management*. Springer publications, New York.

I. Course Title : Design of Drip and Sprinkler Irrigation Systems

II. Course Code : IDE 505

III. Credit Hours : 2+1

IV. Aim of the course

To provide exposure of new cutting-edge technologies to the students in design of drip and sprinkler irrigation systems including selection of pipe and fertigation techniques.

V. Theory

Unit I

Suitability of sprinkler and drip irrigation systems under Indian conditions. Basic hydraulics of sprinkler and micro irrigation system.

Unit II

Pipe flow analysis. Friction losses and pressure variation. Flow in nozzles and emitters.

Unit III

Design and evaluation of sprinkler and micro irrigation systems in relation to source, soil, climate and topographical conditions.

Unit IV

Selection of pipe size, pumps and power units. Layout, distribution, efficiency and economics.

Unit V

Fertigation through sprinkler and micro irrigation systems. Fertigation techniques involved in drip and sprinkler irrigation system.

VI. Practical

Design of drip and sprinkler irrigation system. Calculation of total head. Determination of uniformity of sprinkler discharge at field. Numerical on hydraulics of dripper. Calculation of different types of efficiencies of installed drip system. Calculation of cost benefits of drip and sprinkler irrigation system.

VII. Learning outcome

Students will understand design aspects of various drip and sprinkler irrigation systems including friction losses and flow variations. They may also expose to various fertigation techniques involved in the system.

VIII. Lecture Schedule

S.No.	Topic	No. of lectures
1	Plant-soil-atmosphere relationships	3
2	Evapotranspiration, methods for estimation of evapotranspiration, Irrigation water requirements, Irrigation principles, Numerical Problems	2
3	Drip irrigation, adaptability, limitations, components and classification of systems	2
4	Pipe flow analysis, types of friction losses in main, sub-main and lateral, pressure variation in drip irrigation system and their calculations	2

S.No.	Topic	No. of Lectures
5	Design of drip irrigation system based on source of irrigation, soil, climate and topographical conditions and hydraulics of drip components with numerical problems	3
6	Selection of pipe, pump and power unit	2
7	Fertigation: advantages, limitations, methods, fertilizers solubility and their compatibility, precautions, frequency, duration and injection rate, Emitter clogging and prevention	2
8	Performance evaluation of drip irrigation system	1
9	Sprinkler irrigation, adaptability, limitations, components and classification of systems	2
10	Pipe flow analysis, types of friction losses, pressure variation in sprinkler irrigation system and their calculations	2
11	Flow in nozzles, drop size distribution, spray evaporation	1
12	Hydraulic and engineering design of sprinkler irrigation system on source of irrigation, soil, climate and topographical conditions, numerical problems	3
13	Fertigation techniques in sprinkler irrigation	1
14	Selection of pipe, pump and power unit	2
15	Performance evaluation of sprinkler irrigation system	1
16	Irrigation scheduling techniques and automation in drip and sprinkler irrigation system	2
17	Benefit cost ratio of drip and sprinkler irrigation system	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of different components of drip and sprinkler irrigation system	1
2.	Determination of physical properties of soil	1
3.	Design of drip irrigation system for orchards	1
4.	Design of micro-irrigation system for row crops	1
5.	Design of sprinkler irrigation system for vegetable crops	1
6.	Design of sprinkler irrigation system for field crops	1
7.	Estimation of total head in drip and sprinkler irrigation system	1
8.	Determination of filtration efficiency of different filters	1
9.	Evaluation of drip irrigation system	1
10.	Determination of uniformity of sprinkler discharge at field	1
11.	Study of hydraulics of drippers	1
12.	Estimation of fertigation rate in drip irrigation system	1
13.	Calculation of different types of efficiencies of installed drip system	1
14.	Study of Automation in micro-irrigation system	1
15.	Calculation of cost benefits of drip irrigation system	1
16.	Calculation of cost benefits of sprinkler irrigation system	1
	Total	**16**

X. Suggested Reading

- Jensen ME. (Editor). 1983. *Design and Operation of Farm Irrigation Systems*. ASAE, Monograph No. 3. USA.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.

- Michael AM. 2006. *Irrigation Theory and Practice*. Vikas Publ. New Delhi.
- Withers Bruce and Vipond Stanley. 1974. *Irrigation: Design and Practice.* B.T. Batsford Ltd, London.
- Sivanappan RK. 1987. *Sprinkler Irrigation*. Oxford and IBH Publishing Co. New Delhi.

I. Course Title : Ground Water Engineering

II. Course Code : IDE 506

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge to the students in aquifers, groundwater flow, artificial groundwater recharge techniques, well hydraulics and groundwater models.

V. Theory

Unit I

Water resources of India. Occurrence, storage and movement of groundwater in alluvial and hard rock formations. Principles of groundwater flow. Interaction between surface water and groundwater.

Unit II

Natural and artificial groundwater recharge. Conjunctive use of surface and groundwater. Groundwater balance. Fluctuation of water table beneath a recharge site. Delineation of groundwater potential zones using RS and GIS, MODFLOW equation.

Unit III

Derivation of hydraulics of fully and partially penetrating wells in confined, leaky and unconfined aquifers. Flow net analysis.

Unit IV

Analysis of multi aquifers. Flow analysis in interfering wells. Pumping tests for estimation of aquifer parameters. Wells near recharge and impermeable boundaries. Skimming well technology.

Unit V

Design of well field. Salt water intrusion in inland and coastal aquifers. Application of groundwater models for groundwater management. Calibration and validation of models.

VI. Practical

Water table contour maps and determination of groundwater flow. Estimation of aquifer characteristics. Problems on non-leaky and leaky aquifers. Analysis of pumping test data. Computation of interference of wells. Groundwater computer simulation models.

VII. Learning outcome

The student will be able to analyze storage, movement and flow characteristics of different aquifers and also model ground water and plan for ground water recharge including delineation of potential groundwater recharge zones.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Water Resources of India. Occurrence, movement of groundwater and storage of groundwater in geological formation	2
2.	Study of hydro geological formation in India	1
3.	Principal of Groundwater flow. Interaction between surface water and groundwater.	
4.	Natural and artificial groundwater recharge. Conjunctive use of surface and groundwater	1
5.	Groundwater balance and fluctuation of water table beneath recharge sites	2
6.	Delineation of groundwater potential zones using RS and GIS	2
7.	Study of MODFLOW and its application	2
8.	Hydraulics of wells	1
9.	Steady state flow to fully penetrating well in unconfined, confined and leaky aquifer	2
10.	Unsteady state flow to fully penetrating wells in unconfined, confined and leaky aquifer	3
11.	Steady state flow to partially penetrating well in unconfined, confined and leaky aquifer	2
12.	Unsteady state flow to partially penetrating wells in unconfined, confined and leaky aquifer	3
13.	Flow net analysis for groundwater flow	1
14.	Steady and Unsteady flow in Multi aquifers	2
15.	Flow analysis in interfering multiple wells	2
16.	Pumping tests for estimation of aquifer parameters	1
17.	Flow to wells near recharge and impermeable boundaries	2
18.	Design of well field and skimming well technology (multiple well point system)	2
19.	Salt water intrusion in inland and coastal aquifers	2
20.	Groundwater modelling approaches	1
21.	Study of various groundwater models	2
22.	Application of groundwater models for groundwater management	2
23.	Calibration and validation of models	2
	Total	**40**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of water table contour maps.	2
2.	Determination of groundwater flow using contour maps	1
3.	Estimation of aquifer characteristics by Theis and Cooper-Jacob method	2
4.	Estimation of aquifer characteristics by Chow's and Theis recovery method	2
5.	Hand on exercise for analysis groundwater flow through well in leaky aquifers.	2
6.	Hand on exercise for analysis groundwater flow through well in non-leaky aquifers.	2
7.	Analysis of pumping test data for estimation of aquifer parameters.	1
8.	Computation of drawdown and discharge under interference of wells.	2
9.	Simulation of groundwater flow using various computer models (MODFLOW, etc)	2
	Total	**16**

X. Suggested Reading

- Boonstra J and de Ridder NA. 1981. *Numerical Modeling of Groundwater Basins*. ILRI.
- Demenico PA. 1972. *Concept and Models in Groundwater Hydrology*. McGraw Hill.
- Huisman L 1972. *Ground Water Recovery*. Mac Millan.
- Jat ML and SR Bhakar 2008. *Ground Water Hydrology*. Agro-tech Publishing Academy. Udaipur.
- Polubarinova Kochina P Ya. 1962. *Theory of Ground Water Movement*. Princeton Univ. Press.
- Raghunath HM 1992. *Ground Water*. Wiley Eastern.
- Todd DK 1997. *Ground Water Hydrology*. Wiley Eastern.

I. Course Title : GIS and Remote Sensing for Land and Water Resource Management

II. Course Code : IDE 507/SWCE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of land use, surface and ground water.

V. Theory

Unit I

Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme.

Unit II

Satellite data analysis. Visual interpretation. Digital image processing. Image pre-processing. Image enhancement. Image classification. Data merging.

Unit III

Basic components of GIS. Map projections and co-ordinate system. Spatial data structure: Raster, vector. Spatial relationship. Topology. Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database. Common sources of error. Data quality: Macro, micro and Usage level components, Meta data. Spatial data transfer standards.

Unit IV

Thematic mapping. Measurement in GIS: Length, perimeter and areas. Query analysis. Reclassification, Buffering and Neighbourhood functions. Map overlay: Vector and raster overlay. Interpolation and network analysis. Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.

Unit V

Spatial data sources. 4M GIS approach water resources system. Thematic maps. Rainfall runoff modelling, groundwater modelling and water quality modelling. Flood inundation mapping and modelling. Drought monitoring. Cropping pattern change analysis. Performance evaluation of irrigation commands. Site selection for artificial recharge. Reservoir sedimentation.

VI. Practical

Familiarization with the remote sensing instruments and satellite imagery. Aerial Photograph and scale determination with stereoscope. Interpretation of satellite imagery and aerial photograph. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

VII. Learning outcome

The student will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps and also able to integrate satellite data with GIS to undertake recourse mapping and lanning studies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and brief history of RS and GIS, applications of RS and GIS	1
2.	Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation.	1
3.	Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme	2
4.	Satellite data analysis. Visual interpretation.	1
5.	Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging.	3
6.	Basic components of GIS- Map projections and co-ordinate system.	2
7.	Spatial data sources,Thematic maps.	1
7.	Spatial data structure: Raster, vector data, Spatial relationship-Topology	1
8.	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
9.	Data quality, Common sources of error, Macro, micro and Usage level components, Meta data and Spatial data transfer standards	2
10.	Measurement in GIS- Length, perimeter and areas.	1
10.	Query analysis. Reclassification, Buffering and Neighbourhood functions.	1
11.	Map overlay: Vector and raster overlay	1
12.	Interpolation and network analysis	1
13.	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.	3
14.	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling.	2
15.	GIS approach to Groundwater modelling and water quality modelling,	2
16.	Site selection for artificial recharge. Reservoir sedimentation	1
17.	Drought monitoring	1
18.	Performance evaluation of irrigation commands	1
19.	Cropping pattern change analysis	1
	Total	**32**

7 IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization with the remote sensing instruments and satellite imagery	1

S.No.	Topic	No. of Practicals
2.	Methods of establishing ground truth survey and Comparison between ground truth and remotely sensed data	2
3.	Aerial Photograph and scale determination with stereoscope	1
4.	Interpretation of satellite imagery and aerial photograph	1
5.	Determination of Parallaxes in images	1
6.	Demonstration on GPS; Provision of Ground Control by GPS in different mode	1
7.	Introduction to digital image processing software	1
8.	Introduction to GIS software	1
9.	Data input; Data editing and Topology creation -Digitization of point, line and polygon features	
10.	SRTM and CARTO DEM download from web and Georeferencing of an image	1
11.	Delineation of Watershed, DEM generation: slope, Aspect, flow direction, Flow accumulation, Drainage, network and morphometric analysis	2
12.	LULC by supervised classification and LULC by unsupervised classification	1
13.	Application of Remote Sensing data and GIS for water quality parameters	
14.	Temporal satellite data analysis for vegetation condition, crop water requirement calculation	1
15.	Erosion mapping using aerial and satellite Data	1
	Total	**17**

X. Suggested Reading

- Charles Elach and Jakob van Zyl. 2006. *Introduction to the Physics and Techniques of Remote Sensing*. John Wiley & Sons publications.
- Ian Heywood Sarah, Cornelius and Steve Carver. 2002. *An Introduction to Geographical Information Systems*. Pearson Education. New Delhi.
- James B Campbell and Randolph H Wynne. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lillesand TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation*. John Wiely and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.
- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.
- Thanappan Subash. 2011. *Geographical Information System*. Lambert Academic Publishing.

I. Course Title : Waste Water Management and Utilization in Agriculture

II. Course Code : IDE 508

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about status of waste water and water quality requirements, standards both for domestic and irrigation purposes and also to provide in depth knowledge of waste water treatment methods and utilization in agriculture.

V. Theory

Unit I

Status of wastewater in India. Sources of contamination and characterization of urban and rural wastewater for irrigation. Water quality: Physical, chemical and biological parameters of wastewater.

Unit II

Water quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards and guidelines for their restricted and unrestricted uses. Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization.

Unit III

Control measures for preventing soil and other surface/groundwater source contamination. Different types of wastewater, pollutants and contaminants. Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.

Unit IV

Wastewater treatment methods: Physical, chemical and biological. General water treatments: Wastewater recycling, constructed wetlands, reed bed system. Carbon foot prints of wastewater reuse. Environmental standards.

Unit V

Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Stages of EIA-Monitoring and Auditing. Environmental clearance procedure in India.

VI. Practical

Measurement of water quality indices in the lab. Field demonstration of impact of waste water on eco-system and human health. Waste water treatment methods and effect of waste water in contamination of ground water. Visit of waste water treatment plant near by area.

VII. Learning outcome

The students will be able to understand sources and treatment methods of waste water quality with standard norms of water quality for domestic and irrigation purposes and also be exposed to waste water recycling and environmental standards.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Status of wastewater in India, Sources of contamination and characterization of urban and rural wastewater for irrigation	2
2.	Water quality: Physical, chemical and biological parameters of wastewater	2
3.	Wastewater quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses.	2
4.	Different types of wastewater, pollutants and contaminants.	1
5.	Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.	2
6.	Key drivers of wastewater use in agriculture and existing approaches for regulating wastewater reuse in agriculture	2
7.	Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for irrigation	3
8.	Health Risks Associated with the Use of Wastewater for Irrigation	1
9.	Wastewater treatment methods: Physical, chemical and biological.	3

S.No.	Topic	No. of Lectures
10.	Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation	2
11.	General water treatments: Wastewater recycling, constructed wetlands, reed bed system.	2
12.	Carbon foot prints of wastewater reuse. Environmental standards.	2
13.	Management of health and environmental risks of wastewater irrigation	1
14.	Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts.	3
15.	Impact on groundwater resources and soil health, EIA process, Stages of EIA-monitoring and auditing. Environmental clearance procedure in India	3
16.	Economics of wastewater irrigation	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study on physical, chemical and biological parameters of wastewater	1
2.	Determination of EC and pH of wastewater	1
3.	Determination of BOD of wastewater	1
4.	Determination of COD of wastewater	1
5.	Determination of TSS and TDS of wastewater	1
6.	Determination RSC of wastewater	1
7.	Determination of e-coli in the wastewater	1
8.	On field demonstration of wastewater use for the irrigation	1
9.	Determination of nutrient (N, P and K) concentration in wastewater	2
10.	Field demonstration of impact of waste water on eco-system and human health.	1
11.	Study on various wastewater treatment methods	2
12.	Study on effect of wastewater on contamination of ground water	1
13.	Visit of village pond treatment nearby area	1
14.	Visit of sewerage treatment plant nearby area	1
	Total	**16**

X. Suggested Reading

- Charis Michel Galanakis. *Sustainable Water and Wastewater Processing*. Elsevier Publication, Amsterdam.
- Sean X Liu. 2014. *Food and Agricultural Wastewater Utilization and Treatment*. Wileu Blackwell New York.
- Shirish H, Sonawane Y, Pydi Setty T, Bala Narsaiah and S Srinu Naik. 2017. *Innovative Technologies for the Treatment of Industrial Wastewater: A Sustainable Approach*. CRC Press.
- Stuetz Richard. *Principles of Water and Wastewater Treatment Processes* (*Water and Wastewater Process Technologies*). IWA Publishing.
- Syed R Qasim and Guang Zhu. 2018. *Wastewater Treatment and Reuse: Theory and Design Examples*. CRC Press.

I. Course Title : Water Conveyance and Distribution

II. Course Code : IDE 509

III. Credit Hours : 2+1

IV. Aim of the course

To develop the common understanding of different conveyance structure in irrigation network and provide knowledge of various flow and their computations including sediment transport in channels.

V. Theory

Unit I

Channel characteristics. Prismatic and non-prismatic channel. Steady, unsteady, uniform and non-uniform flow. Open channel and their properties. Energy and momentum, critical flow computation and application. Basic Concepts of free surface flow, classification of flow, velocity and pressure distribution.

Unit II

Uniform flow, conservation laws and specific energy. Application of momentum and energy equation. Channel transition. Study of critical flow, uniform flow, gradually varied flow, rapid varied flow, spatially varied flow and unsteady flow and their computations.

Unit III

Energy dissipation. Flow control structures and flow measurement. Theories and methods of open channel design.

Unit IV

Sediment transport in channels. Regime flow theories. Tractive force theory. Design of stable channels.

Unit V

Basic principles of pipe flow, pipe flow problems and equivalent pipe. Principles of network synthesis. Pipe network analysis. Water transmission lines. Cost considerations: Single-Input source. Branched systems: Single-Input source. Looped Systems: Multi-Input source. Branched systems: Multi-Input source, Looped systems. Decomposition of a large water system and optimal zone size.

VI. Practical

Computation and use of geometrical and hydraulic elements of open channel. Use of flow measuring devices and methods and their limitations. Examination of velocity distribution and calculation of energy and momentum coefficients. Solution of channel design problems. Appraisal of flow control and distribution structures. Analysis and computation of flow profiles.

VII. Learning outcome

The student will be able to infuse the knowledge about different types of channel flow and their behavior and also able to gain the knowledge of appraisal of flow control and distribution structures including design of stable channel.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Channel characteristics. Prismatic and non-prismatic channel	1
2.	Steady, unsteady, uniform and non-uniform flow	1
3.	Open channel and their properties	2
4.	Energy and momentum, critical flow computation and application	2
5.	Basic Concepts of free surface flow, classification of flow, velocity and pressure distribution	2
6.	Uniform flow, conservation laws and specific energy	2
7.	Application of momentum and energy equation	1
8.	Channel transition	1
9.	Study of critical flow, uniform flow, gradually varied flow, rapid varied flow	2
10.	Spatially varied flow and unsteady flow and their computations	2
11.	Energy dissipation	1
12.	Flow control structures and flow measurement	1
13.	Theories and methods of open channel design	2
14.	Sediment transport in channels	1
15.	Regime flow theories	1
16.	Tractive force theory	1
17.	Design of stable channels	1
18.	Basic principles of pipe flow, pipe flow problems and equivalent pipe	1
19.	Principles of network synthesis. Pipe network analysis	1
20.	Water transmission lines. Cost considerations: Single-Input source. Branched systems: Single-Input source	2
21.	Looped Systems: Multi-Input source. Branched systems: Multi-Input source, Looped systems	2
22.	Analysis and computation of flow profiles	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Computation and use of geometrical and hydraulic elements of open channel	2
2.	Study of Flow measuring devices,methods and their limitations	2
3.	Examination of velocity distribution	2
4.	Calculation of energy and momentum coefficients	2
5.	Channel design: problems and its solution	3
6.	Appraisal of flow control and distribution structures	2
7.	Analysis and computation of flow profiles	3
	Total	**16**

X. Suggested Reading

- Chaudhry MH. 1993. *Open Channel Flow*. Prentice-Hall, NJ.
- Chow VT. 1979. *Open Channel Hydraulics*. McGraw Hill Inc. N York.
- French RH. 1986. *Open Channel Hydraulics*. McGraw Hill Pub Co., N York
- Henderson FM. 1966. *Open Channel Flow*. Macmillan Co. New York.
- Prabhata K Swamee and Ashok K Sharma. *Design of Water Supply Pipe Networks*. John Wiley New York.
- Subramanya K. 2008. *Flow in Open Channels*. Tata McGraw Hill Pub.
- Terry Sturm. 2011. *Open Channel Hydraulics*. Tata McGraw Hill Pub.

I. Course Title : Minor Irrigation

II. Course Code : IDE 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the need and scope of minor irrigation in India. To provide in-depth knowledge in design and operation of surface and groundwater-based irrigation practices.

Unit I

Definition, scope, historical background and progress in minor irrigation works in India, Assessment of surface water resource. Design and operation of surface water storage structures.

Unit II

Evaporation and seepage control. Groundwater development methods and their scope. Groundwater extraction devices and methods. Aquifer characteristic and their evaluation. Wells in alluvial and rocky aquifers.

Unit III

Well interference, spacing and multiple well point system for controlled groundwater pumping. Safe yield from wells. Augmentation of well yield through pumping and recovery time management.

Unit IV

Well design, drilling and construction. Tube well strainers, gravel packing and resistance to flow. Pumps and prime movers for groundwater lifting. Diagnosis of sick and failed wells and their remediation.

Unit V

Conjunctive use of surface and groundwater. Legislation for groundwater development and management. Groundwater recharge and its use.

V. Practical

Measurement of seepage loss from reservoirs. Estimation of inflow to surface reservoir. Measurement of evaporation loss from surface reservoirs. Pumping test and determination of aquifer parameters. Establishment of draw down-discharge characteristic. Well log analysis and deciding on length and placement of strainers. Computation of well interference and deciding on well spacing. Estimation of irrigation for given discharge from well. Estimating pumping cost for irrigation. Analysis of ground water quality. Problems on well design.

VI. Learning outcome

The students will be able to understand minor irrigation practices and their importance in Indian agriculture. They will also expose to conjunctive use of surface and groundwater and able to perform groundwater development legislation, recharge and utilization practices.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Definition and scope of minor irrigation works in India	1
2.	Historical background and progress in minor irrigation works in India	2

S.No.	Topic	No. of Lectures
3.	Assessment of surface water resource	1
4.	Design and operation of surface water storage structures	2
5.	Evaporation and seepage control	1
6.	Groundwater development methods and their scope	2
7.	Groundwater extraction devices and methods	1
8.	Aquifer characteristic and their evaluation	2
9.	Wells in alluvial and rocky aquifers	1
10.	Well interference	2
11.	Spacing and multiple well point system for controlled groundwater pumping	2
12.	Safe yield from wells	1
13.	Augmentation of well yield through pumping and recovery time management	2
14.	Well design, drilling and construction	2
15.	Tube well strainers	1
16.	Gravel packing and resistance to flow	2
17.	Pumps and prime movers for groundwater lifting	2
18.	Diagnosis of sick and failed wells and their remediation	1
19.	Conjunctive use of surface and groundwater	1
20.	Legislation for groundwater development and management	1
21.	Groundwater recharge and its use	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Measurement of seepage loss from reservoirs	1
2.	Estimation of inflow to surface reservoir	2
3.	Measurement of evaporation loss from surface reservoirs	1
4.	Pumping test and determination of aquifer parameters	2
5.	Establishment of draw down-discharge characteristic	2
6.	Well log analysis and deciding on length and placement of strainers	2
7.	Computation of well interference and deciding on well spacing	2
8.	Estimation of irrigation for given discharge from well	1
9.	Estimating pumping cost for irrigation	1
10.	Analysis of ground water quality	1
11.	Problems on well design	1
	Total	**16**

IX. Suggested Reading

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publisher, Delhi.
- Garg SK. 1987. *Hydrology and Water Resource Engineering*. Khanna Publishers, Delhi.
- Michael AM. 2006. *Irrigation Theory and Practice*. Vikas Publications, New Delhi.
- Sharma RK. 1987. *Hydrology and Water Resources Engineering*. Dhanpat Rai and Sons, New Delhi.
- Subramanian K. 1993. *Engineering Hydrology*. Tata Mc-Graw-Hill Co. New Delhi.

I. Course Title : Design of Pumps for Irrigation and Drainage

II. Course Code : IDE 511

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about basic hydraulic design of various pumps, energy requirement in pumping, solar photovoltaic system and solar pump including design of pumping station.

V. Theory

Unit I

Basic hydraulic design of centrifugal pump. Net positive suction head and cavitation, vapour pressure, water hammering problem in centrifugal pump.

Unit II

Principles and design of pumping systems for agricultural drainage. Selection and performance of characteristics of vertical turbine pump, submersible pump and axial flow pump.

Unit III

Multiple well point system and their design. Energy requirement in groundwater pumping.

Unit IV

Non-conventional energy sources for pumping, wind mills, micro turbines, solar pumps. Hydraulic ram: Selection and design criteria. Solar photovoltaic system.

Unit V

Design of pumping station. Techno-economic evaluation. Efficient pumping system operation, flow control strategies and conservation measures for pumping systems.

VI. Learning outcome

The students will be able to select the pump for desired discharge to be pumped from particular water source by developing pump characteristics curve, able to analyze the flow in different types of pump and also able to design the pumping station for managing the irrigation and drainage system.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Different types of pumps used under different conditions	1
2.	Principal and working of centrifugal pump	1
3.	Basic hydraulic design of centrifugal pump	1
4.	Net positive suction head and cavitation, vapour pressure, water hammering problem in centrifugal pump	3
5.	Use of pumpsets for agricultural drainage under different conditions.	1
6.	Principles and design of pumping systems for agricultural drainage.	2
7.	Selection and performance of characteristics of vertical turbine pump	2
8.	Flow pattern in turbine pumps	1
9.	Selection and performance of characteristics of vertical submersible pump	2
10.	Flow pattern in submersible pumps	1
11.	Visit to Pumping Industry	5
12.	Use of Multiple well point/skimming well point system under different conditions and its design	1
13.	Energy requirement and efficiency for Multiple well point/skimming well point system	1
14.	Introduction and use of Non-conventional energy sources for pumping	1
15.	Selection and design criteria for Solar photovoltaic system	2
16.	Selection and design criteria for wind mills, micro turbines, solar pumps. Hydraulic ram	3

S.No.	Topic	No. of Lectures
17.	Introduction to pumping station and its components & design	1
18.	Techno-economic design evaluation in pumping sets	1
19.	Energy conservation measures under different pumping units under different flow conditions	2
	Total	**32**

VIII. Suggested Reading

- Bansal RK. 1990. *A Text Book of Fluid Mechanics and Hydraulic Machines*. Laxmi Publications, New Delhi.
- Church AH and Jagdish Lal. 1973. *Centrifugal Pumps and Blowers*. Metropolitan Book Co. Pvt. Ltd. Delhi.
- Luthin JN. 1966. *Drainage Engineering*. Wiley and Sons. New York, USA.
- Michael AM and Khepar SD. 1989. *Water Wells and Pump Engineering*. Tata McGraw Hill Publishing Co., New Delhi.

I. Course Title : Crop Environmental Engineering

II. Course Code : IDE 512

III. Credit Hours : 2+0

IV. Aim of the course

To develop the common understanding aerial and edaphic environments for plant growth, energy and mass transfer which help to maximizing the crop yield. To understand the basic interface of soil and root and its characteristics.

V. Theory

Unit I

Principles of heat, mass and momentum transport. Transport of radiant energy, radiation environment, micro climatology of radiation. Micrometeorology: Turbulent transfer profiles and fluxes. Interpretation of flux measurement. Laws of electromagnetic radiation, its measurement and estimation.

Unit II

Profile balance of heat, mass and momentum in and above crop communities. Climatic changes and plant response to environmental stresses. Measurement and estimation of potential evapotranspiration on point and regional scale.

Unit III

Root anatomy, water flow in roots and root density models (microscopic and macroscopic). Stem anatomy and pressure volume curves. Methods of measuring water status in plants. Estimating ET using three temperature model and MODIS algorithm. Soil–Plant–Atmosphere system: Basic properties. Dynamics of water movement. ET-yield relations.

Unit IV

Principles of optimal scheduling of irrigation and seasonal allocation of limiting water supplies using LP and DP. Seasonal and dated production functions. Crop yield modelling and condition assessment. Instrumentation and techniques for monitoring plant environments.

Unit V

Design and operation of controlled environment facilities and their instrumentation. Climatic changes and plant response to environmental stresses. Evapotranspiration models.

VI. Learning outcome

The students will be able to identify climatic changes on plant and how plant responds to environmental stresses and evapotranspiration. The students will be exposed for design and operation of controlled environment facilities and crop yield modeling.

VII. Lecture Schedule

S.No.	Topic	No. of lectures
1.	Principles of heat, mass and momentum transport	2
2.	Transport of radiant energyradiation environment, micro climatology of radiation	2
3.	Micrometeorology: Turbulent transfer profiles and fluxes. Interpretation of flux measurement	1
4.	Laws of electromagnetic radiation, its measurement and estimation	1
5.	Profile balance of heat, mass and momentum in and above crop communities	1
6.	Climatic changes and plant response to environmental stresses	1
7.	Measurement and estimation of potential evapotranspiration on point and regional scale	1
8.	Root anatomy, water flow in roots and root density models (microscopic and macroscopic)	1
9.	Stem anatomy and pressure volume curves	1
10.	Methods of measuring water status in plants	1
11.	Estimating ET using three temperature model and MODIS algorithm	2
12.	Soil–Plant–Atmosphere system: Basic properties	1
13.	Dynamics of water movement	1
14.	ET-yield relations	2
15.	Principles of optimal scheduling of irrigation	1
16.	Seasonal allocation of limiting water supplies using LP and DP	2
17.	Seasonal and dated production functions	2
18.	Crop yield modelling and condition assessment	2
19.	Instrumentation and techniques for monitoring plant environments	2
20.	Design and operation of controlled environment facilities and their instrumentation	2
21.	Climatic changes and plant response to environmental stresses	1
22.	Evapotranspiration models	2
	Total	**32**

VIII. Suggested Reading

- Abtew W and Melese A. 2017. *Evaporation and Evapotranspiration: Measurements and Estimations*. Springer Publications.
- Campbell GS and Norman JM. *An Introduction to Environmental Biophysics*. Springer Publication New York.
- Ghildyal BP and Tripathy RP. 1987. *Fundamental of Soil Physics.* Wiley Eastern.
- Monteith JL and Unsworth MH. *Principles of Environmental Physics*. Elsevier, Amsterdam.
- Slatyor O P 1967. *Plant Water Relationship*. Academic Press.
- Yang Y. *Evapotranspiration over Heterogeneous surfaces: Models and Applications*. Springer Publications.

I. Course Title : Water Resources Systems Engineering

II. Course Code : IDE 513

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concept of optimization and its application in water resources management, mathematical programming techniques and multi objective water resources planning.

V. Theory

Unit I

Concepts and significance of optimization in water resources management. Model development in water management. Objective functions, deterministic and stochastic inputs.

Unit II

Soil plant atmosphere system. Problem formulation. Mathematical programming techniques: Linear programming, simplex method.

Unit III

Non-linear programming, quadratic programming, integer programming. Transportation problem and solution procedure. Geometric programming and dynamic programming.

Unit IV

Application of optimization techniques for water resources planning. Conjunctive use of water resources. Crop production functions and irrigation optimization.

Unit V

Multi objective water resources planning. Critical path method. Programme evaluation and review technique. Economic models. Project evaluation and discounting methods.

VI. Practical

Assessment of water resources. Problems related to water allocation in agriculture under single and multiple cropping system. Use of computer software for linear and dynamic programming. Introduction to the use of other programming methods. Sensitivity analysis of different alternatives of water resources development and allocation. Analysis of water demand and supply. Analysis of Competitive demands for water by various sectors of development. Benefits and cost of water resources development.

VII. Learning outcome

The students will be able to identify objective function and components in water resource planning problems and also able to formulate and solve various mathematical programming models of water resource system as well as to develop conjunctive use and crop production function optimization models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concepts and significance of optimization in water resources management	1
2.	Model development in water management	1

S.No.	Topic	No. of Lectures
3.	Objective functions, deterministic and stochastic input	1
4.	Soil plant atmosphere system. Problem formulation. Mathematical programming techniques	1
5.	Linear programming, simplex method	5
6.	Non-linear programming, quadratic programming, integer programming	5
7.	Transportation problem and solution procedure	3
8.	Geometric programming	3
9.	Dynamic programming	4
10.	Application of optimization techniques for water resources planning	2
11.	Conjunctive use of water resources	1
12.	Crop production functions and irrigation optimization	2
13.	Multi objective water resources planning. Critical path method	2
14.	Programme evaluation and review technique	1
15.	Economic models	2
16.	Project evaluation and discounting methods	1
	Total	**35**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Assessment of water resources of the region	1
2.	Problems on water allocation in agriculture under single and multiple cropping system	2
3.	Familiarization with computer software for linear programming	3
4.	Hands on exercise for non-linear programming on computer	3
5.	Hands on exercise for dynamic programming on computer	3
6.	Sensitivity analysis of different alternatives of water resources development and allocation	2
7.	Analysis of water demand and supply	2
8.	Benefits and cost of water resources development	1
	Total	**17**

X. Suggested Reading

- Larry WM. 1996. *Water Resources Handbook*. Mc-Graw-Hill.
- Loucks DP *et al*. 1981. *Water Resources System Planning and Analysis*. Prentice Hall.
- Rao SS. 1978. *Optimization Theory and Application*. Wiley Eastern.
- Wallander WW and Bos M. 1990. *Water Resource System Planning and Management*.

I. Course Title : Irrigation Economics Planning and Management

II. Course Code : IDE 514

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of various public and government policy on regulation and allocation of irrigation water, cost and benefit analysis including project evaluation, decision making process and risk analysis.

V. Theory

Unit I

Economic analysis. Problems in project selection. Methods and approaches to water pricing. Criteria for investment and pricing in irrigation projects. Social benefits, problems and causes of under-utilization. Mathematics of economic analysis. Cost allocation, separable and non-separable costs. Discounting factors and techniques. Determination of benefits, cost and benefit analysis. Project evaluation. Limitations of benefit-cost analysis. Dynamics of project analysis.

Unit II

Role of financial analysis. Distinctions from economic analysis. Financial feasibility and analysis. Impact of public policies on regulation and allocation of irrigation water. Relative economic efficiency of alternative irrigation water management models. Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency.

Unit III

Indian agriculture, main problems, population, government policies, systems, organizing agriculture production. Farm Management: Definition, importance, scope, relation with other sciences and its characteristics.

Unit IV

Socio-economic survey. Importance of such survey in planning, implementation and evaluation of project performance. Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data, classification and analysis of data.

Unit V

Role of farm management principles in decision making for irrigated agriculture. Decision making process, assessing risk and uncertainty in planning.

VI. Learning outcome

The students will be able to estimate the cost benefit analysis, pricing and investment criteria on irrigation project evaluation and finding their problems. The students will also expose to conduct socio-economic survey and analyse secondary data.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Economic analysis, problems in project selection	1
2.	Methods and approaches to water pricing	1
3.	Criteria for investment and pricing in irrigation projects	1
4.	Social benefits, problems and causes of under-utilization	1
5.	Mathematics of economic analysis	1
6.	Cost allocation, separable and non-separable costs	1
7.	Discounting factors and techniques	1
8.	Determination of benefits and limitations of cost-benefit analysis	1
9.	Project evaluation	1
10.	Dynamics of project analysis	1
11.	Role of financial analysis	1
12.	Distinctions from economic analysis	1
13.	Financial feasibility and analysis	1
14.	Impact of public policies on regulation and allocation of irrigation water	1
15.	Relative economic efficiency of alternative irrigation water management models	2

S.No.	Topic	No. of Lectures
16.	Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency	2
17.	Indian agriculture, main problems, population, government policies, systems, organizing agriculture production	2
18.	Farm Management: Definition, importance, scope, relation with other sciences and its characteristics	2
19.	Socio-economic survey: Importance of survey in planning, implementation and evaluation of project performance	2
20.	Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data	2.
21.	Classification and analysis of data	1
22.	Role of farm management principles in decision making for irrigated agriculture	2
23.	Decision making process	1
24.	Assessing risk and uncertainty in planning	2
	Total	**32**

VIII. Suggested Reading

- Heady, Early Orel, Hexem R and Roger W. 1978. *Water Production Functions for Irrigated Agriculture*.
- James Douglas and Lee Rober R. 1995. *Economics of Water Resource Planning*. Tata Mcgraw-Hill Publication Company Ltd, Bombay, New Delhi.
- Joshi SS and TR Kapoor. 2001. *Fundamentals of Farm Business Management*. Kalyani Publishers, Ludhiana.
- *Management of Water Project-Decision Making and Investment Appraisal*. Oxford Publication Co.
- Sharma VK. 1985. *Water Resource Planning and Management*. Himalaya Publication House, New Delhi.

I. Course Title : Sensing and Automation in Irrigation Systems

II. Course Code : IDE 515

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about the concept of sensing and automation in irrigation system, wireless sensor network and digital signal processor. To provide knowledge of surface irrigation automation.

V. Theory

Unit I

Sensing and sensors. Sensor classifications. Wireless sensor networks. History of wireless sensor networks (WSN). Communication in a WSN. Important design constraints of a WSN like Energy, self management, wireless networking, decentralized management, design constraints, security etc.

Unit II

Node architecture. Sensing subsystem. Analog-to-Digital converter. The processor subsystem, architectural overview, microcontroller, digital signal processor, application-specific integrated circuit, field programmable gate array (FPGA).

Unit III

Communication interfaces, serial peripheral interface, inter-integrated circuit, the IMote node architecture, The XYZ node architecture, the Hogthrob node architecture.

Unit -IV

Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc.

VI. Learning outcome

The students will be able to understand concept of automation in irrigation system which is quite important to enhance water use efficiency and also able to understand Node architecture and other routing protocols.

VII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Sensing and sensors	2
2.	Sensor classifications	2
3.	History of wireless sensor networks (WSN) and Wireless sensor networks	3
4.	Communication in a WSN	1
5.	Important design constraints of a WSN like Energy, self-management, wireless networking, decentralized management, design constraints, security etc	3
6.	Node architecture	1
7.	Sensing subsystem	1
8.	Analog-to-Digital converter	2
9.	The processor subsystem	1
10.	Architectural overview	1
11.	Microcontroller	2
12.	Digital signal processor	2
13.	Application-specific integrated circuit	2
14.	Fieldprogrammable gate array (FPGA)	2
15.	Communication interfaces	2
16.	Serial peripheral interface	3
17.	Inter-integrated circuit	2
18.	The IMote node architecture	2
19.	The XYZ node architecture	2
20.	The Hogthrob node architecture	2
21.	Applications in surface irrigation automation	3
22.	Automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc	4
	Total	**45**

VIII. Suggested Reading

- Cauligi S Raghavendra, Krishna M Sivalingam and Taieb Znati. *Wireless Sensor Networks*. Springer.
- Edgar H, Callaway Jr. and Edgar H Callaway. *Wireless Sensor Networks: Architectures and Protocols*.
- Holger Karl and Andreas Willig. *Protocols and Architectures for Wireless Sensor Networks*. John Wiley & Sons.
- Waltenegus Dargie and Christian Poellabauer. *Fundamentals of Wireless Sensor Networks:* Theory and Practice. A John Wiley and Sons, Ltd, Publication.

Course Title with Credit Load
Ph.D. in Irrigation and Drainage Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
IDE 601*	Recent Developments in Irrigation Engineering	2+1
IDE 602*	Advances in Drainage Engineering	2+1
IDE 603	Hydro-Mechanics and Ground Water Modeling	3+0
IDE 604	Soil-Water-Plant-Atmospheric Modeling	2+1
IDE 605	Plant Growth Modeling and Simulation	2+0
IDE 606	Multi Criteria Decision Making System	2+0
	Total	**13+3**

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
SWCE 502	Applied Watershed Hydrology	2+1
SWCE 603	Reservoir Operation and River Basin Modeling	2+1
SWCE 604	Modeling Soil Erosion Processes and Sedimentation	2+1
CSE 503	Neuro-Fuzzy Application in Engineering	2+1
CSE 506	Digital Image Processing	2+1
FMPE 602	Advances in Machinery for Precision Agriculture	2+1
REE 615	Energy Planning, Management and Economics	3+0
	Any other course(s) of other department can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
CPE-RPE*	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

***Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

List of other Essential Requirements

Course Code	Course Title	Credit Hours
IDE 691	Seminar-I	0+1
IDE 692	Seminar-II	0+1
IDE 699	Thesis Research	0+75

Course Contents
Ph.D. in Irrigation and Drainage Engineering

I. Course Title : Recent Developments in Irrigation Engineering

II. Course Code : IDE 601

III. Credit Hours : 2+1

IV. Aim of the course

To focus the students for the recent designs progressed in surface irrigation systems, surface and subsurface drip irrigation systems and for utilizing good and poor-quality waters for sustaining crop productivity.

V. Theory

Unit I

Geospatial analysis of hydraulic properties of the soil. Surge flow irrigation systems. One dimensional and two-dimensional zero inertia modelling of border irrigation, surge irrigation and furrow irrigation. Integral equation solutions to surface irrigation. Design of irrigation runoff recovery systems. Cablegation: Automated supply for surface irrigation. Analyzing wind distortion in sprinkler irrigation systems uniformity.

Unit II

Design of sub-surface drip irrigation systems. Modeling soil water regimes and solute distribution emanating from surface and sub-surface drip irrigation systems. Recent developments in designs of surface and sub-surface drip irrigation systems. Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity. Irrigation scheduling through partial root zone irrigation. Low energy drip irrigation systems.

Unit III

Drip irrigation for poor quality water. Drip automation for time and volume. Drip irrigation system modification for waste water utilization. Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function. Crop water salinity response function.

Unit IV

Drip irrigation in command area development. Mulching and its effect on crop productivity. Analyzing moisture and temperature profiles with time and depth. Effect of shading and mulching on crop productivity, vapour phase movement.

VI. Practical

Designing border irrigation using zero inertia model, volume balance approaches, evaluating surge flow irrigation systems, operation of segmented border irrigation systems for enhancing water use efficiency, geospatial analysis of soil properties, design and planning of surface drip irrigation systems using various designs, design of subsurface drip irrigation, analyzing three dimensional moisture movement under subsurface drip irrigation using simple empirical models, design and planning of surface and subsurface drainage systems, developing the irrigation schedules using partial root zone irrigation, seasonal and dated production functions for forecasting crop yield

VII. Learning outcome

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems and managing crop productivity with poor quality of waters without deteriorating soil conditions.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Geospatial analysis of hydraulic properties of soil: Geospatial analysis, Spatial interpolation, Data quality assessment, Vegetation analysis, Correlation analysis	3
2.	Surge flow: Effect of surging on infiltration and surface flow hydraulics, surge flow systems	2
3.	Zero inertia modeling of border irrigation	2
4.	Integral equation solutions to surface irrigation: Border and furrow irrigation method	2
5.	Design of irrigation runoff recovery systems: Border and furrow irrigation method	3
6.	Cablegation: Automated supply for surface irrigation	2
7.	Wind effects on sprinkler irrigation performance: Analyzing wind distortion in sprinkler irrigation system uniformity	2
8.	Design of sub-surface drip irrigation systems, Modeling soil water regimes and solute distribution emanating from sub-surface drip irrigation systems	3
9.	Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity	2
10.	Irrigation scheduling through partial root zone irrigation.	2
11.	Low energy drip irrigation systems	2
12.	Drip irrigation for poor quality water, Drip automation for time and volume, Drip irrigation system modification for waste water utilization	2
13.	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function, Crop water salinity response function	3
14.	Drip irrigation in command area development	2
15.	Mulching and its effect on crop productivity, Analyzing moisture and temperature profiles with time and depth, Effect of shading and mulching on crop productivity, vapour phase movement	3
	Total	**35**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of geospatial analysis of soil properties	
2.	Design of border irrigation using zero inertia model	1
3.	Design of border irrigation using volume balance approach	1
4.	Design and evaluation of surge flow irrigation system	1
5.	Design of irrigation runoff recovery system for border irrigation method	1

S.No.	Topic	No. of Practicals
6.	Design of irrigation runoff recovery system for furrow irrigation method	1
7.	Design and planning of cablegation system	1
8.	Analysis of wind distortion in sprinkler irrigation system uniformity	1
9.	Design and planning of subsurface drip irrigation system	1
10.	Analysis of three dimensional moisture movement under subsurface drip irrigation using simple empirical models	2
11.	Development of irrigation schedules using partial root zone irrigation	1
12.	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function	1
13.	Analysis of moisture and temperature profiles with time and depth	1
14.	Development of seasonal and dated production functions for forecasting crop yield	
	Total	**15**

X. Suggested Reading

- Cuenca RH. 1989. *Irrigation System Design: An Engineering Approach*. Prentice Hall, New York.
- Hoffman GJ, Evans RG, Jensen ME, Martin DL and Elliot RL. (ed). 2007. *Design and Operation of Farm Irrigation Systems*. American Society of Agricultural Engineers St. Joseph Michigan.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.
- Nakayama FS and Bucks DA. 1986. *Trickle Irrigation for Crop Production: Design, Operation and Management*. Elsevier Publications, Amsterdam.
- Skogerboe GV and Walkar WR. 2008. *Surface Irrigation Theory and Practice*. Prentice Hall, New York.

I. Course Title : Advances in Drainage Engineering

II. Course Code : IDE 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge of advances in land drainage, synthetic materials for drainage systems, linear flow laws and environmental issues related to drainage.

V. Theory

Unit I

Physics of land drainage. Forces, surface tension and energy effects water. Energy of soil water. Capillary potential.

Unit II

Devices to measure capillary potential. Hystersis, Darcy's law. Synthetic materials for drainage systems. Environmental issues related to drainage. Socio-economic impacts of drainage systems.

Unit III

Laplace equation its derivation and solution in various forms. Boundary value problems, Liner flow laws.

Unit IV

Drainage criteria saturated flow theory, steady flow and non steady flow. Controlled drainage for reducing agricultural non-point pollution. Application of simulation models for drainage systems.

Unit V

Flow equations in general and the approach. Flow problem and physical boundary conditions.

VI. Practical

Steady state and non steady state flow problems. Measurement of capillary potential. Use of various synthetic materials under the field condition. Use of simulated models for drainage system.

VII. Learning outcome

The student will be familiar about energy of soil water, capillary potential, drainage material and various sources of agricultural pollution and also able to develop and apply simulation model for management of drainage system for particular area.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physics of land drainage: Forces acting on movement of water through soil profile, surface tension, capillary forces and energy effects movement of water, Energy of soil water	5
2.	Capillary potential: Effect of capillary potential on movement of water through porous media, devices to measure capillary potential. Hystersis effect in drainage of soil, Darcy's law	3
3.	Synthetic materials for drainage systems: Design of filter and envelop for drainage system with synthetic materials	2
4.	Environmental issues related to drainage. Socio-economic impacts of drainage systems	2
5.	Drainage Flow Equation: Laplace equation its derivation and solution in various forms, Liner flow laws	4
6.	Boundary value problems: Initial and boundary condition and its solution	3
7.	Drainage criteria: Drainage criteria for different type of soils and crops, guidelines for design and installation of drainage system	2
8.	Saturated flow theory: steady flow and non steady saturated flow	3
9.	Controlled drainage for raising crop and reducing agricultural non-point pollution	2
10.	Application of simulation models for drainage systems (DRAINMOD, SALTMOD, etc)	4
11.	Flow equations: general drainage flow equations and the approach, drainage flow problems and solutions with physical boundary conditions	3
	Total	**34**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Steady state drainage flow problems	3
2.	Unsteady state drainage flow problems	3
3.	Measurement of capillary potential	2

S.No.	Topic	No. of Practicals
4.	Use of various synthetic materials for drainage filter under the field condition	2
5.	Design of filter and envelop with synthetic materials	2
6.	Use of simulated models for drainage system	4
	Total	**16**

X. Suggested Reading

- Chauhan HS. 1999. *Mathematical Modeling of Agricultural Drainage, Ground Water and Seepage*. ICAR Publication New Delhi.
- Kirkham DL and Powers WL. 1972. *Advanced Soil Physics*. Inter Science, New York.
- Lambert K Smedema, Willem FV, Lotman and David Rycroft. 2004. *Modern Land Drainage: Planning, Design and Management of Agricultural Drainage Systems.* CRC Press.
- Ritzema HP. (Ed.). 1994. *Drainage Principles and Applications*. ILRI.
- Skaggs RW and Schilfgaarde Jan Van. 1999. *Agriculture Drainage*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

I. Course Title : Hydro-Mechanics and Groundwater Modeling

II. Course Code : IDE 603

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about the concept of soil aquifer system, unsaturated flow models, numerical modeling of groundwater flow, theory of krigging and movement of groundwater in fractured and swelling porous media.

V. Theory

Unit I

Concept of soil aquifer system, flow of water in partially saturated soils. Partial differential equation of flow, pressure under curved water films, moisture characteristic functions.

Unit II

Physical models, Analog models, Mathematical modelling, Unsaturated flow models, Numerical modelling of groundwater flow, Finite difference equations and solutions. Successive over relaxation. Alternating direction implicit procedure. Crank Nicolson equation. Iterative methods. Direct methods. Inverse problem. Finite element method.

Unit III

Determination of unsaturated hydraulic conductivity and model for its estimation. Diffusivity and its measurement. Infiltration and exfiltration from soils in absence and presence of water table.

Unit IV

Fence diagram and aquifer mapping. Movement of groundwater in fractured and swelling porous media. Spatial variability, theory of krigging.

Unit V

Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions. Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation. Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction.

VI. Learning outcome

The students will be able to understand complex mechanics movement of water in soil systems and also able to estimate the statistical parameters for better understanding of soil aquifer system, model validation and prediction.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of soil aquifer system	1
2.	Flow of water in partially saturated soils	1
3.	Partial differential equation of flow	1
4.	pressure under curved water films, moisture characteristic functions	1
5.	Different types of Models used in hydrology and Groundwater	1
6.	Unsaturated flow models	1
7.	Numerical modelling of groundwater flow	1
8.	Finite difference equations and solutions, Finite difference equations and solutions, Alternating direction implicit procedure	4
9.	Crank Nicolson equation. Iterative methods	2
10.	Inverse problem. Finite element method	1
11.	Determination of unsaturated hydraulic conductivity and model for its estimation	2
12.	Diffusivity and its measurement	1
13.	Infiltration and exfiltration from soils in absence and presence of water table	2
14.	Fence diagram and aquifer mapping	2
15.	Movement of groundwater in fractured and swelling porous media, Spatial variability, theory of krigging	4
16.	Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions	4
17.	Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation	4
18.	Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction	6
19.	Course Seminar	4
	Total	**43**

VIII. Suggested Reading

- Anderson MP and Woessner WW. 1992. *Applied Groundwater Modelling: Simulation of Flow and Advective Transport*. Academic Press, Inc.
- Elango L and Jayakumar R. 2001. *Modelling in Hydrology*. Allied Publishers Ltd.
- Fetter CW. 1999. *Contaminant Hydrogeology*. Prentice Hall.
- Kirkham and Powers. 1972. *Advanced Soil Physics*. John Wiley & Sons.
- Muskat M. 1937. *The Flow of Homogeneous Fluid through Porous Media*. McGraw Hill.
- Rushton KR. 2003.*Groundwater Hydrology: Conceptual and Computational Models. Wiley,*

I. Course Title : Soil-Water-Plant-Atmospheric Modeling

II. Course Code : IDE 604

III. Credit Hours : 2+1

IV. Aim of the course

To impart the knowledge of measurement of radiation within plant cover, thermodynamics of flow through plant cells, heat transfer and radiation exchange under plant cover.

V. Theory

Unit I

Radiation balance of earth's surface. Turbulent transport of heat and momentum. Radiation exchange and heat transfer in a low plant cover.

Unit II

Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover. Predicting potential evapotranspiration.

Unit III

Thermodynamics of flow through plant cells. Dynamics of water movement through soil plant atmosphere system. Stomatal aperture, photosynthesis and actual evapotranspiration relationship.

Unit IV

Production functions of evapotranspiration. Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture.

Unit V

Crop water requirement under protected cultivation and remote sensing-based modeling.

VI. Practical

Estimation of potential evapotranspiration. Measurement of ET parameters under open and protected cultivation and development of stochastic and deterministic models of ET. Use of software for estimation of crop water requirement and ET.

VII. Learning outcome

The students will be able to understand the measurement of radiation, photosynthesis and actual evapotranspiration relationship along with modeling of evapotranspiration.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Radiation balance of earth's surface	1
2.	Turbulent transport of heat and momentum	2
3.	Radiation exchange and heat transfer in a low plant cover	2
4.	Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover	2
5.	Predicting potential evapotranspiration	2
6.	Thermodynamics of flow through plant cells	2
7.	Dynamics of water movement through soil plant atmosphere system	2

S.No.	Topic	No. of Lectures
8.	Stomatal aperture, photosynthesis and actual evapotranspiration relationship	1
9.	Production functions of evapotranspiration	3
10.	Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture	4
11.	Crop water requirement under protected cultivation and remote sensing-based modeling	4
	Total	**29**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of potential evapotranspiration using FAO 56 Penman Monteith equation	1
2.	Estimation of potential evapotranspiration using FAO Cropwat model	1
3.	Estimation of potential evapotranspiration using FAO ETo calculator	2
4.	Measurement of ET parameters under open condition	1
5.	Measurement of ET parameters under protected cultivation	1
6.	Development of stochastic models of ET	3
7.	Development of deterministic models of ET	3
8.	Use of software for estimation of crop water requirement and ET	2
	Total	**14**

X. Suggested Reading

- Amarjit Basra. 1994. *Mechanisms of Plant Growth and Improved Productivity*. CRC Press New York.
- Daniel Hillel. *Advances in Irrigation*. All Volumes.
- Nieder AR and Benbi D. 2003. *Handbook of Processes and Modeling in the Soil-Plant System*. CRC Press New York.
- Peter J Gregory. *Plant Roots, their Growth Activity and Interaction with Soils*. Wiley Blackwell New York.

I. Course Title : Plant Growth Modeling and Simulation

II. Course Code : IDE 605

III. Credit Hours : 2+0

IV. Aim of the course

To impart the in-depth knowledge of plant growth modeling, type of modeling approach, quantitative analysis of photosynthesis and remote sensing-based modeling.

V. Theory

Unit I

Introduction to plant growth modeling. Simulation and simulation language. Types of models and modeling approaches.

Unit II

Relational diagram of principle process. Structure of a generalized agricultural simulator. Input environment and techniques for monitoring plant environment.

Unit III

Process and aspects of growth and development. Input yield models. Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions.

Unit IV

Remote sensing-based modeling and field variability of growth influencing factors.

VI. Learning outcome

The students will be able to know various plant growth models and their application based on input environmental parameters. Student will be acquainted with generalized agricultural simulator.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to plant growth modelling	4
2.	Simulation and simulation language	4
3.	Types of models and modeling approaches	4
4.	Relational diagram of principle process	2
5.	Structure of a generalized agricultural simulator	2
6.	Input environment and techniques for monitoring plant environment	4
7.	Process and aspects of growth and development. Input yield models	4
8.	Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions	3
9.	Remote sensing-based modelling	3
10.	Field variability of growth influencing factors	2
	Total	**32**

IX. Suggested Reading

- Charls-Edwards DA. 1981. *The Mathematics of Photosynthesis and Productivity*. Academic Press, London.
- Evans LT. 1963. *Environmental Control of Plant Growth*. Academic Press, New York, USA.
- Goudriaan J and Van Laar HH. 1994. *Modelling Potential Crop Growth Process*. Kluweer Academic Publisher, Dordrecht, The Netherlands.
- Jones JW and Ritchie JT. 1990. *Crop Growth Models*. In: ASAE Monograph on Management of Farm Irrigation.
- Thorwey JHM and Johnson IR. 1990. *Plant and Crop Modelling: A Mathematical Approach to Plant and Crop Physiology*. Clarendon Press, Oxford.

I. Course Title : Multi Criteria Decision Making Systems

II. Course Code : IDE 606

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about multi criteria decision making system which include multi-attribute decision making and multi-objective decision making.

V. Theory

Unit I

Introduction: MCDM overview, basic foundations and Pareto optimality elementary decision analysis. Decision trees and influence diagrams.

Unit II

Multi–attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition, Multi–facility location analysis, expected utility theory, single attribute utility functions, multi–attribute overview, two–attribute utility models, multi–attribute computer programs, multi–attribute assessment.

Unit III

Multi-objective decision making (MODM): Vector optimization theory, weighting methods, weighting example. Linear vector optimization (LVOP), parametric decomposition, LVOP algorithm, LVOP example.

Unit IV

Non interactive and interactive methods: Geoffrion's Bi-criterion method, linear goal programming, nonlinear and integer goal programming.

Unit V

Interactive trade-off methods: Zionts–Wallenius, Surrogate worth, Group decision making methods.

VI. Learning outcome

The students will be able to understand and learn to apply various techniques for the best solutions of real-life command area and other hydrological problems.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	MCDM overview	1
2.	Basic foundations and Pareto optimality elementary decision analysis	2
3.	Decision trees and influence diagrams	1
4.	Multi-attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition	2
5.	Multi-facility location analysis	1
6.	Expected utility theory	1
7.	Single attribute utility functions	1
8.	Multi-attribute overview	1
9.	Two-attribute utility models	1
10.	Multi-attribute computer programs and multi–attribute assessment	2
11.	Multi-objective decision making (MODM)	1
12.	Vector optimization theory	1
13.	Weighting methods and examples related with weighting	2
14.	Linear vector optimization (LVOP)	1
15.	Parametric decomposition	2
16.	LVOP algorithm and LVOP example	2
17.	Non interactive and interactive methods	2
18.	Geoffrion's Bi-criterion method	1
19.	linear goal programming, nonlinear and integer goal programming	2
20.	Interactive trade-off methods	1
21.	Zionts-Wallenius and Surrogate worth	2
22.	Group decision making methods	2
	Total	**32**

VIII. Suggested Reading

- Cohon JL. 2004. *Multiobjective Programming and Planning*. Dover Publications.
- Doumpos M and Grigoroudis E. 2013. *Multicriteria Decision Aid and Artificial Intelligence: Links, Theory and Applications*. Wiley-Blackwell.
- Figueira J, Greco S and Ehrgott M 2007. *Multiple Criteria Decision Analysis: State of the Art Surveys*. Springer.
- Tzeng GH and Huang JJ. 2011. *Multiple Attribute Decision Making: Methods and Applications*. Chapman and Hall/CRC.
- Tzeng GH and Huang JJ. 2013. *Fuzzy Multiple Objective Decision Making*. Chapman and Hall/CRC.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Renewable Energy Engineering

Preamble

(Renewable Energy Engineering)

Course curricula and course outlines in Renewable EnergyEngineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Farm Machinery and Power Engineering, Irrigation and Drainage Engineering, Process and Food Engineering.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields.Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector.

All courses are designed to cover all basic topics andhave been designed by taking into consideration demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students.The emphasis has been given on precision irrigation and modeling management and accordingly new courses “Wind energy, solid waste management, new alternate energy system, advances in renewable energy systemsand Energy generation from agricultural waste and byproducts”are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Renewable Energy Engineering.The revised courses cover the areas:Energy auditing, conversion and management, Solar photovoltaic system design and analysis, Renewable energy policy, planning and economics, Advances in renewable energy systems, New alternate energy systems, Fuel and combustion, Advances in biogas technology, Solid waste and waste water management, Advanced photovoltaic power generation, Renewable energy for industrial application, Bio-fuel technologies and application and Energy modeling and simulation.

The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech. in Renewable Energy Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
REE 501*	Renewable Energy Technologies	2+1
REE 502*	Solar Thermal Energy Conversion Technologies	2+1
REE 503*	Biomass Energy Conversion Technologies	2+1
REE 504	Energy Auditing, Conservation and Management	2+1
REE 505	Wind Energy Conversion and Utilization	2+1
REE 506	Solar Photovoltaic System Design and Analysis	1+1
REE 507	Renewable Energy Policy, Planning and Economics	3+0
REE 508	Alternate Fuels and Applications	2+1
REE 509	Biogas Technology and Mechanism	1+1
REE 510	Energy, Ecology and Environment	3+0
REE 511	Design and Analysis of Renewable Energy Conversion Systems	2+1
REE 512	Energy Generation from Agricultural Waste and Byproducts	2+1
REE 513	Agro Energy Audit and Management	2+1
REE 514	Green House Energetic and Passive Architecture	1+1
REE 515	Energy Management in Food Processing Industries	1+1
	Total	**28+13**

*Compulsory Course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
FMPE 517	Machinery for Precision Agriculture	2+1
FMPE 518	Machinery for Horticulture and Protected Agriculture	2+0
PFE 511	Application of Engineering Properties in Food Processing	2+1
PFE 519	Bioprocess Engineering	2+1
IDE 511	Design of Pumps for Irrigation and Drainage	2+0
CE 501	Dimensional Analysis and Similitude	2+0
FMPE 515	Computer Aided System Design	0+2
CSE 501	Big Data Analytics	2+1
CSE 502	Artificial Intelligence	2+1
CSE 504	Soft Computing Techniques in Engineering	2+1
MATH 501	Finite Element Methods	1+1

Course Code	Course Title	Credits
MATH 502	Numerical Methods for Engineers	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
	Any other course(s) of other department other than courses from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credits
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credits
*PGS 501	Library and Information Services	1+0
*PGS 502	Technical Writing and Communication Skills	1+0
*PGS 503	Intellectual Property and its management in Agriculture	1+0
*PGS 504	Basic Concepts in Laboratory Techniques	1+0
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Course Code	Course Title	Credits
IDE 591	Seminar	0+1
IDE 599	Thesis Research	0+30

Course Contents
M.Tech. in Renewable Energy Engineering

I. Course Title : Renewable Energy Technologies

II. Course Code : REE 501

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge, understanding and application oriented skills on renewable energy sources and relevant technologies towards their effective utilization for meeting energy demand.

V. Theory

Unit I

Solar Energy: Heat transfer, estimation and physical conversion, Instruments for measurement. Energy collection and analysis: FPC, ETC, concentrating collectors. Solar energy application: Direct and indirect. Solar photovoltaic technology: Conversion, Systems components, integrations and applications.

Unit II

Energy from biomass and wastes: Production, distribution, characterization, treatments, recycling. Biomass conversion technologies: Thermo-chemical, bio-chemical and agro-chemical technology. Raw materials, process parameters, end products and utilization.

Unit III

Wind energy: Resource estimation, technologies, performance curves, power and torque characteristics. Airfoils and rotors: Wind mill parameters, wind farms design and considerations.

Unit IV

Alternate Energy Technologies: Ocean Thermal Energy Conversion, Geothermal, Tidal, Hydro. Energy conversion systems: Resources, systems integrations and analysis, applications. Energy storage: Types, materials, characteristics and application.

VI. Practical

Analysis of solar collectors.Solar Photovoltaic cell characteristics, analysis of SPV systems.Characterization of biomass. Design and benefit analysis of energy systems. Design and efficiency testing of wind energy conversion devices.

VII. Learning outcome

The students is acquainted the skill to understand technical aspects and principles of renewable energy characteristics of the resource base (solar radiation, wind energy, bio energy, etc.) In a further steps an economic analysis of supply technologies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Solar energy: introduction. Solar radiations measuring Instruments	1
2.	Passive Flat plate solar collectors, types. Passive solar water heaters. Performance of solar water heater. Effect of various parameters on performance	2
3.	Solar passive concentrators: Brief introduction to main types of solar concentrators, solar cookers	1
4.	Solar passive crop dryers: Description of various types of solar crop dryers, Applications of solar crop dryers	2
5.	Solar photovoltaic technology: Conversion, Systems components, integrations and applications	2
6.	Biomass Production, distribution, characterization, treatments, recycling.	1
7.	Review of gasifiers basics; Selection criteria for type and capacity of gasifier; Performance parameters for gasifiers e.g. SGR, turn down ratio etc;	1
8.	Basic design of small scale Imbert type downdraft gasifier (without use of Tables) and Basic features of throatless and inverted downdraft gasifiers (No designing)	1
9.	Baling for densification of biomass and briquetting machines for densification of biomass	1
10.	Bio-chemical and agro-chemical technologies for biomass conversion	2
11.	Raw materials, process parameters, end products and utilization for bio-chemical and agro-chemical technologies	2
12.	Resource estimation of wind energy, technologies and performance curves	2
13.	Power and torque characteristics	2
14.	Wind mill parameters	2
15.	Wind farms design and considerations	2
16.	Ocean Thermal Energy Conversion	2
17.	Geothermal, Tidal and Hydro Energy conversion systems	2
18.	Energy storage: Types, materials, characteristics and application	4
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Analysis of solar collectors	3
2.	Solar Photovoltaic cell characteristics, analysis of SPV systems	3
3.	Characterization of biomass	4
4.	Design and benefit analysis of energy systems	3
5.	Design and efficiency testing of wind energy conversion devices	3
	Total	**16**

X. Suggested Reading

- Culp AW. 1991. *Principles of Energy Conversion*. McGraw-Hill Pub. Co Inc., New York.
- Duffie JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New York.
- Garg HP and Prakash J. 1976. *Solar Energy, Fundamentals and Applications*. Tata McGraw-Hill Pub. Co. Inc., New Delhi.
- Odum HT and Odum EC. 1976. *Energy Basis for Man and Nature*. McGraw-Hill Pub. Co. Inc., New York.

- Rai GD. 2001. *Non Conventional Energy Sources*. Khanna Publishers, Delhi.
- Sukhatme SP. 1997. *Solar Energy, Principles of Thermal Collection and Storage*. Tata McGraw-Hill. Pub. Co. Ltd, New Delhi.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd., London.

I. Course Title : Solar Thermal Energy Conversion Technologies

II. Course Code : REE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in-depth knowledge, understanding and application oriented skills on solar thermal conversion technologies and their effective utilization for meeting energy demand.

V. Theory

Unit I

Characteristics of solar radiation: Attenuation, absorption, scattering and air mass. Solar earth geometry.

Unit II

Solar flux and weather data. Solar radiation data and estimation: Radiation estimation models and applications. Heat and mass transfer in solar energy utilization: Gray surface, sky radiation, radiation heat transfer coefficient, reflectivity, transitivity, transmittance absorption product. Selective surfaces and materials.

Unit III

Solar thermal energy collectors (track and untrack): Heat capacity effect, time constant measurement, design and efficiency calculations, F chart method utility.

Unit IV

Techno-economic feasibility of solar thermal energy applications: Cooking, air heating for drying, steam generation, space heating and cooling, refrigeration, architecture, absorption cooling, thermal power generation.

VI. Practical

Solar radiation measurement, estimation model applications, design of collectors, study of materials used in solar system. Energy balance and efficiency calculation of collectors.

VII. Learning outcome

The student is able to understand the detail knowledge about working and design of various solar thermal devices able to design different solar thermal devices.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to characteristics of solar radiation and Solar earth geometry	2
2.	Solar flux and weather data measurement and interpretation	2
3.	Estimation of Solar radiation data using models and estimation	3
4.	Heat and mass transfer in solar energy utilization	2

S.No.	Topic	No. of Lectures
5.	Gray surface, sky radiation, radiation heat transfer coefficient	2
6.	Reflectivity, Transitivity, Transmittance Absorption	2
7.	Selective surfaces and materials as solar energy collectors	2
8.	Heat capacity effect, time constant measurement of solar energy	2
9.	Design and efficiency calculations of Solar thermal energy collectors	4
10.	F chart method utility for Designing Solar Thermal Water Heating Systems	2
11.	Techno-economic feasibility of solar thermal energy in cooking, drying of food products, space heating and cooling.	4
12.	Economic feasibility of solar thermal energy in refrigeration, architecture, absorption cooling, thermal power generation.	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Measurement of Solar radiation	1
2.	Estimation of solar energy by model applications	2
3.	Design of solar energy collectors	2
4.	Study of materials used in solar system	1
5.	Energy balance in solar energy collectors	2
6.	Efficiency calculation of collectors	2
	Total	**10**

X. Suggested Reading

- Bansal NK, Kleeman MK and Meliss M. 1990. *Renewable Energy Sources and Conversion Technologies*.Tata McGraw-Hill Pub. Co. Ltd, Delhi.
- Duffie JA and Beckman WA. 2006. *Solar Thermal Engineering Process*. John Wiley & Sons, New Jersey.
- Hsien JS. 2014. *Solar Energy*. Prentice Hall Inc., New Jersey.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht, Netherland.
- Kalogirou SA. 2013. *Solar Energy Engineering*. Academic Press, Cambridge, Massachusetts.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.
- Pai BR and Ramaprasad MS. 1991. *Power Generation through Renewable Sources of Energy*. Tata McGraw-Hill Pub. Co., New Delhi.
- Sukhatme SP and Nayak J. 2008. S*olar Energy: Principles of Thermal Collection and Storage*. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

I. Course Title : Biomass Energy Conversion Technologies

II. Course Code : REE 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the bio-conversion technologies and fuels system, types of biomass derived fuels and energy, thermo-chemical conversion of biomass to heat and power, value adding of agro-residues.

V. Theory

Unit I

Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept. Direct use of biomass: Size reduction, baling, pelletization, briquetting technologies.

Unit II

Biochemical conversion of biomass: Feedstock, process design, operation, optimized process parameters and utilization for biogas and bioethanol production.

Unit III

Biomass combustion: Stoichiometric air requirement, chemistry of combustion, design of combustion system, combustion zones, flame structure, stability, emissions. Co-firing of biomass.

Unit IV

Thermo-chemical conversion of biomass: Feedstock, chemistry, reactor design, operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.

Unit V

Cogeneration technologies: Cycles, topping, bottoming, selection, problems, applications. Waste heat recovery: Estimation, systems, design and application.

VI. Practical

Biomass characterization.Design of bioreactors.Study of techno-economical feasibility of bio-chemical conversion process.Performance evaluation of combustion gadgets, gasifiers and pyrolytic converters.Design of waste heat recovery system.

VII. Learning outcome

The students is enable to extract the energy from biomass and acquainted the skill to know how to choose the suitable biomass fuels for different industrial applications with design and economics of the system.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept.	3
2.	Direct use of biomass	1
3.	Size reduction, baling, pelletization, briquetting technologies.	2
4.	Biochemical conversion of biomass	1
5.	Feedstock, process design, operation, optimized process parameters.	2
6.	Utilization for biogas and bioethanol production.	1
7.	Biomass combustion	1
8.	Stoichiometric air requirement, chemistry of combustion.	3
9.	Design of combustion system.	2
10.	Combustion zones, flame structure, stability, emissions.	2
11.	Co-firing of biomass.	1
12.	Thermo-chemical conversion of biomass: Feedstock, chemistry.	2
13.	Reactor design.	1

S.No.	Topic	No. of Lectures
14.	Operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.	2
15.	Cogeneration technologies: Cycles, topping, bottoming, selection.	2
16.	Cogeneration Problems and applications.	2
17.	Waste heat recovery	2
18.	Estimation, systems, design and application.	2
	Total	**32**

IX. List of Practicals

S.No.	Topics	No. of Practicals
1.	Characterization of biomass	2
2.	Design of bio-reactors	1
3.	Determination of techno-economical feasibility of bio-chemical conversion process.	2
4.	Performance evaluation of combustion gadgets	1
5.	Performance evaluation of gasifiers	1
6.	Performance evaluation of pyrolytic converters	1
7.	Design of waste heat recovery system	2
	Total	**10**

X. Suggested Reading

- Chakravorty A. 1985. *Biogas Technology & other Alternative Technologies*. Oxford & IBH Publication Ltd, Delhi.
- Chaturvedi P. 1995. *Bio-Energy Resources: Planning, Production and Utilization*. Concept Pub. Co., New Delhi.
- Goswami DY. 1986. *Alternative Energy in Agriculture*.Vol. II (Ed), CRC, Press Inc., Florida, USA.
- Stout BA. 1984. *Biomass Energy Profiles*. FAO Agril. Services Bulletin No.54., Elsevier Science Publishers Ltd, England.
- Twidell JW and Weir AD. 2006. *Renewable Energy Sources*. E & F N Spon Ltd, New York.
- Vimal OP. 1984. *Energy from Biomass*.Agrcole Publishing Academy, New Delhi.

I. Course Title : Energy Auditing, Conservation and Management

II. Course Code : REE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip about the sources of energy, conservation of energy and its management. Study of energy efficiency, energy planning, forecasting and energy economics.

V. Theory

Unit I

Energy conservation: Concepts, energy classification, equivalents, scenario, energy pricing, importance. Energy conservation act.

Unit II

Energy auditing and economics: Energy management, energy audit strategy, types. Energy performance: Bench marking, fuel substitutions, energy audit instruments, material and energy balance. Energy conversion: Energy index, cost index. Financial management.

Unit III

Thermal energy audit: Performance evaluation, energy conservation opportunities in boilers, steam system and furnaces, insulation, refractory's and other thermal utilities.

Unit IV

Electrical Energy audit: Electrical systems, electricity billing, load management, power factor. Performance evaluation and energy conservation opportunities in motors, compressed air system, HVAC and refrigeration system, fans and blowers, pumps and lighting system.

Unit V

Energy auditing and reporting in industries, Replacement of renewable energy technology option, case study in agro-industries.

VI. Practical

Problems on energy index, cost index. Problems on material balance and energy balance. Financial management.Energy audit and conservation opportunities in thermal and electrical utilities. Case studies on energy audit and conservation.

VII. Learning outcome

Able to understand the concept of energy auditing, conservation and management. The in-depth knowledge about the quantification, conservation opportunity and retrofitting of energy efficient system integration is expected from the course.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy conservation: Introduction, Concepts, Scenario	2
2.	Classification of Energy	1
3.	Energy equivalents, energy pricing, importance.	2
4.	Energy conservation act.	2
5.	Introduction to energy management, energy audit strategy and types.	2
6.	Energy performance: Bench marking, fuel substitutions.	1
7.	Energy audit instruments, material and energy balance.	2
8.	Energy conversion: Energy index, cost index. Financial management.	2
9.	Performance evaluation and energy conservation opportunities in boilers.	1
10.	Insulation, refractory's and other thermal utilities.	2
11.	Performance evaluation and energy conservation opportunities in steam system and furnaces.	2
12.	Electrical Energy audit: Electrical systems, electricity billing, load management, power factor.	2
13.	Performance evaluation and energy conservation opportunities in motors, compressed air system.	2
14.	Performance evaluation and energy conservation opportunities in HVAC and refrigeration system.	2
15.	Performance evaluation and energy conservation opportunities in fans and blowers, pumps and lighting system.	2
16.	Energy auditing and reporting in industries.	1
17.	Replacement of renewable energy technology option.	2
18.	Case study in agro-industries.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Problems on energy index.	2
2.	Problems on cost index.	2
3.	Problems on material balance.	2
4.	Problems on energy balance.	2
5.	Financial management.	2
6.	Energy audit and conservation opportunities in thermal utilities.	2
7.	Energy audit and conservation opportunities in electrical utilities.	2
8.	Case studies on energy audit and conservation.	2
	Total	**16**

X. Suggested Reading

- *Energy Management*, *Bi-monthly Journal* National Productivity Council, New Delhi.
- Guide Books for *National Certification Examination for Energy Managers and Energy Auditors,* Book 1–4, 2005 Bureau Energy Efficiency, New Delhi.
- Murgai MP and Chandra R. 1990. *Progress in Energy Auditing and Conservation, Boiler Operations.* Wiley Eastern Ltd, New Delhi.
- Murphy WR and McKay G. 1982. *Energy Management.* Butterworth & Co., Publishers Ltd., London.
- Porter R and Roberts T. 1985. *Energy Saving by Waste recycling.* Elsevier applied science publishers, New York, USA.
- Smith CB. 1981. *Energy Management Principles, Applications, Benefits and Savings.* Pergamon Press Inc., Oxford, England.
- Victor B. 1983. *Ottaviano, Energy Management.* An OTIS Publication, Ottaviano Technical Service Inc., Melville, New York.

I. Course Title : Wind Energy Conversion and Utilization

II. Course Code : REE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquire the in-depth knowledge of wind energy conversion systems, wind potential mapping, estimation and analysis of wind data.

V. Theory

Unit I

Wind mapping and assessment: Wind energy potential, nature of wind, Weibull and Rayleigh analysis, instruments, history and taxonomy of wind mills, wind power laws.

Unit II

Wind turbine aerodynamics: Momentum theories, basic aerodynamics, airfoils and their characteristics. Horizontal Axis Wind Turbine (HAWT): Blade element theory, wake analysis. Vertical Axis Wind Turbine (VAWT): Aerodynamics, rotor design, power regulation, yaw system.

Unit III

Selection of site.Mechanical and electrical applications. Wind farms: Interfacing, maintenance. Management of power generated by wind mill: Instruments and controls. Stand alone and grid connected systems. Wind energy storage. Wheeling and banking. Cost economics. Testing and certification procedures.

Unit IV

Wind turbine loads: Aerodynamic loads in steady operation, wind turbulence, static. Wind energy control system (WECS). Synchronous and asynchronous generators. Annual Energy Output (AEO). Testing of WECS.

VI. Practical

Visit to meteorological observatory. Wind velocity mapping and curve analysis. Wind energy instruments and resource assessment. Design of wind mills, water pumping wind mills.Performance evaluation of wind aero-generator. Wind turbine loads. Economics of wind energy systems.

VII. Learning outcome

The students will acquire knowledge regarding mechanism of wind energy and different types of wind machines available to harness wind power and also able to design wind turbine for irrigation as well as for power generation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Mapping of Wind energy and its assessment, nature of wind, Wind energy potential	2
2.	Weibull and Rayleigh analysis	2
3.	Instruments, history and taxonomy of wind mills, wind power laws	2
4.	Aerodynamics of Wind turbine, Momentum theories, airfoils and their characteristics	3
5.	Elemental theory of Horizontal and Vertical Axis Wind Turbine (HAWT)	2
6.	Aerodynamics of wind turbines, rotor design, power regulation, yaw system	2
7.	Selection of site for wind mill installation, Mechanical and electrical applications of wind mills	2
8.	Wind farms: Interfacing and maintenance, Instruments and controls for management of power generated by wind mill	3
9.	Stand alone and grid connected systems, Wind energy storage, Wheeling and banking.	2
10.	Economics of wind mills	2
11.	Testing and certification procedures for wind mills	3
12.	Wind turbine Aerodynamic loads in steady operation, wind turbulence, static.	2
13.	Wind energy control system (WECS), Synchronous and asynchronous generators	2
14.	Annual Energy Output (AEO), Testing of Wind energy control system	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Visit to meteorological observatory	1
2.	Wind velocity mapping and curve analysis	2
3.	Wind energy instruments and resource assessment	1
4.	Design of wind mills	1

S.No.	Topic	No. of Practicals
5.	Water pumping wind mills	1
6.	Performance evaluation of wind aero-generator	2
7.	Study of Wind turbine loads	2
8.	Economics of wind energy systems.	2
	Total	**12**

X. Suggested Reading

- Cheremision NP. 1978. *Fundamental of Wind Energy*: Ann Arbor Science, Pub. Inc., Michigan.
- Eldridge FR. 1980. *Wind Machines*. Van Nostr and Reinhold Co., New York.
- More HG and Maheshwari RC. *Wind Energy Utilization in India,* Technical Bulletin No. CIAE/82/38, CIAE, Bhopal.
- Lipman NH, Muggrove PJ and Pontin GW. 1982. *Wind Energy for the Eighties*. Peter Peregrinus Ltd. Stenvenage, New York.
- Lysen EH. 1983. *Introduction to Wind Energy*. Consultancy Services Wind Energy Developing Countries, Netherlands.
- Manwell JF, McGswan JG and Rogers AL. 2012. *Wind Energy Explained–Theory Design and Application*. John Wiley and Sons, New Jersey.
- Powar AG and Mohod AG. 2010. *Wind Energy Technologies*. Jain Publication, New Delhi.

I. Course Title : Solar Photovoltaic System Design and Analysis

II. Course Code : REE 506

III. Credit Hours : 1+1

IV. Aim of the course

To provide detail knowledge about working and design of various solar photovoltaic systems for power generation.

V. Theory

Unit I

Physics of solar cells: Crystal structure, band theory, semiconductor, p-n junctions, absorption of radiation, generation, recombination and carrier separation. Standard solar cell structure: I,V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature.

Unit II

Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies, Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion. Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies.

Unit III

Solar PV systems: Balance of System (BoS), SPV system design guideline and methodologies, introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use. Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.

Unit IV

Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.

VI. Practical

Solar cell efficiency testing.SPV fabrication technologies.System integration and BoS matching studies.PV software's operation and utilization.Design and estimation of SPV systems components for agrobased industrial applications.Batteries performance testing.

VII. Learning outcome

Student is able to design different solar photovoltaic system for power generation with system integration and economic analysis.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physics of solar cells: Crystal structure, band theory, semiconductor, p-n junctions	1
2.	Absorption of radiation, generation, recombination and carrier separation.	2
3.	Standard solar cell structure: I,V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature.	2
4.	Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies.	1
5.	Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion.	1
6.	Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies.	2
7.	Solar PV systems: Balance of System (BoS), SPV system design guideline and methodologies,	1
8.	Introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use.	2
9.	Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.	2
10.	Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), Fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level and efficiency determination.	1
2.	To demonstrate the I-V and P-V characteristics of series combination of PV modules and efficiency determination.	1
3.	To demonstrate the I-V and P-V characteristics of parallel combination of PV modules and efficiency determination.	1
4.	To show the effect of variation in tilt angle on PV module power.	1
5.	To demonstrate the effect of shading on module output power and efficiency determination.	1
6.	Study on SPV fabrication technologies.	1
7.	Study on system integration and BoS matching.	1

S.No.	Topic	No. of Practicals
8.	PV software's operation and utilization.	1
9.	Design and estimation of SPV systems components for agrobased industrial applications.	1
10.	Battery performance testing.	1
	Total	**10**

X. Suggested Reading

- Garg HP. 1990. *Advances in Solar Energy Technology*. D. Publishing Company, Tokyo.
- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications*. Prentice Hall, Upper Saddle River, New Jersey.
- Kreith F and Kreider JF. 1978. *Principles of Solar Engineering*. McGraw-Hill, New York.
- Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education*. John Wiley & Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Ltd, Delhi.
- Sze SM and Kwok K Ng. 2007. *Physics of Semiconductor Devices*. 3rd Edn. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. Vol.5. McGraw-Hill, New York.

I. Course Title : Renewable Energy Policy, Planning and Economics

II. Course Code : REE 507

III. Credit Hours : 3+0

IV. Aim of the course

To provide the in-depth knowledge about the current energy policy and planning, environmental economics, policy and ecology.

V. Theory

Unit I

Introduction to policy parameters, regulatory bodies.Introduction to overall policy environment on energy sector, policy formulation parameters. Entities: Consumers and their tariffs, generator, DISCOM, Regulators: CERC and SERC, Statutory bodies. Typical issues of Indian power sector.

Unit II

Indian energy Policy: Introduction, Electricity Act, National Policy on Tariff, Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions. Concept of Grid Code, Green Corridor, Solar and Hybrid Parks. Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.

Unit III

Policy and planning: Energy, environment interaction, clean development mechanism, financing of energy systems, software for energy planning, socio-economical approach. Project management in energy: Cost economics-sensitivity and risk analysis.

Unit IV

Energy economics: economic evaluation of renewable energy systems, life cycle costing, components of energy investment and risk and uncertainties in energy investment.

VI. Learning outcome

A student is be able to develop an interdisciplinary knowledge base that will enable them to understand and solve contemporary energy policy, planning and environmental problems.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to policy parameters and regulatory bodies in Energy	2
2.	Introduction to overall policy environment on energy sector, policy formulation parameters	3
3.	Entities: Consumers and their tariffs	2
4.	Generator, DISCOM, Regulators: CERC and SERC, Statutory bodies.	3
5.	Typical issues of Indian power sector.	2
6.	Introduction to Indian energy Policy and Electricity Act	3
7.	National Policy on Tariff	2
8.	Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions	3
9.	Concept of Grid Code, Green Corridor, Solar and Hybrid Parks.	3
10.	Clean development mechanism, financing of energy systems	3
11.	Policy and planning in Energy, environment interaction	2
12.	Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.	4
13.	Software for energy planning, socio-economical approach.	3
14.	Project management in energy: Cost economics-sensitivity and risk analysis.	4
15.	Energy economics: economic evaluation of renewable energy systems	3
16.	Life cycle costing, components of energy investment	3
17.	Risk and uncertainties in energy investment	3
	Total	**48**

VIII. Suggested Reading

- BEE Reference book: no.1/2/3/4.
- Bhattacharyya SC. 2011. *Energy Economics*. Springer, New York City, USA.
- Brown CE. 2002. *World Energy Resources*. Springer, New York City, USA.
- Conti J. 2016. *International Energy Outlook*. US Energy Information Administration (*EIA*), Washington.
- Culp AW. 1991. *Principles of Energy Conversion*. McGraw-Hill Int. edition, New York.
- Krithika PR and Mahajan S. 2014. *Governance of Renewable Energy in India: Issues and Challenges*. TERI, New Delhi.
- Parikh JK. 1981. *Modeling Approach to Long Term Demand and Energy Policy Implication for India*. IIASA, Laxenburg, Austria.
- Reddy AKN, Williams RH, Goldenberg J and Johansson TB. 1987. *Energy for a Sustainable World*. Wiley-Eastern Ltd, New Delhi, India.
- TEDDY Year Book Published by Tata Energy Research Institute (TERI).

I. Course Title : Alternate Fuels and Applications

II. Course Code : REE 508

III. Credit Hours : 2+1

IV. Aim of the course

To get acquainted with various alternate fuels, their applications and also to learn safety factors of alternate fuel, efficiency, economics and commercial considerations.

V. Theory

Unit I

Introduction to alternate fuels: Methanol, ethanol, biogas, producer gas, hydrogen and fuel cell. Production composition and properties, combustion characteristics, comparison with conventional fuels, potential, possibilities and problems.

Unit II

Fuel cell: Principle, classification, system efficiency. Life cycle assessment of fuel cell systems.

Unit III

Hydrogen fuel: Production, gas cleanup, challenges and opportunities. Hydrogen storage and energy economy.

Unit IV

Utilization: Thermal and mechanical applications. Environmental impact and safety factors of alternate fuel, efficiency, economics and commercial considerations.

VI. Practical

Performance of I.C. engines on alternate fuels, measurement of flue gas parameters, thermal applications of alternate fuels. Hydrogen production. Biomass based fuel cell. Integrated biomass based gasifier for power generation.

VII. Learning outcome

Students will understand various properties of alternate fuels like methanol, ethanol, fuel cells, hydrogen fuel for energy efficient utilization.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to alternate fuels: methanol, ethanol, biogas, producer gas, and hydrogen fuel cell.	3
2.	Alternate fuels: potential, possibilities and problems.	2
3.	Production, composition and properties of methanol.	2
4.	Production, composition and properties of ethanol.	2
5.	Production, composition and properties of biogas.	2
6.	Production, composition and properties of producer gas.	2
7.	Production and properties of hydrogen fuel cell.	2
8.	Combustion characteristics of alternate fuels, comparison of with conventional fuels.	3
9.	Fuel cell: Principle, classification, system efficiency.	2
10.	Life cycle assessment of fuel cell systems.	2
11.	Hydrogen fuel: gas cleanup.	2
12.	Hydrogen fuel: challenges and opportunities	2

S.No.	Topic	No. of Lectures
13.	Hydrogen storage and energy economy.	1
14.	Thermal and mechanical applications alternate fuel.	2
15.	Environmental impact and safety factors of alternate fuels, efficiency, economics and commercial considerations.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Performance of I.C. engines on alternate fuels (biogas, producer gas and bio diesel)	3
2.	Measurement of flue gas parameters.	1
3.	Thermal applications of alternate fuels (biogas, producer gas and bio diesel)	3
4.	Hydrogen production.	1
5.	Biomass based fuel cell.	1
6.	Integrated biomass-based gasifier for power generation.	1
	Total	**10**

X. Suggested Reading

- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization in Combustion Engines*. CRC Press, Florida.
- Bungay HR. 1981. *Energy, the Biomass Options*. John Willey & Sons, New York.
- Dahiya A. 2014. *Bioenergy: Biomass to Biofuels. Engines*. Springer, New York City, New York.
- Demirbas A. 2010. *Biodiesel: A Realistic Fuel Alternative for Diesel Chemicals*. Academic Press, Cambridge, England.
- Klass DL. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals*. Academic Press, Cambridge, England.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India.
- San PA. 1980. *Biochemical and Photosynthetic: Aspects of Energy Production*. Academic Press. London.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press. Florida.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd, New York.

I. Course Title : Biogas Technology and Mechanism

II. Course Code : REE 509

III. Credit Hours : 1+1

IV. Aim of the course

To provide the in-depth knowledge about biogas technology and its mechanism in detail to use the biogas as domestic as well as commercial fuel.

V. Theory

Unit I

Biogas Technology: Potential and status, chemistry, physical conditions and utilization of alternate feedstock materials.

Unit II

Types of reactors: Single phase, two phase processes. High rate biomethanation process, selection of model and size, construction technique, material requirement. Design concept of night soil, kitchen waste, solid state cold condition biogas plants.

Unit III

Biogas distribution and utilization: Properties and uses of biogas, design of gas distribution system. Biogas utilization devices: Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power. Testing of biogas appliances.

Unit IV

Effluent: Handling of effluent biogas plant, effluent treatment and management, BDS applications and enrichment. Cost and financial viability of biogas plants.Repair and maintenance of biogas plants.

VI. Practical

Design of biogas plant for solid and liquid wastes, cost estimation, analysis of biogas, purification of biogas.Performance evaluation of biogas appliances.Testing of biogas burner for heat transfer, thermal and cooking efficiency. Bio digested slurry analysis, use of biogas spent slurry. Carbon credits.

VII. Learning outcome

Students are able to design, select, estimate and analyzed the biogas technology, chemical and physical conditions and get acquainted with various biogas appliances.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biogas Technology potential and status	1
2.	Chemistry, physical conditions and utilization of alternate feedstock materials	1
3.	Types of reactors: Single phase, two phase processes.	1
4.	High rate bio-methanation process, selection of model and size, construction technique, material requirement	2
5.	Design concept of night soil, kitchen waste, solid state cold condition biogas plants	1
6.	Properties and uses of biogas, design of gas distribution system	1
7.	Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power	2
8.	Testing of biogas appliances	2
9.	Handling of biogas plant effluents, effluent treatment and management	1
10.	Bio digested Slurry applications and enrichment	2
11.	Cost and financial viability of biogas plants	1
12.	Repair and maintenance of biogas plants	1
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design of biogas plant for solid and liquid wastes	1
2.	Cost estimation of different biogas plants: KVIC, Janta, Deenbandhu, type	2

S.No.	Topic	No. of Lectures
3.	Analysis of biogas	1
4.	Experiment on purification of biogas	1
5.	Performance evaluation of biogas appliances	1
6.	Testing of biogas burner for heat transfer, thermal and cooking efficiency	2
7.	Analysis of Bio-digested slurry	2
8.	Study on use of biogas spent slurry	1
9.	Study and analysis of Carbon credits.	1
	Total	**12**

IX. Suggested Reading

- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Pub. House, New Delhi.
- Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi.
- Khandelwal KC and Mahdi SS. 1986. *Biogas Technology*. A Practical Hand Book, Vol.I, Tata McGraw-Hill Pub. Co. Ltd, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international (P) Ltd, New Delhi.
- Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes*. National Academy of Sciences, Washington.
- Tasneem A, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer Publications, Springer Science and Business Media, New York, USA.
- Van BA. 1981. *Chinese Biogas Manual*. Intermediate Technology Publications, London.

I. Course Title : Energy, Ecology and Environment

II. Course Code : REE 510

III. Credit Hours : 3+0

IV. Aim of the course

To provide detail knowledge of carbon cycle, ecosystem, climate change and global environmental change and inter linkages of renewable energy sources.

V. Theory

Unit I

Global carbon cycle.Carbon reservoirs flow and human interventions. Global warming and climate change. Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.

Unit II

Ecosystem: Kinds, transfection, components of ecosystem, ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.

Unit III

Climate change: Impact and models. Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions. Low carbon technologies: Energy efficiency projects, carbon trading.

Unit IV

Environment, Environmental degradation: Thermal and chemical pollution, primary and secondary pollutant, air pollution, water pollution, unclear energy hazard, radioactive hazards, mining hazards, land use, oil spills and gas leaks.

Unit V

Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC), Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation.

VI. Learning outcome

Students will able to understand the relationship between carbon cycle, energy policies, energy use and economic growth and factors affecting environment.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Global carbon cycle.	1
2.	Carbon reservoirs flow and human interventions.	2
3.	Global warming and climate change.	2
	Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.	4
4.	Ecosystem: Kinds, transfection, components of ecosystem,	3
5.	Ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.	3
6.	Climate change: Impact and models.	3
	Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions.	2
7.	Low carbon technologies: Energy efficiency projects, carbon trading.	3
8.	Environment, Environmental degradation	1
9.	Thermal and chemical pollution, primary and secondary pollutant, air pollution,	3
10.	Water pollution	1
11.	unclear energy hazard	1
12.	Radioactive hazards, mining hazards, land use, oil spills and gas leaks.	3
13.	Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC)	4
14.	Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation.	4
	Total	**40**

VIII. Suggested Reading

- Canter LC. 1979. *Environmental Impact Assessment*. McGraw Hill Pub. Co., New York.
- Coley D. 2008. *Energy and Climate Change*. John Wiley & Sons, Ltd., New Jersey.
- Dessler A. 2011. *Introduction to Modern Climate Change*. Cambridge University Press, Cambridge, England.
- Essam E and Hinnami EI. 1991. *Environmental Impact of Production and Use of Energy*. Tycooly Press Ltd, Dublin.
- Fowler JM. 1984. *Energy and the Environment, Second Edition*. McGraw-Hill, New York.
- Kaushika ND and Kaushik K. 2004. *Energy, Ecology and Environment: A Technological Approach*. Capital Publishing, New Delhi.
- Mathur AN, Rathore NS and Vijay VK. 1995. *Environmental Awareness*, Himanshu Pub., Udaipur.

- Puppy HG. *Energy and Environment, Mankind and Energy Needs*. Elsevier Pub. Co., New York.
- Rathore NS and Kurchania AK. 2001. *Climatic Changes and their Remedial Measures*. Shubhi Publications, Gurgaon.
- Thomdike EH. 1978. *Energy and Environment: A Premier for Scientists and Engineers*. Adson, Wesley Pub. Co., Boston, US.
- Wilson R and Jones WJ. 1974. *Energy, Ecology and the Environment*. Academic Press Inc., Cambridge, Massachusetts, US.

I. Course Title : Design and Analysis of Renewable Energy Conversion Systems

II. Course Code : REE 511

III. Credit Hours : 2+1

IV. Aim of the course

To design and analyze renewable energy conversion systems, thermodynamics involved in it and performance of renewable energy systems.

V. Theory

Unit I

Energy cycle of the earth. Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides, biomass energy, solar energy, wind energy and other renewable energy sources.

Unit II

Thermodynamics of renewable energy conversion: Energy and exergy analysis of renewable energy power systems. Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.

Unit III

Design of renewable energy systems: Design concept, operational parameters, consideration and rational values for agro industrial applications.

Unit IV

Performance analysis of renewable energy systems: Standards and test codes, optimum performance records, evaluation and maintenance aspects, uses of HOMER (Hybrid Optimization Model for Electric Renewable) software.

VI. Practical

Estimation and assessment of renewable energy sources in India.Thermodynamic principles of energy conversion.Design and operational parameters of renewable energy systems. Study on standards and test codes of renewable energy systems.

VII. Learning outcome

Students will able to design of various energy conversion systems, standards and test codes of renewable energy systems and their performance analysis.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy cycle of the earth	1
2.	Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides	2

S.No.	Topic	No. of Lectures
3.	Estimation and assessment of renewable energy sources: biomass energy, solar energy, wind energy	3
4.	Estimation and assessment of renewable energy sources: other renewable energy sources.	2
5.	Thermodynamics of renewable energy conversion: Energy and energy analysis of renewable energy power systems.	4
6.	Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.	4
7.	Design of renewable energy systems: Design concept, operational parameters,	4
8.	Design of renewable energy systems: Consideration and rational values for agro industrial applications.	4
9.	Performance analysis of renewable energy systems: Standards and test codes, optimum performance records	3
10.	Performance analysis of renewable energy systems: Evaluation and maintenance aspects	3
11.	Uses of HOMER (Hybrid Optimization Model for Electric Renewable) software.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation and assessment of renewable energy sources in India	1
2.	Thermodynamic principles of energy conversion	2
3.	Design and operational parameters of biogas plant	2
4.	Design of a updraft gasifier using solid biomass	2
5.	Design of solar photovoltaic plant for a hostel/building	2
6.	Life cycle assessment and financial assessment of a photovoltaic plant for a hostel/building	1
7.	Study on standards of renewable energy systems	1
8.	Study on test codes of renewable energy systems	2
	Total	**13**

X. Suggested Reading

- Boyle G. 1996. *Renewable Energy: Power for Sustainable Future*. Oxford Univ. Press, England.
- Culp AW. 1991. *Principles of Energy Conservation*. Tata McGraw-Hill, New Delhi.
- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, Hoboken, North America.
- Garg HP and Prakash J. 1997. *Solar Energy: Fundamental and Application*. Tata McGraw-Hill, New Delhi.
- Grewal NS, Ahluwalia S, Singh S and Singh G. 1997. *Hand Book of Biogas Technology*. TMH New Delhi.
- Lambert T and Lilienthal P 2004. *Homer: The Micro-Power Optimization Model*. National Renewable Energy Lab., Philippines.
- Manwell JF, McGowan JG and Rogers AL. 2003. *Wind Energy Explained*. John Wiley, Hoboken, North America.
- Mittal KM. 1985. *Biomass Systems: Principles and Applications*. New Age International, New Delhi.
- Patel MK. 1999. *Wind and Solar Power Systems*. CRC Press, Florida.

I. Course Title : Energy Generation from Agricultural Waste and Byproducts

II. Course Code : REE 512

III. Credit Hours : 2+1

IV. Aim of the course

To focus on agricultural wastes and by products for its utilization for energy generation.

V. Theory

Unit I

By Products: Generation, estimation and utilization. Agricultural and agro industrial by-products/wastes: Properties, characterization, on site handling, storage and processing. Concept, scope and maintenance of waste management and effluent treatment

Unit II

Waste as fuel: Utilization pattern, pretreatments, secondary treatments, mechanism, construction, efficiency and suitability.

Unit III

Utilization of agro based industrial wastes for paper production, production of particle board, fertilizer through vermi-composting and fuel.

Unit IV

Thermo-chemical and biochemical conversion of agricultural waste and byproducts: Densification, combustion, gasification, extraction, pyrolysis, carbonization, torrefaction, liquefaction, anaerobic digestion and fermentation process.

VI. Practical

Estimation and characterization of agricultural waste and byproducts, production of fuel from agricultural wastes and by products, techno-economic feasibility of waste to fuel systems.

VII. Learning outcome

Student will be able to understand the estimation, characterization, storage and handling of agricultural wastes and by products to generate the energy.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Agricultural and agro industrial by-products/wastes:.	1
2.	Generation, estimation and utilization of Agricultural and agro-industrial by-products/wastes	2
3.	Properties, characterization, of Agricultural and agro industrial by-products/wastes	1
4.	On site handling, storage and processing Agricultural and agro industrial by-products/wastes	2
5.	Concept, scope and maintenance of waste management and effluent treatment	2
6.	Introduction to Waste as fuel:.	1
7.	Utilization pattern of waste as Fuel in India and world	1

S.No.	Topic	No. of Lectures
8.	Pretreatments and secondary treatments for waste for conversion to Fuel	2
9.	Mechanism, construction, efficiency and suitability of treatments	2
10.	Utilization of agro based industrial wastes for paper production	2
11.	Production of particle board,	1
12.	Fertilizer through vermi-composting and fuel	1
13.	Introduction to Thermo-chemical of agricultural waste and by-products	1
14.	Introduction to biochemical conversion of agricultural waste and by-products	1
15.	Densification	1
16.	Combustion	1
17.	Gasification	1
18.	Extraction	1
19.	Pyrolysis	1
20.	Carbonization	1
21.	Torrefaction	1
22.	Liquefaction	1
23.	Anaerobic digestion	2
24.	Fermentation process	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of agricultural waste by remote sensing and field Method	2
2.	Characterization of agricultural waste and by products	1
3.	Determination of moisture content of biomass	1
4.	Determination of Volatile solids	1
5.	Determination of Fixed carbon content of biomass	1
6.	Determination of ash content of biomass	1
7.	Estimation of calorific value of biomass	1
8.	Estimation of calorific value of biogas	1
9.	Estimation of calorific value of producer gas	1
10.	Determination of Lignin Cellulose Hemicellose in Biomass	1
11.	Production of fuel from agricultural wastes and by products,	1
12.	Production of Biogas, Producer gas and Biodiesel from Agricultural waste	2
13.	Techno-economic feasibility of waste to fuel systems	2
	Total	**16**

X. Suggested Reading

- Anonymous. 1984. *Manure Production and Characteristics*. ASAE Standards, America.
- Chahal DS. 1991. *Food, Feed and Fuel from Biomass*. Oxford & IBH, New Delhi.
- David C Wilson. 1981. *Waste Management, Planning, Evaluation, Technologies*. Clarendon Press, Oxford, England, UK.
- Klass DL and George EH. 1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ., New York.
- Luh BS. 1991. *Rice: Production and Utilization*. AVI Publ. Company Inc., Westport, Connecticut.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. *Biomass Briquetting and Utilization*. Jain Bros. Publications, New Delhi.

I. Course Title : Agro Energy Audit and Management

II. Course Code : REE 513

III. Credit Hours : 2+1

IV. Aim of the course

To emphasize the energy audit and its management in agriculture production system and agro based industries.

V. Theory

Unit I

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products.Pattern of energy consumption and their constraints in production of agriculture.

Unit II

Direct and indirect energy, energy audit of production agriculture, rural living and scope of conservation.

Unit III

Energy requirement in different agro-based industries: Energy analysis, energy ratio and specific energy value. Identification of energy efficient machinery systems: energy losses and their management.

Unit IV

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

VI. Practical

Study of energy audit techniques, energy use pattern and management strategies in various agro-industries, assessment of overall energy consumption, production and its cost in selected agro- industries. Estimation of energy requirement in different agriculture production system, study of energy input/output ratio of different agriculture production system.

VII. Learning outcome

Students will learn detail energy audit, energy balance techniques, energy management strategies, energy conservation planning and practices in agriculture production system.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy resources on the farm.	2
2.	Conventional and non-conventional forms of energy and their use.	2
3.	Heat equivalents and energy coefficients for different agricultural inputs and products.	3
4.	Pattern of energy consumption and their constraints in production of agriculture.	3
5.	Direct and indirect energy	2
6.	Energy audit of production agriculture, rural living and scope of conservation.	3

S.No.	Topic	No. of Lectures
7.	Energy requirement in different agro-based industries.	2
8.	Energy analysis, energy ratio and specific energy value.	2
9.	Identification of energy efficient machinery systems.	2
10.	Energy losses and their management.	2
11.	Energy analysis techniques and methods.	2
12.	Energy conservation planning and practices.	2
13.	Energy balance, output and input ratio, resource utilization.	3
14.	Conservation of energy sources.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of energy audit techniques.	2
2.	Energy use pattern and management strategies in various agro-industries.	2
3.	Assessment of overall energy consumption, production and its cost in selected agro-industries.	2
4.	Estimation of energy requirement in different agriculture production system.	2
5.	Study of energy input/output ratio of different agriculture production system.	2
	Total	**10**

X. Suggested Reading

- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publ. Company, Inc., Westport, Connecticut.
- Kennedy WJ Jr and Turner WC. 1984. *Energy Management*. Prentice Hall, Upper Saddle River, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.
- Rai GD. 1998. *Nonconventional Sources of Energy*. Khanna Publ., New Delhi.
- Singh CP. 1978. *Energy Requirement of Important Farm Operations for Existing Cropping System in Punjab*. PAU, Ludhiana.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F.N. Spon Ltd, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*.USG Publ. & Distr, Ludhiana.

I. Course Title : Green house Energetic and Passive Architecture

II. Course Code : REE 514

III. Credit Hours : 1+1

IV. Aim of the course

To provide the in-depth knowledge about greenhouse design, energetics, production technique, passive heating concept and evaporative cooling etc.

V. Theory

Unit I

Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector. Instrumentation and control in green house.

Unit II

Passive concepts and components: Passive heating concepts, direct gain, indirect grain, isolated gains and sunspace passive cooling concepts,

Unit III

Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling, use of isolation, shading, paint sand cavity walls for cooling.

Unit IV

Passive heating and cooling: Concepts, roof pond/sky therm, roof radiation trap, vary thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage.

VI. Practical

Design of passive structures for animals, rural housing, study of evaporative cooling, air and light flows in house, survey of green houses, green house energetic.

VII. Learning outcome

Students get knowledge of thermal energy flows, analysis of green house, instrumentation and control in green house.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector.	3
2.	Instrumentation and control in green house.	2
3.	Passive concepts and components	1
4.	Passive heating concepts	1
5.	Direct gain, indirect grain, isolated gains and sunspace passive cooling concepts	3
6.	Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling	2
7.	Use of isolation, shading, paint sand cavity walls for cooling.	1
8.	Passive heating and cooling	1
9.	Concepts, roof pond/sky theorem, roof radiation trap, vary thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage.	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design of passive structures for animals.	2
2.	Design of passive structures for rural housing	2
3.	Study of evaporative cooling	1
4.	Study of air and light flows in house	1
5.	Survey of green houses	8
6.	Green house energetic	2
	Total	**16**

X. Suggested Reading

- Parkar BE. 1991. *Solar Energy in Agriculture*. Elsevier, Amsterdam.
- Pattern AR. 1975. *Solar Energy for Heating and Cooling of Building*. Noyal Date Corporation (NDC), Park Ridge, New Jersey, USA.
- Paul JK. 1975. *Passive Solar Energy Design and Materials*. Noyel Data Corporation, Park Ridge, New Jersey, USA.
- Radhamanohar K and Igathinathane C. 2000. *Green House Technology and Management*. B.S. Publication. 4309 Sultan Basar, Hyderabad.
- Sodha MS, Bansal NK, Kumar PKA and Malik MAS. 1986. *Solar Passive: Building Science and Design*. Pergamon Press, New York.

I. Course Title : Energy Management in Food Processing Industries

II. Course Code : REE 515

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with different energy management techniques including energy auditing of food industries.

V. Theory

Unit I

Energy forms and units, energy perspective, norms and scenario, energy auditing, data collection and analysis for energy conservation in food processing industries.

Unit II

Sources of energy, its audit and management in various operational units of the agro-processing units, passive heating, passive cooling, sun drying and use of solar energy, biomass energy and other non-conventional energy sources in agro-processing industries.

Unit III

Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources. Energy accounting methods, measurement of energy, design of computer-based energy management systems, economics of energy use.

VI. Practical

Study of energy use pattern in various processing units i.e., rice mills, sugar mills, dal mills, oil mills, cotton-ginning units, milk plants, food industries etc. Energy audit study and management strategies in food processing plants.Identification of energy efficient processing machines.Assessment of overall energy consumption, production and its cost in food processing plants, visit to related food processing industry.

VII. Learning outcome

Student's capability to understand energy sources, analyze energy requirement in food processing operations and to economize it in food industries.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy forms and units, energy perspective, norms and scenario	2
2.	Energy auditing: definition, types of energy audit, planning	2
3.	Data collection and analysis for energy conservation in food processing industries.	2
4.	Sources of energy, its audit and management in various operational units of the agro-processing units	2
5.	Passive heating, passive cooling, sun drying and use of solar energy in agro-processing industries.	1
6.	Use of biomass energy and other non-conventional energy sources in agro-processing industries.	2
7.	Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources.	2
8.	Energy accounting methods, measurement of energy	1
9.	Design of computer-based energy management systems, economics of energy use.	2
	Total	**16**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of energy use pattern in rice mill	1
2.	Study of energy use pattern in sugar mill	1
3.	Study of energy use pattern in dal mill	1
4.	Study of energy use pattern in oil mill	1
5.	Study of energy use pattern in cotton-ginning unit	1
6.	Study of energy use pattern in milk plant	1
7.	Energy management strategies in rice mill	1
8.	Energy management strategies in sugar mill	1
9.	Energy management strategies in oil mill	1
10.	Energy management strategies in milk plant	1
11.	Identification of energy efficient processing machines	2
12.	Assessment of overall energy consumption, production and its cost in food processing plants	2
13.	Visit to related food processing industry	1
	Total	**15**

X. Suggested Reading

- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press.
- Rai GD. 1998. *Non-conventional Sources of Energy*. Khanna Publisher.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F. N. Spon Ltd.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publisher and Distributors, Ludhiana.

Course Title with Credit Load
Ph.D. in Renewable Energy Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
*REE 601	Biochemical Conversion of Biomass	2+1
*REE 602	Thermo-Chemical Conversion of Biomass	2+1
*REE 603	Advances in Renewable Energy Systems	2+1
REE 604	New Alternate Energy Systems	2+1
*REE 605	Fuels and Combustion	2+1
REE 606	Advances in Biogas Technology	2+1
REE 607	Solid Waste and Waste Water Management	2+1
REE 608	Advanced Photovoltaic Power Generation	1+1
REE 609	Energy Planning, Management and Economics	3+0
REE 610	Renewable Energy for Industrial Application	2+1
REE 611	Biofuel Technologies and Applications	1+1
REE 612	Energy Modelling and Simulation	1+1
	Total	**22+11**

*****Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
FMPE 612	Farm Machinery Management and System Engineering	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
PFE 614	Agri- Project Planning and Management	1+1
	Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

***Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.**

List of other Essential Requirements

Course Code	Course Title	Credit Hours
IDE 691	Doctoral Seminar-I	0+1
IDE 692	Doctoral Seminar-II	0+1
IDE 699	Doctoral Research	0+75

Course Contents
Ph.D. in Renewable Energy Engineering

I. Course Title : Biochemical Conversion of Biomass

II. Course Code : REE 601

III. Credit Hours : 2+1

IV. Aim of the course

To impart the advanced knowledge about biochemical conversion technologies of biomass, engineering design and kinetic of bio-energy systems.

V. Theory

Unit I

Biomass formation: Energy recovery and recycling. Biochemical conversion of organic wastes: Methane production, vertical through digesters, high solid digestion, sludge treatment.

Unit II

Lagoons: Composting, contact and filter digestion, reactors, physical and chemical removal of dissolved materials. Activated sludge and other suspended culture process parameters. Waste waters, biological film flow processes, sanitation land fill, pre-digestion of waste.

Unit III

Engineering design of biogas units: Biogas boosters, structural behaviour, alternate construction materials, multi-criteria optimization, immobilization, modular biogas for tropical areas, kinetic models.

Unit IV

Bioconversion of biomass to alcohol: Types and pre-treatment of biomass, production process. Fermenter design and process parameters.Economics of bio-alcohol production, reaction kinetics, gasohol.Bio-hydrogen from algae/biomass.

VI. Practical

Lagoons and compositing. Biogas plant: Analysis of biogas system. Determination of methane production rate and parameters, biogas storage, purification, utilization and kinetic equations.Alcohol production, optimization of process parameters, fermenter designing and evaluation.Economic calculations of biogas and alcohol.

VII. Learning outcome

The student will able to design, analyze and evaluate the various biomass conversion technologies and parameters related to biomass for utilization of it for fuel extraction.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biomass formation.	1
2.	Energy recovery and recycling.	1

S.No.	Topic	No. of Lectures
3.	Biochemical conversion of organic wastes.	1
4.	Methane production, vertical through digesters, high solid digestion.	2
5.	Sludge treatment.	1
6.	Lagoons: Composting, contact and filter digestion, reactors.	2
7.	Physical and chemical removal of dissolved materials.	2
8.	Activated sludge and other suspended culture process parameters.	2
9.	Waste waters	1
10.	Biological film flow processes, sanitation land fill, pre-digestion of waste.	2
11.	Engineering design of biogas units	2
12.	Biogas boosters, structural behaviour.	1
13.	Alternate construction materials.	1
14.	Multi-criteria optimization, immobilization.	2
15.	Modular biogas for tropical areas. Kinetic models	2
16.	Bioconversion of biomass to alcohol	1
17.	Types and pre-treatment of biomass production process.	2
18.	Fermenter design and process parameters.	2
19.	Economics of bio-alcohol production.	1
20.	Reaction kinetics, Gasohol.	1
21.	Bio-hydrogen from algae/biomass.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Lagoons and compositing.	1
2.	Analysis of biogas systems.	2
3.	Determination of methane production rate and parameters.	1
4.	Biogas storage, purification.	1
5.	Biogas storage utilization and kinetic equations.	1
6.	Alcohol production, optimization of process parameters.	1
7.	Fermenter designing and evaluation.	1
8.	Economic calculations of biogas and alcohol.	2
	Total	**10**

X. Suggested Reading

- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
- Klan E. 1985. *Energy from Biomass and Wastes*. Institute of Gas Technology, Chicago.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management*. McGraw Hill Book Company, New York, USA.

I. Course Title : Thermo-Chemical Conversion of Biomass

II. Course Code : REE 602

III. Credit Hours : 2+1

IV. Aim of the course

To help students to understand in depth knowledge of thermo-chemical conversion of organic waste, combustion chemistry and different heat based conversion technologies for fuel and power generation.

V. Theory

Unit I

Biomass: Characterization, resources and energy recovery. Thermo-chemical conversion of organic wastes.Chemical thermodynamics, stoichiometry and thermodynamics.

Unit -II

Combustion of fuels: Solid fuels, stoker, types, fluidised bed. Liquid fuels: Atomization, vapour concentration, combustion phenomena. Gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.

Unit III

Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification. Coal gasification technologies.Syngas characteristics.Tar and particulates in gasification.Integrated coal gasification.Gas turbine technologies.

Unit IV

Pyrolysis: Models, regimes, kinetics and effect of process parameters. Radiant heat flux, heterogeneous reactions, wall heat transfer.Fluidised bed reactors: Heat transfer circulating beds, moving bed reactor.

Unit V

Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output, energy density ratios and characterization of finished products.

VI. Practical

Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels.TGA studies. Liquid and gaseous burners, flame studies, flue gas, heat budgeting. Kinetic study on gasifiers. Producer gas based power generation systems. Kinetic and model studies for torrefaction, char coal and bio oil production.

VII. Learning outcome

Students will enable to critical analysis of combustion of fuel and system design for thermos chemical conversion technologies for domestic and industrial applications.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biomass: Characterization, resources and energy recovery.	2
2.	Thermo-chemical conversion of organic wastes.	1
3.	Chemical thermodynamics and stoichiometry.	3
4.	Combustion of solid fuels: stoker, types, fluidized bed.	2
5.	Combustion of liquid fuels: Atomization, vapour concentration, combustion phenomena.	2
6.	Combustion of gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.	2
7.	Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification.	3
8.	Coal gasification technologies, Integrated coal gasification.	2

S.No.	Topic	No. of Lectures
9.	Syngas characteristics, Tar and particulates in gasification.	2
10.	Gas turbine technologies.	2
11.	Pyrolysis: Models, regimes, kinetics and effect of process parameters.	2
12.	Radiant heat flux, heterogeneous reactions, wall heat transfer.	2
13.	Fluidized bed reactors: Heat transfer circulating beds, moving bed reactor.	2
14.	Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output	2
15.	Energy density ratios and characterization of finished products.	2
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels	2
2.	Determination of efficiency of improved chulha through water boiling test procedure.	1
3.	Thermo-gravimetric analysis of biomass sample	1
4.	Study of liquid burners	1
5.	Study of gaseous burners	1
6.	Flame studies and flue gases	1
7.	Study on heat budgeting	1
8.	Study on kinetics of fluidized bed gasifier	1
9.	Producer gas based power generation systems	1
10.	Kinetic and model studies for Torrefaction	2
11.	Kinetic and model studies for charcoal production.	2
12.	Kinetic and model studies for bio oil production.	2
	Total	16

X. Suggested Reading

- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Klan E. 1985. *Energy from Biomass and Wastes*. Institute of Gas Technology, Chicago.
- Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
- Rezaiyan J and Cheeremisinoff NP. 2005. *Gasification Technologies–A Primer for Engineers and Scientists*. CRC Press, Taylor and Francis group, New York, USA.
- Tchobanoglous G and Elliassen HTR. 1978. *Solid Wastes*. McGraw Hill Book Company, New York, USA.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management*. Van Nostrand Reinhold Company, New York.

I. Course Title : Advances in Renewable Energy Systems

II. Course Code : REE 603

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge, understanding and application oriented skills on advanced renewable energy systems and relevant technologies towards their effective utilization for meeting energy demand.

V. Theory

Unit I

Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies. Design and performance of solar thermal systems, mathematical models, power plants, design and performance.

Unit II

Photovoltaics: Thermodynamic limitations of photocells. Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter. Photo electro chemical cells, photo electrolysis cell.

Unit III

Wind power: Rotor design procedure, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation, performance prediction wind turbine rotor dynamics and dynamic models.

Unit IV

Designing of water pumping wind mills: Electric power, power transformers, electrical machines, ancillary electrical equipment, wind power to consumer/grid. Wind turbine: Sitting, installation and operation issues, offshore wind farms, operation in severe climates.

VI. Practical

Design parameters of air collectors. Thermal analysis and heat loss, regularity models of heliostatic fields, power plant design. Photovoltaic cells characteristic curves. Water pumping.Power control system, grid control devices.Design of wind mills, rotor design procedure, momentum theory and blade element theory. Wind mill installation and operation issues.

VII. Learning outcome

The student is able to design and analyzed the renewable energy systems and relevant technologies critically with economic feasibility.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Solar thermal energy systems.	1
2.	Kinetics and heat transfer analysis, modelling studies.	3
3.	Design and performance of solar thermal systems	2
4.	Mathematical models, power plants, design and performance.	2
5.	Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies.	2
6.	Design and performance of solar thermal systems, mathematical models, power plants, design and performance.	3
7.	Photo-voltaic	1
8.	Thermodynamic limitations of photocells.	2
9.	Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter.	2
10.	Photo electro chemical cells, photo electrolysis cell	1

S.No.	Topic	No. of Lectures
11.	Wind power	1
12.	Design procedure of rotor, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation,	3
13.	Performance prediction wind turbine rotor dynamics and dynamic models.	1
14.	Designing of water pumping wind mills.	1
15.	Electric power, power transformers.	1
16.	Electrical machines, ancillary electrical equipment, wind power to consumer/grid.	2
17.	Wind turbine: Sitting, installation and operation issues,	2
18.	Offshore wind farms, operation in severe climates	2
	Total	**32**

IX. Practical

S.No.	Topic	No. of Practicals
1.	Design parameters of air collectors.	1
2.	Thermal analysis and heat loss,	1
3.	Regularity models of heliostatic fields	1
4.	Design of power plant.	2
5.	Photovoltaic cells characteristic curves.	1
6.	Analysis of water pumping with photovoltaic cells.	1
7.	Power control systems.	1
8.	Grid control devices.	1
9.	Design of wind mills.	2
10.	Rotor design procedure	1
11.	Momentum theory and blade element theory	2
12.	Installation of wind mill.	1
13.	Wind mill operation issues.	1
	Total	16

X. Suggested Reading

- Anderson EE. 1983. *Fundamentals of Solar Energy Conversion*. Addision Wesley publication Company, Boston, United State.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.
- More HG and Maheshwari RC. *Wind Energy Utilization in India*. Technical Bulletin No.CIAE/82/38,CIAE, Bhopal.
- Powar AG and Mohod AG. 2010. *Wind Energy Technology*. Jain Publication, New Delhi, India.
- Rai GD. 1994. *Nonconventional Sources of Energy*. Khanna Publishers, New Delhi, India.
- Rao S and Parulekar BB. 1994. *Energy Technology Nonconventional, Renewable and Conventional*. Khanna Publishers, New Delhi, India.
- Sitharthan R and Geethanjali M. 2014. *Wind Energy Utilization in India: A Review*. Middle-East Journal of Scientific Research, Pakistan.
- Solanki CS. 2011. *Solar Photovoltaics: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, New Delhi, India.
- Sukhatme SP and Nayak J. 2008. *Solar Energy: Principles of Thermal Collection and Storage.* Tata McGraw Hill Publishing Company Limited, New Delhi, India.

I. Course Title : New Alternate Energy Systems

II. Course Code : REE 604

III. Credit Hours : 2+1

IV. Aim of the course

To get acquainted with various recent and emerging alternate fuels and their various applications for power generation.

V. Theory

Unit I

Hydrogen production: Water splitting, electrolytic meth-ods, chemical cycle, photo splitting, photo galvanic, photo chemical. Hydrogen storage and utilization. Fuel cells: Reactions, types, design, applications, conversion and problems. Thermoelectric convertor and thermionic convertors.Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types.

Unit II

Tidal energy: Operating mode, energy content. Estimation of wave power, tidal power sites and ocean thermal energy cycle (OTEC): Baseline design, heat design, power cycle design, plant working.

Unit III

Geo-thermal energy system: Classification, binary cycle conversion, waterfed heat pumps, electric generation, steam generation, steam field. Heat mining, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks.

Unit IV

Power generation through alternative sources. Environmental pollution: Measurements and control methods, instrumentation, pollution standards, social cost estimates, CO_2 reduction potential, CO_2 sequestration.

VI. Practical

Testing of electrolysis plant, photo electric plant, photo plant, design criteria of fuel cell. Design considerations for alternative energy systems.

VII. Learning outcome

Students are able to understand the various recent and emerging alternate energy sources and their utilization for meeting the increasing energy demand.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrogen production: Water splitting, electrolytic meth-ods, chemical cycle, photo splitting, photo galvanic, photo chemical.	2
2.	Hydrogen storage and utilization.	1
3.	Fuel cells: Reactions, types, design, applications, conversion and problems.	2
4.	Thermoelectric convertor and thermionic convertors.	2
5.	Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types.	2
6.	Tidal energy: Operating mode, energy content.	1
7.	Estimation of wave power, tidal power sites and ocean thermal energy	

S.No.	Topic	No. of Lectures
	cycle (OTEC)	2
8.	Baseline design, heat design, power cycle design, plant working.	3
9.	Geo-thermal energy system	1
10.	Classification, binary cycle conversion, waterfed heat pumps, electric generation, steam generation, steam field.	4
11.	Heat mining, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks.	3
12.	Power generation through alternative sources.	1
13.	Environmental pollution	1
14.	Measurements and control methods for environmental pollution.	1
15.	Instrumentation, pollution standards,	2
16.	Social cost estimates.	1
17.	CO_2 reduction potential, CO_2 sequestration.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design parameters of air collectors.	1
2.	Thermal analysis and heat loss,	1
3.	Regularity models of heliostatic fields	1
4.	Testing of electrolysis plant	2
5.	Testing of photo electric plant	2
6.	Testing of photo plant.	2
7.	Design criteria of fuel cell	2
8.	Design considerations for alternative energy systems	2
	Total	**10**

X. Suggested Reading

- Culp JA. 1979. *Principles of Energy Conversion*. McGraw-Hill Book Company, London.
- Appleby A C 1987. *Fuel Cells: Trends in Research and Application*. Hemisphere, Washington.
- Blomen LJMJ and Mugerwa MN. 1993. *Fuel Cell System*. Plenum Press, New York, USA.
- Thielhein KD. 1977. *Alternate Energy Sources*. International compendium, Hemi sphere publishing company, London.

I. Course Title : Fuel and Combustion

II. Course Code : REE 605

III. Credit Hours : 2+1

IV. Aim of the course

To get acquainted with in depth knowledge about solid, liquid and gaseous fuels and their combustion kinematics. Understand of different combustion technologies.

V. Theory

Unit I

Solid and liquid fuels: Type and availability, oxidation, hydrogenation of solid fuel and processing of solid fuels. Liquid Fuels: Processing, properties testing of liquid fuels and refining. Liquid fuels from other sources: Preparation and storage. Production technologies for solid and liquid fuel.

Unit II

Gaseous Fuels: Types, processing and testing of gaseous fuels, gases from biomass refinery gases, LPG, oil gasification, cleaning and purification of gaseous fuels. Gaseous fuel production technologies.

Unit III

Combustion Stoichiometry: Thermodynamics and kinetics, solid, liquid and gaseous fuels. Combustion of solid fuels. Biomass combustion, stages of wood combustion, industrial biomass combustion concepts, types of combustion system.

Unit IV

Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition. Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.

Unit V

Combustion of gaseous fuel: Character, shape and size of the flame. Flame stabilization of bluff bodies.Effect of equivalence on reaction rate and extinction velocity, submerged combustion, combustion with explosion flame, pulsating combustion.

VI. Practical

Determination of fuel properties of solid, liquid and gaseous fuels.Determination of efficiency of combustion system using solid, liquid and gaseous fuel.Standard testing of burners for thermal efficiency for solid, liquid and gaseous fuel.

VII. Learning outcome

Students will able to design, estimate and critical analysis of various combustion techniques for efficient utilization of fuels.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Type and availability of solid and liquid fuels.	1
2.	Oxidation and hydrogenation of solid fuel.	1
3.	Processing of solid fuels.	1
4.	Processing of liquid fuel, properties and testing of liquid fuels.	2
5.	Refining of liquid fuel.	1
6.	Liquid fuels from other sources: Preparation and storage.	1
7.	Production technologies for solid and liquid fuel.	2
8.	Gaseous fuel production technologies.	1
9.	Gases from biomass, refinery gases and LPG.	2
10.	Oil gasification.	1
11.	Types, processing and testing of gaseous fuels.	2
12.	Cleaning and purification of gaseous fuels.	1
13.	Combustion Stoichiometry: thermodynamics and kinetics.	1
14.	Solid, liquid and gaseous fuels.	2
15.	Combustion of solid fuels, biomass combustion, stages of wood combustion.	2
16.	Industrial biomass combustion concepts.	1
17.	Types of combustion systems.	1
18.	Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition.	2

S.No.	Topic	No. of Lectures
19.	Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.	2
20.	Combustion of gaseous fuel: Character, shape and size of the flame.	2
21.	Flame stabilization of bluff bodies.	1
22.	Effect of equivalence on reaction rate and extinction velocity.	1
23.	Submerged combustion, Combustion with explosion flame, Pulsating combustion.	1
	Total	**32**

IX. Practical

S.No	Topic	No. of Practicals
1.	Determination of fuel properties of solid fuels.	1
2.	Determination of fuel properties of liquid fuels.	1
3.	Determination of fuel properties of gaseous fuels.	1
4.	Determination of efficiency of combustion system using solid fuels.	1
5.	Determination of efficiency of combustion system using liquid fuels.	1
6.	Determination of efficiency of combustion system using gaseous fuels.	1
7.	Standard testing of burners for thermal efficiency for solid.	1
8.	Standard testing of burners for thermal efficiency for liquid fuel.	1
9.	Standard testing of burners for thermal efficiency for gaseous fuel.	1
	Total	**09**

X. Suggested Reading

- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization in Combustion Engines*. CRC Press, Boca Raton, Florida.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India Publication, New Delhi, India.
- Sarkar S. 1990. *Fuels and Combustion*. Orient Longmans, Bombay.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press, Boca Raton, Florida.

I. Course Title : Advances in Biogas Technology

II. Course Code : REE 606

III. Credit Hours : 2+1

IV. Aim of the course

The students will understand advances in biogas technology and its mechanism in detail. To analyze the case studies for understanding success and failures. To facilitate the students in developing skills in the decision making process.

V. Theory

Unit I

Worldwide review of anaerobic digesters, realistic potential- of biogas, analysis of biogas system and proposed means for their prospects.Engineering design of biogas units for biogas production from solid and liquid wastes.

Unit II

Design parameters: Affecting and failure of biogas systems, structural behaviour and conditions of fixed dome digesters, alternate construction- materials, gas holders for gas production in colder regions, heating, stirring etc.

Unit III

Multi-criteria optimization design of fermentation systems, immobilization, modular biogas for tropical rural areas.Toxicity effect of pesticides herbicides on the anaerobic digestion process. Kinetic models, design equa-tions, contact and anaerobic filter digesters, high rate digesters.

Unit IV

Scrubbing, purification and compression of biogas. Scaling-up and standardization of biogas plant for power generation and heating. Advanced biofuels: Bio-CNG/ renewable natural gas (RNG) as vehicle fuel.Liquefaction of biogas.

VI. Practical

Engineering design and analysis of biogas system.Development of kinetic equations.Biogas purification, compression and liquefaction.Industrial applications of biogas.

VII. Learning outcome

The student is able to analyse the various aspects of biogas energy management systems, Carry out techno-economic feasibility for biogas plant, to apply the knowledge in planning and operations of biogas energy system.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Review of anaerobic digesters	1
2.	Realistic potential- of biogas	1
3.	Analysis of biogas system	2
4.	Proposed means for prospects of biogas systems	1
5.	Engineering design of biogas units for biogas production from solid and liquid wastes	3
6.	Design parameters: Affecting and failure of biogas systems	2
7.	Structural behavior and conditions of fixed dome digesters	2
8.	Alternate construction- materials for biogas plants	1
9.	Design of biogas plants for colder regions	1
10.	Heating and stirring systems for biogas plants	2
11.	Multi-criteria optimization design of fermentation systemscontact and anaerobic filter digesters, high rate digesters	2
12.	Immobilization, modular biogas for tropical rural areas	2
13.	Toxicity effect of pesticides herbicides on the anaerobic digestion process	1
14.	Chemical kinetics and mathematical modeling of bio-methanation process	2
15.	Contact and anaerobic filter digesters, high rate digesters	1
16.	Scrubbing, purification and compression of biogas.	2
17.	Scaling-up and standardization of biogas plant for power generation and heating	2
18.	Bio-CNG/renewable natural gas (RNG) as vehicle fuel	2
19.	Liquefaction of biogas	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Engineering design and analysis of biogas system	3
2.	Development of kinetic equations	3
3.	Biogas purification, compression and liquefaction	3
4.	Industrial applications of biogas	3
5.	Preparation of Detailed Project Reports for commercial biogas projects	4
	Total	**16**

X. Suggested Reading

- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Publication House, New Delhi.
- Abbasi T, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer publications, New York, USA.
- Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international Publication Limited, New Delhi.
- Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes*. National Academy of Sciences, Washington.

I. Course Title : Solid Waste and Waste Water Management

II. Course Code : REE 607

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge, understanding and application oriented skills on sources, quality, classification and characteristics of solid waste along with municipal and compost treatment and remote sensing technologies for waste management.

V. Theory

Unit I

Solid waste: Sources, quality, classification and characteristics, collection and reduction at source, handling, storage, transportation and disposal methods.

Unit II

Reactor for anaerobic digestion: Contact and filter digestion, homogenous and non-homogeneous reactors. Energetic and kinetics of anaerobic treatment.

Unit III

Gas transfer, mass models, bubble aeration, film flow oxygen transfer, stripping, solids removal. Activated sludge and other suspended culture processes parameters. Biosorption of contact stabilization.

Unit IV

Sanitation land fill, munici-pal and compost treatment. Predigestion of waste.Sensors, ICT and remote sensing technologies for waste management.

VI. Practical

Design principles in waste treatment, equipment specifica-tion and instrumentation.

Mathematical modelling of BOD and COD reduction rate, recovery by batch distillation.

VII. Learning outcome

The student is able to estimate, characterize and design of solid waste conversion system and also able to understand the energetic and kinetics of anaerobic treatment, sanitation land fill, pre-digestion of waste etc.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Solid waste	1
2.	Sources, classification and characteristic and quality	2
3.	Collection and handling and Transportation	2
4.	Disposal methods, reduction at source	3
5.	Reactor for anaerobic digestion	2
6.	Contact and filter digestion	2
7.	homogenous and non-homogeneous reactors	2
8.	Energetic and kinetics of anaerobic treatment.	2
9.	Gas transfer, mass models,	3
10.	Bubble aeration, film flow oxygen transfer, stripping, solids removal.	2
11.	Activated sludge and other suspended culture processes parameters.	2
12.	Biosorption of contact stabilization	1
13.	Sanitation land fill,	2
14.	Municipal and compost treatment	2
15.	Predigestion of waste.	1
16.	Sensors, ICT and remote sensing technologies for waste management	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Design principles in waste treatment	3
2.	Specifica-tion of equipment for waste treatment	2
3.	Instrumentation for waste treatment	2
4.	Mathematical modelling of BOD and COD reduction rate	3
5.	Development of computer code for Mathematical modelling of BOD and COD reduction rate	3
6.	Recovery by batch distillation.	3
	Total	**16**

X. Suggested Reading

- Bridgwater AV and Mum-ford CJ. 1979. *Waste Recycling and Pollution Control Handbook*. Van Nostrand Reinhold Company, New York.
- Kreith F and Tchobanoglous G. 2002. *Handbook of Solid Waste Management*. McGraw Hill Book Company, New York.
- Ramachandra TV. 2006. *Management of Municipal Solid Waste*. Capital Publication Company, New Delhi.
- Tchobanoglous G, Theisenand H and Elliassen R. 1978. *Solid Wastes*. McGraw Hill Book Company, New York.

I. Course Title : Advanced Photovoltaic Power Generation

II. Course Code : REE 608

III. Credit Hours : 1+1

IV. Aim of the course

To develop a comprehensive technological understanding in solar PV system components. To provide in depth understanding of design parameters to help design and simulate the performance of a solar PV power plant. To pertain knowledge about planning, project implementation and operation of solar PV power generation.

V. Theory

Unit I

Semiconductors: Transport properties, junctions, dark and illumination characteristics. Single junction and multi junction films. Solar PV concentrator cells and systems. Thin film solar cells: Nano, micro, and polycrystalline solar cells.

Unit II

Systems for remote applications and large solar PV power plants: System integrations, roof top system, sizing methodology, power control, storage, tracking and control. PCID simulation of industrial solar cell structure, software's in solar cell simulation.

Unit III

Space charge control, low pressure diode, MMPT, cesium converter, system considerations. Photo electro chemical cells and materials.Photogalvanic cells: Recent development.

Unit IV

Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics. Software's for PV system integration and designing. PV system for ground mounted and rooftop plants with shadow analysis.

VI. Practical

PV systems for typical applications, water pumping, solar PV tracking and mechanical clock tracking. Testing of power control system for output regulation, charging and discharging characteristics of storage by PV panels.

VII. Learning outcome

Student will able to design different solar photovoltaic system for power generation. Design and simulate a PV power plant using software tool, Plan, project implementation, operation and maintenance. Carry out techno-economic-environmental performance evaluation of a solar PV power plant.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Semiconductors: Transport properties, junctions, dark and illumination characteristics.	1
2.	Single junction and multi junction films, Solar PV concentrator cells and systems.	1
3.	Thin film solar cells: Nano, micro, and polycrystalline solar cells.	1
4.	Systems for remote applications, Large solar Photovoltaic power plants: System integrations, roof top system and sizing methodology	2

S.No.	Topic	No. of Lectures
5.	Power control, storage, tracking and control in Photovoltaic power plants.	1
6.	PCID simulation of industrial solar cell structure, software's in solar cell simulation	2
7.	System considerations for Space charge control, low pressure diode, MMPT and cesium converter	2
8.	Photo electro chemical cells and materials	1
9.	Recent development in Photogalvanic cells	1
10.	Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics	1
11.	Softwares for PV system integration and designing.	2
12.	PV system for ground mounted and rooftop plants with shadow analysis	1
	Total	16

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Typical applications of Photovoltaic (PV) systems	1
2.	Applications of Photovoltaic systems in water pumping	2
3.	Study of Solar PV tracking and mechanical clock tracking	2
4.	Testing of power control system for output regulation	3
5.	Charging and discharging characteristics of storage by PV panels.	2
	Total	**10**

X. Suggested Reading

- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Fonash SJ. 1982. *Solar Cell Device Physics*. Academic Press, Cambridge, England.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht, Netherland.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications*. Prentice Hall, New Jersey.
- Kreith F and Kreider JF. 1978. *Principles of Solar Engineering*. McGraw Hill, New York.
- Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education*. John Wiley and Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, Delhi.
- Sze SM and Kwok KN. 2007. *Physics of Semiconductor Devices*. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. McGraw Hill, New York.

I. Course Title : Energy Planning, Management and Economics

II. Course Code : REE 609

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint and equip with energy planning, management and economical evaluation for agricultural production system.

V. Theory

Unit I

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products.Pattern of energy consumption and their constraints in production of agriculture.Direct and indirect energy.

Unit II

Energy audit of production agriculture and rural living and scope of conservation. Identification of energy efficient machinery systems, energy losses and their management.

Unit III

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

Unit IV

Energy forecasting, energy economics, energy pricing and incentives for energy conservation, factors effecting energy economics. Techno-economic evaluation of RET's, computation of programme for efficient energy management.

VI. Learning outcome

The student will be able to quantify, analyze and forecast the demand and supply of different energy for agriculture production system.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy resources on the farm: Conventional and non-conventional forms of energy and their use.	3
2.	Heat equivalents and energy coefficients for different agricultural inputs and products.	3
3.	Pattern of energy consumption and their constraints in production agriculture. Direct and indirect energy.	3
4.	Energy audit of production agriculture and rural living and scope of conservation.	4
5.	Identification of energy efficient machinery systems	3
6.	Energy losses and their management.	4
7.	Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources.	4
8.	Energy conservation planning and practices.	4
9.	Energy forecasting	3
10.	Energy pricing and incentives for energy conservation,	3
11.	Energy economicsand factors affecting energy economics	4
12.	Techno-economic evaluation of RET's	4
13.	Computation of programme for efficient energy management.	3
	Total	45

VIII. Suggested Reading

- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publication, United State.
- Kennedy WJ and Turner WC. 1984. *Energy Management*. Prentice Hall, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.

- Rai GD. 1998. *Nonconventional Sources of Energy*.Khanna Publication, New Delhi.
- Twindal JW and Wier AD. 1986. *RenewableEnergy Sources*. E & F N Spon, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publication, Chicago.

I. Course Title : Renewable Energy for Industrial Application

II. Course Code : REE 610

III. Credit Hours : 2+1

IV. Aim of the course

To provide the knowledge regarding the energy consumption pattern in agro based industries, quantification techniques and identification of opportunities for renewable energy sources.

V. Theory

Unit I

Elucidation of unit operations in industry.Energy quantification techniques, system boundary, estimation of productivity, plant capacity utilization, energy density ratio and energy consumption pattern.Energy flow diagram conservation opportunities identification.

Unit II

Solar energy for industrial application: Solar water heating, steam solar cooking system, industrial solar dryer and solar process heat, solar cooling system (refrigeration, air conditioning and solar architecture technology), solar furnace and solar green house technology for high-tech cultivation. Solar photovoltaic technology for industrial power.

Unit III

Bio energy for industrial application: Quantification of industrial bio-waste, characterization, power generation through bio-methanation, gasification and dendro thermal power plant.

Unit IV

Wind energy: Aero generator of new era and national and international state of art in wind power generation. Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.

VI. Practical

Elucidation and energy consumption for unit operations in industry. Study of energy quantification and identification of opportunities for RET's. Design of solar dryers.Design of solar photovoltaic system.Design of gasifiers for thermal energy and power generation. Design of combuster (gasifier stove). Study of solar greenhouse.Study of biogas engine generator set.Case study of agro-industrial energy estimation and visit to RSE power generation site.

VII. Learning outcome

Students will be acquainted with energy quantification techniques, design of system, economic evaluation and utilization of renewable energy sources for agro-industrial applications.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Elucidation of unit operations in industry.	1
2.	Energy quantification techniques, system boundary,	2
3.	Estimation of productivity, plant capacity utilization,	2
4.	Energy density ratio and energy consumption pattern.	2
5.	Energy flow diagram conservation opportunities identification.	1
6.	Solar energy for industrial application.	1
7.	Solar water heating.	1
8.	Steam solar cooking system.	1
9.	Industrial solar dryer and solar process heat.	2
10.	Solar cooling system (refrigeration, air conditioning and solar architecture technology).	2
11.	Solar furnace.	1
12.	Solar greenhouse technology for high-tech cultivation.	2
13.	Solar photovoltaic technology for industrial power.	1
14.	Bio energy for industrial application	1
15.	Quantification of industrial bio-waste, its characterization	2
16.	Power generation through bio-methanation,	2
17.	Gasification and dendro thermal power plant.	2
18.	Wind energy: Aero generator of new era.	1
19.	National and international state of art in wind power generation.	2
20.	Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Elucidation and energy consumption for unit operations in industry.	1
2.	Study of energy quantification and identification of opportunities for RET's	1
3.	Design of solar dryers.	2
4.	Design of solar photovoltaic system.	2
5.	Design of gasifiers for thermal energy and power generation.	2
6.	Design of combuster (gasifier stove).	2
7.	Study of solar greenhouse.	1
8.	Study of biogas engine generator set.	1
9.	Case study of agro-industrial energy estimation	2
10.	Visit to RSE power generation site.	1
	Total	**15**

X. Suggested Reading

- Duffie JA and Beakman WA. 2006. *Solar Energy Thermal Process*. John Wiley and Sons, New York.
- Kumar S. 2011. *Energy Conservation Building User Code Guide*. Bureau of Energy Efficiency, New Delhi.
- Rathore NS, Kurchania AK and Panwar NL. 2007. *Non Conventional Energy Sources*. Himanshu Publications, Udaipur, Rajasthan.
- Sayigh AAM. 2012. *Solar Energy Engineering*. Academic Press, New York.
- Singh P, Kurchania AK, Rathore NS and Mathur AN. 2005. *Sustainable Development through Renewable Energy Sources*. Yash Publications, Bikaner, Rajasthan.

I. Course Title : Biofuel Technologies and Applications

II. Course Code : REE 611

III. Credit Hours : 1+1

IV. Aim of the course

To get acquainted with recent biofuel production technologies and their applications.To perform financial estimations of the biofuel projects.To get insight of the various biofuel technologies.

V. Theory

Unit I

Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization. World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.

Unit II

Bioethanol: First and second generation ethanol production technologies. Production of syngas from biomass, production of methanol from syngas, production of ethanol from lingo-cellulosic biomass. Syngas and poly-generation, chemical conversion of syngas to methanol and ethanol and some advanced fuels like bio butanol, bio-propanol.

Unit III

BioCNG: Biogas to green vehicle fuel, anaerobic digestion. Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.

Unit IV

Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel, biodiesel from algae, biodiesel engines.

Unit V

Pyrolysis oil: Fast pyrolysis technologies, composition and issues of bio oil. Bio oil upgradation technologies.

VI. Practical

Evaluation of liquid fuel system for heat and power generation and characterization of liquid fuel, transesterification process.Engine performance on biodiesel.Biogas-engine system for transport vehicle.Bio oil production by pyrolysis.

VII. Learning outcome

Student will able to understand the bio-fuel production technologies with financial viability and applications of bio-fuel in different sector of development.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization.	1
2.	World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.	1
3.	Bioethanol: First- and second-generation ethanol production technologies.	1
4.	Production of syngas from biomass.	1

S.No.	Topic	No. of Lectures
5.	Production of methanol from syngas.	1
6.	Production of ethanol from lingo-cellulosic biomass.	1
7.	Syngas and poly-generation.	1
8.	Chemical conversion of syngas to methanol and ethanol, some advanced fuels like bio butanol, bio-propanol.	1
9.	Bio CNG: Biogas to green vehicle fuel, anaerobic digestion.	1
10.	Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.	1
11.	Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel.	2
12.	Biodiesel from algae, biodiesel engines.	1
13.	Pyrolysis oil: Fast pyrolysis technologies.	1
14.	Composition and issues of bio oil	1
15.	Bio oil up-gradation technologies.	1
	Total	**16**

IX. List of Practicals

S. No.	Topic	No. of Practicals
1.	Evaluation of liquid fuel system for heat and power generation.	2
2.	Characterization of liquid fuel.	1
3.	Transesterification process.	2
4.	Engine performance on biodiesel.	1
5.	Biogas-engine system for transport vehicle.	1
6.	Bio oil production by pyrolysis.	1
	Total	**08**

X. Suggested Reading

- Boyle G. 2008. *Renewable Energy*. Atlantic Publishing Company, New Delhi.
- Gonsalves JB. 2006. *An Assessment of the Biofuels Industry in* John *India.* Wiley & Sons, New Delhi.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium. Education.* TERI Press, Delhi.
- Klass D. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals.* Entech International, Barrington, Illinois, USA.
- Mitzlaff KV. 1988. *Engines for Biogas–Theory, Modification, Economic Operation.* Deutsches Zentrum für Entwicklungstechnologien–GATE, Germany.

I. Course Title : Energy Modelling and Simulation

II. Course Code : REE 612

III. Credit Hours : 1+1

IV. Aim of the course

The objective of this course is to provide in depth knowledge about various mathematical models, interdependence of energy, ecology and environment, energy modelling in the context of climate change.

V. Theory

Unit I

Model: Basics, system, boundary, interaction, types of models, physical, analogy models and applications. Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment, modelling concept and application.

Unit II

Energy Modelling: Review of various energy sector models, energy demand analysis and forecasting, energy supply assessment and evaluation, energy demand, supply balancing, energy modelling in the context of climate change.

Unit III

Model studies in gasification, pyrolysis, biogas, fermentation, biodiesel, solar, wind technologies and heat transfer applications. Moving boundary models.

Unit -IV

Energy economics of energy sources: Investment and cost management in various energy technologies. Economics of energy generation, energy conservation economics, financial analysis, sensitivity and risk analysis.

VI. Practical

Formulating dimensionless numbers, applications, types of models, mathematical model formulation and types, Software's and model evaluation. Development of models in thermo-chemical and biochemical conversion processes. Studies on model development in solar and wind technologies, economics of energy generation and conservation, financial analysis.

VII. Learning outcome

Students will get thorough knowledge about energy modelling of gasification, pyrolysis, biogas system, fermentation, biodiesel production system, solar and wind technologies etc.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Model	1
2.	Basics, system, boundary, interaction, types of models, physical, analogy models.	2
3.	Model applications.	1
4.	Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment.	3
5.	Modelling concept and application.	1
6.	Energy Modelling	1
7.	Review of various energy sector models.	1
8.	Energy demand analysis and forecasting.	1
9.	Energy supply assessment and evaluation	1
10.	Energy demand, supply balancing.	2
11.	Energy modelling in the context of climate change.	2
12.	Model studies in gasification, pyrolysis.	2
13.	Model studies in biogas, fermentation.	1
14.	Model studies in biodiesel.	1
15.	Model studies in solar.	1
16.	Model studies in wind technologies.	1
17.	Heat transfer applications.	1
18.	Moving boundary models.	1

S.No.	Topic	No. of Lectures
19.	Energy economics of energy sources	1
20.	Investment and cost management in various energy technologies.	2
21.	Economics of energy generation.	1
22.	Energy conservation economics, financial analysis.	2
23.	Energy conservation sensitivity and risk analysis	2
	Total	32

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Formulating dimensionless numbers.	1
2.	Applications of dimensionless numbers.	1
3.	Types of models for dimensionless numbers.	1
4.	Mathematical model formulation and types.	2
5.	Software's and model evaluation.	2
6.	Development of models in thermo-chemical	1
7.	Development of models in biochemical conversion processes.	1
8.	Studies on model development in solar technologies.	1
9.	Studies on model development in wind technologies	1
10.	Economics of energy generation and conservation	2
11.	Financial analysis.	1
	Total	**14**

X. Suggested Reading

- Desai A V 1990. *Energy Planning and Economics*. New Age International Publication Limited, New Delhi.
- Munasinghe M and Meier P 1993. *Energy Policy Analysis and Modelling* (*Cambridge Energy and Environment Series*). Cambridge University Press, England.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Agricultural Engineering
– Soil and Water Conservation Engineering

Preamble
(Soil and Water Conservation Engineering)

Course curricula and course outlines in Soil and Water Conservation Engineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Soil Science, Agronomy and Agricultural Meteorology.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector.

All courses are designed to cover all basic topics and have been designed by taking into consideration demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students. The emphasis has been given on advanced watershed hydrology and modeling management and accordingly new courses "Stochastic hydrology, Climate change and water resources, Waste water treatment and utilization, Multi criteria decision making system" are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Soil and Water Conservation Engineering. The revised courses cover the areas: Advanced Soil and Water Conservation Engineering, Applied Watershed Hydrology, Soil and Water Conservation Structures, Watershed Management and Modeling, Flow Through Porous Media, Remote sensing and GIS for land and water resource management, Dryland Water Management Technologies, Minor irrigation, Design of Drip and Sprinkler Irrigation Systems, Groundwater engineering, Water Resources Systems Engineering, Advances in Hydrology, Soil and Water Systems Simulation and Modeling, Reservoir Operation and River Basin Modeling, Modeling Soil Erosion Processes and Sedimentation.

The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

Course Title with Credit Load
M.Tech. in Soil and Water Conservation Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*SWCE 501	Advanced Soil and Water Conservation Engineering	2+1
*SWCE 502	Applied Watershed Hydrology	2+1
SWCE 503	Soil and Water Conservation Structures	2+1
SWCE 504	Stochastic Hydrology	2+1
*SWCE 505	Watershed Management and Modeling	2+1
SWCE 506	Flow Through Porous Media	2+0
SWCE 507/IDE 507	Remote Sensing and GIS for Land and Water Resource Management	2+1
SWCE 508	Climate Change and Water Resources	3+0
SWCE 509	Numerical Methods in Hydrology	2+0
SWCE 510	Dryland Water Management Technologies	2+0
	Total	**19+6**

*Compulsory course

Minor Courses (Requirement: 08 Credits)

Course Code	Course Title	Credit Hours
IDE 505	Design of Drip and Sprinkler Irrigation Systems	2+1
IDE 506	Groundwater Engineering	2+1
IDE 510	Minor Irrigation	2+1
IDE 513	Water Resources Systems Engineering	2+1
CE 501	Dimensional Analysis and Similitude	2+0
CE 502	Water Quality and Pollution Control	2+1
FMPE 517	Machinery for Precision Agriculture	2+1
REE 513	Energy, Ecology and Environment	3+0
CSE 501	Big Data Analytics	2+0
CSE 502	Artificial Intelligence	2+0
CSE 504	Soft Computing Techniques in Engineering	2+1
MATH 501	Finite Element Methods	2+0
MATH 502	Numerical Methods for Engineers	2+0
ME 501	Mechatronics and Robotics in Agriculture	2+0
	Any other course(s) of other department can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
*STAT 501	Statistical Methods for Research Works	2+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*PGS 501	Library and Information Services	1+0
*PGS 502	Technical Writing and Communication Skills	1+0
*PGS 503	Intellectual Property and its management in Agriculture	1+0
*PGS 504	Basic Concepts in Laboratory Techniques	1+0
*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of other Essential Requirements

Course Code	Course Title	Credit Hours
SWCE 591	Seminar	0+1
SWCE 599	Thesis Research	0+30

Course Contents
M.Tech. in Soil and Water Conservation Engineering

I. Course Title : Advanced Soil and Water Conservation Engineering
II. Course Code : SWCE 501
III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip students with the advances in soil and water conservation measures, use of RS and GIS and Software's for design of soil and water conservation structures.

V. Theory

Unit I

Concept of probability in design of soil and water conservation structures. Probability and continuous frequency distribution. Fitting empirical distributions.

Unit II

Relevance of soil and water conservation in agriculture and in the river valley projects. Layout and planning of soil and water conservation measures. Software's for design of conservation structures.

Unit III

Productivity loss due to soil erosion. Water stress and water excess. Types and mechanics of soil erosion. Software's for soil loss estimation, WEAP, EPIC

Unit IV

Theories of sediment transport. Control of runoff and sediment loss. Sediment deposition process. Estimation of sediment load.

Unit V

Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture. Application of Remote Sensing and GIS in Soil and Water Conservation.

VI. Practical

Assessment of erosive status of a watershed through field measurement or analysis of morphometric properties. Estimation of erosivity index of rainfall. Determination of soil physical properties: Texture, grain size distribution, Atterberg's limits, various moisture percentages. Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status. Estimation of costs of soil and water conservation measures.

VII. Learning outcome

The students will able to plan and design soil and water conservation measures in particular watershed using RS and GIS techniques. They can estimate the sedimentation and capacity losses, design of gully control structures and earthen dams usingsoftware's.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of probability in design of soil and water conservation structures	2
2.	Probability and continuous frequency distribution	2
	Fitting empirical distributions	2
3.	Relevance of soil and water conservation in agriculture and in the river valley projects	2
4.	Layout and planning of soil and water conservation measures	2
5.	Software's for design of conservation structures	1
6.	Productivity loss due to soil erosion	1
7.	Water stress and water excess	1
8.	Types and mechanics of soil erosion	1
9.	Software's for soil loss estimation, WEAP, EPIC	3
10.	Theories of sediment transport	2
11.	Control of runoff and sediment loss	1
12.	Sediment deposition process and estimation of sediment load	2
13.	Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture	6
14.	Application of Remote Sensing and GIS in Soil and Water Conservation	3
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Assessment of erosive status of a watershed through field measurement	2
2.	Morphometric analysis of a watershed	2
3.	Estimation of erosivity index of rainfall	1
4.	Determination of soil texture	1
5.	Determination of soil grain size distribution	1
6.	Determination of Atterberg's limits of soil	1
7.	Determination of various soilmoisture percentages	1
8.	Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status	2
9.	Design of Check dams, gully plugs, gabion structures, earth dams, silt detention dams and farm ponds	4
10.	Estimation of costs of soil and water conservation measures	2
	Total	**17**

X. Suggested Reading

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publishers, New Delhi.
- Kirkby MJ and Morgan PPC (eds). 1980. *Soil Erosion*. John Wiley and Sons. New York, USA.
- Suresh R. 2016. *Soil and Water Conservation Engineering*. Standard Publishers and Distributors, Delhi.

I. Course Title : Applied Watershed Hydrology

II. Course Code : SWCE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in depth knowledge of surface and sub-surface hydrology of watershed including stream flow measurement and computer simulation of hydrological processes in small watersheds.

V. Theory

Unit I

Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle. Runoff phenomena, relationship between precipitation and runoff. Stream flow measurement and analysis of data in detail.

Unit II

Synthetic unit hydrograph. Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds. Use of IUH and various methods of estimation. Runoff estimation models: SCS, CN software.

Unit III

Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements.

Unit IV

Hydrological hazard functions. Methods of estimation of hydrologic parameters. Data transformation.

Unit V

Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds.

VI. Practical

Delineation of watershed and study of watershed characteristics. Measurement of rainfall and runoff in a watershed and data analysis. Estimation of infiltration and runoff from a watershed. Analysis and derivation of various types of hydrographs. Flood routing. Reservoir sedimentation. Watershed model components. Visit to a watershed.

VII. Learning outcome

The students will be able to understand and analyze the process and the effect of various climatic parameters on rainfall-runoff relationship. They can also be able to develop the competency for calibration and evaluation of hydrologic models and computer simulation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle	2
2.	Basics of watershed hydrology and processes, global and watershed perspectives	2

S.No.	Topic	No. of Lectures
3.	Runoff phenomena, relationship between precipitation and runoff	1
4.	Synthetic unit hydrograph, Unit hydrograph and its derivation including for complex storm,	3
5.	S-hydrograph and derivation, Use of IUH and various methods of estimation.	3
6.	Runoff estimation models: SCS, CN software	3
7.	Flood routing principles	2
8.	Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds.	3
9.	Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements	3
10.	Process of sedimentation of reservoirs	2
11.	Hydrological hazard functions, Methods of estimation of hydrologic parameters, Data transformation,	3
12.	Hydrologic modeling approaches, component conceptualization, types of watershed hydrologic models and choice of model.	3
13.	Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of watershed and study of watershed characteristics	1
2.	Measurement of rainfall and runoff in a watershed	1
3.	Analysis of hydrologic data and flow from small watersheds	1
4.	Estimation of infiltration and runoff from a watershed	1
5.	Measurement and analysis of stream flow data	1
6.	Analysis of synthetic unit hydrograph for complex storm	1
7.	Analysis of S-hydrograph for complex storm	1
8.	Use of runoff estimation models: SCS, CN software	2
9.	Study of different types of flood routing methods	2
10.	Computer simulation of hydrological process in small watersheds	1
11.	Study of reservoir sedimentation	1
12.	Study of watershed model components	1
13.	Visit to a watershed	1
	Total	**16**

IX. Suggested Reading

- Haan CT. *Hydrologic Modeling of Small Watershed*.
- Singh VP. 2010. *Rainfall-Runoff Modeling* (Vol. I)—Prentice Hall, New York.
- Singh VP. 2010. *Environmental Hydrology*. Springer, New York.

I. Course Title : Soil and Water Conservation Structures

II. Course Code : SWCE 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with the planning and design of soil and water conservation structures, their stability checks and mechanized soil conservation techniques.

V. Theory

Unit I

Design, planning and layout of soil and water conservation structures. Criteria of selection of appropriate structures as per soil, land use and climatic conditions.

Unit II

Design and construction of earthen dam, stability analysis of land slopes and soil mass including landslides.

Unit III

Hydrological and structural design including stress analysis. Hydraulic jump and energy dissipaters for soil conservation structures.

Unit IV

Seepage through dams, flow net and determination of uplift pressure in drop structures, design of energy dissipaters.

Unit V

Design of water harvesting structures, construction, maintenance and utilization of stored water. Mechanized construction techniques for soil and water conservation structures.

VI. Practical

Numerical approach on probability distribution functions. Stability analysis and structural design of masonry water harvesting structures. Design of earthen dams and other energy dissipating structures. Cost analysis of water harvesting structures. Field visit to already constructed water harvesting structures in the nearby area/ watershed.

VII. Learning outcome

The student will be able to design the soil and water conservation structures as well as permanent gully control structures and water harvesting structures. They can have understanding of mechanized construction of soil and water conservation structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Introduction and need of Soil and Water Conservation in agricultural watershed	1
2	Runoff process and factors affecting it and estimation of runoff using various methods	3
3	Analysis of rainfall data, Probability concepts in the design of structures	3
4	Introduction, classification and functional requirement of soil and water conservation structures-Straight Drop spillway, chute spillway and drop inlet spillway	1
5	Specific energy and specific force	2
6	Hydraulic jump and its application, type of hydraulic jump, energy dissipation due to jump, jump efficiency, relative loss of energy	2
7	Straight drop spillway- Components and their functions, hydrologic, hydraulic and structural design	4

S.No.	Topic	No. of Lectures
8	Drop inlet spillway- Components and their functions, hydrologic, hydraulic and structural design	2
9	Chute Spillway- Components and their functions, hydrologic, hydraulic and structural design	3
10	Criteria of selection of appropriate structures as per soil, land use and climatic conditions	1
11	Design of energy dissipaters in soil and water conservation structures	1
12	Introduction, types, design, criteria and construction of earthen dam, causes of failure of earthen dam, retaining wall and its design	3
13	Stability analysis of land slopes and soil mass including landslides, seepage control in earthen dams, flow net in earthen dams	2
14	Water harvesting: principles, importance and issues. Water harvesting techniques: classification based on source, storage and use. Runoff harvesting: short-term and long-term harvesting techniques, purpose and design criteria.	3
15	Mechanized construction techniques for soil and water conservation structures	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of various probability distribution function for rainfall analysis	1
2.	Construction of specific energy and specific force diagram	2
3.	Measurement of hydraulic jump parameters and amount of energy dissipation	1
4.	Hydrologic and hydraulic design of a straight drop spillway	1
5.	Determination of uplift force and construction of uplift pressure diagram	1
6.	Determination of loads on headwall and construction of triangular load diagram	1
7.	Stability analysis of a straight drop spillway	1
8.	Hydraulic design of a chute spillway	1
9.	Design of drop inlet spillway	1
10.	Design of energy dissipating structures	1
11.	Design of earthen dam	1
12.	Seepage analysis in earthen embankment	1
13.	Design of water harvesting structures	1
14.	Economic analysis of water harvesting structures	1
15.	Field visit to already constructed water harvesting structures in the nearby area/watershed.	1
	Total	**16**

X. Suggested Reading

- Mahnot SC, Singh PK and Chaplot PC. 2011. *Soil and Water Conservation and Watershed Management*. Apex Publishing House, Udaipur.
- Murty VVN. 1988. *Land and Water Management Engineering*. Second Edition Kalyani Publishers, New Delhi.
- Singh Gurmel C, Venkataraman G, Sastri and Joshi BP. 1991. *Manual of Soil and Water conservation Practices*. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi.

- Singh PK. 2000. *Watershed Management* (*Design and Practice*). e-media publications, Udaipur.
- Suresh R. 2006. *Soil and Water Conservation Engineering*. Fourth Edition Standard Publishers and Distributors, Delhi.
- Singh Raj Vir. 2003. *Watershed Management*. Second Edition, Yash Publishing, Bikaner.

I. Course Title : Stochastic Hydrology

II. Course Code : SWCE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the stochastic processes in hydrology including statistical characteristics of hydrological time series data, modeling hydrologic uncertainty and analysis of multivariate hydrologic series,

V. Theory

Unit I

Hydrologic cycle, Systems concept, Hydrologic systems model. Classification of hydrologic models, Statistical, stochastic and deterministic approaches. Statistical characteristics of hydrological data, probability distribution of hydrologic variables. Deterministic and stochastic hydrology, Cause and effect analysis. Hydrologic time series analysis – nature, stationarity and ergodicity, components of time series, trend, periodicity and stochastic parts, parameter estimation of probability distributions. Analysis of hydrologic extremes.

Unit II

Multivariate regression analysis, correlation analysis, correlation coefficient and its significance in regional analysis. Developing prediction equation by simple and multiple linear regression. Reliability of the Model.

Unit III

Stochastic Process: Classification, stationary process. Time series: Classification, component of time series. Methods of investigation: Auto correlation coefficient, moving average process, auto regressive process, auto regressive moving average process, auto regressive integrated moving average process. Spectral analysis, analysis of multivariate hydrologic series.

Unit IV

Thomas Fiering model, Box Jenkins model. Model formulation: Parameter estimation, calibration and validation. Application to hydrologic data. Generation and forecasting. Regional flood frequency analysis. Transformations, Hypothesis testing.

Unit V

Modeling hydrologic uncertainty. First order Markov process, Markov chain, Data generation, Hydrologic time series analysis, Modelling of hydrologic time series.

VI. Practical

To estimate various statistical parameters of the hydrologic variables, estimating missing data in historical series, various parameter estimation methods like method of moments, method of maximum likelihood, method of mixed moments, probability of weighted moments fitting discrete and continuous distribution functions to variables, application of transformation techniques to historical data for estimating variables at different return periods, determining correlation and regression coefficients, analyzing multivariate regression, autocorrelation coefficient for independent and correlated events, fitting ARMA models, fitting Markov models of first and second order, regional frequency analysis, time series analysis of the historical data, estimating and fitting Thomas Fiering Model.

VII. Learning outcome

The students are enabled to understand the stochastic process of hydrology including statistical based analysis of hydrological time series data. They are exposed to stochastic and deterministic modeling of small watersheds.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrologic cycle, Systems concept, Hydrologic systems model	1
2.	Hydrological models, processes and systems - Physical Characterization of watersheds; Rainfall measurements	1
3.	Classification of hydrologic models, Statistical, stochastic and deterministic approaches	1
4.	Statistics and probabilities in hydrology – Basic concepts – Experiment, Sample space, element, event, complement, intersection, disjoint, union, statistical parameters; Uncertainty in hydrological event; Statistical homogeneity, Permutation, combination, probability, conditional probability; Independent events, random variables, discrete and continuous sample space, Probability and Return period	3
5.	Statistics and probabilities in hydrology- Frequency Analysis – Mean, Median, Mode, Variance, Frequency Analysis - Standard deviation, Coefficient of Variance, Skewness, Kurtosis Theorems on Probability; Total probability theorem and Baye's theorem	3
5.	Statistics and probabilities in hydrology- Discrete and Continuous probability - Random Variable and Variate; Probability Distribution of hydrological variables; Co-relation and regression analysis.	3
6.	Introduction and examples of stochastic processes; Specification of stochastic process- nature, stationarity and ergodicity, components of time series,	2
7.	Hydrologic time series analysis –trend, periodicity	1
8.	Stochastic time series analysis- Methods of analysis -Auto correlation coefficient,	1
9.	Stochastic time series analysis- moving average process, auto regressive process,	2
10.	Stochastic time series analysis- auto regressive moving average process,	2
10.	Stochastic time series analysis- auto regressive integrated moving average process.	2
11.	Spectral analysis, analysis of multivariate hydrologic series	2
12.	Thomas Fiering model, Box Jenkins model	2
13.	Model formulation: Parameter estimation, calibration and validation.	2
14.	Application to hydrologic data	2
15.	Generation and forecasting- Regional flood frequency analysis Transformations,	1
16.	Hypothesis testing	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Development of regression models	1
2.	Estimation of missing data in historical series	1
3.	Parameter estimation-Method of Moments	1
4.	Parameter estimation-method of maximum likelihood	1
5.	Parameter estimation- method of mixed moments, Probability of weighted moments	1
6.	Fitting discrete and continuous distribution functions to variables	1
7.	Transformation techniques to historical data for estimating variables at different return periods	1
8.	Regression analysis, Correlation analysis,	1
9.	Analyzing multivariate regression,	1
10.	Autocorrelation coefficient for independent and correlated events,	1
11.	Fitting ARMA models to rainfall runoff data	1
12.	Fitting Markov models of first and second order,	1
13.	Regional frequency analysis,	1
14.	Estimating parameters of Thomas Fiering Model	1
15.	Fitting of Thomas Fiering Model	1
	Total	**15**

X. Suggested Reading

- Clarke RT. *Mathematical Models in Hydrology*. FAO Publication.
- Haan CT. 2002. *Statistical Methods in Hydrology*. Iowa State Press.
- Kotteguda NT. 1982. *Stochastic Water Resources Technology*. The Macmillan Press, New York.
- McCuen RH and Snyder WM. *Hydrological Modelling–Statistical Methods and Applications*. Prentice Hall Inc., New York.
- Yevjevich V *Stochastic Processes in Hydrology*. Water Resources Publications, Colorado.

I. Course Title : Watershed Management and Modeling

II. Course Code : SWCE 505

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with watershed management concept and its benefit for sustainable rural development through participatory approach, including environmental impact as well as policy frame work.

V. Theory

Unit I

Concept of watershed, its hydrological and geomorphological characteristics. Status of watershed management programs in India. Problems of desertification and degradation.

Unit II

Concept of watershed management and sustainability, participatory approach and operational watershed. Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines.

Unit III

Watershed management research instrumentation and measurement, problem identification, simulation and synthesis. Rainfed farming and drought management. Modeling of flood and drought phenomenon.

Unit IV

Use of Remote Sensing and GIS in watershed management and modeling. Watershed modeling approaches, mathematical bases and structure of existing watershed models.

Unit V

Environmental impact assessment of watersheds. Quantitative evaluation of management techniques. National land use policy, legal and social aspects. Case studies of watershed management.

VI. Practical

Selection and delineation of a watershed. Benchmark surveys. Preparation of watershed land use map. Preparation of watershed development proposal. Preparation of watershed evaluation and impact assessment report. Application of watershed models for evaluation of conservation treatments. Use of Remote Sensing and GIS in watershed management and modeling.

VII. Learning outcome

The students will be able to understand different conservation practices and their effect on watershed behavior. They can also estimate the geomorphologic parameters of particular watershed which is quite useful for watershed planning and development of watershed models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Concept of watershed, its hydrological and geomorphological characteristics	2
2	Status of watershed management programs in India	2
3	Problems of desertification and degradation	2
4	Concept of watershed management and sustainability, participatory approach and operational watershed	3
5	Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines	3
6	Watershed management research instrumentation and measurement, problem identification, simulation and synthesis	2
7	Rainfed farming and drought management	2
8	Modeling of flood and drought phenomenon	2
9	Use of Remote Sensing and GIS in watershed management and modeling	2
10	Watershed modeling approaches, mathematical bases and structure of existing watershed models	3
11	Environmental impact assessment of watersheds	2
12	Quantitative evaluation of management techniques	2
13	National land use policy, legal and social aspects	2
14	Case studies of watershed management	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1	Selection and delineation of a watershed	3
2	Benchmark surveys	2
3	Preparation of watershed land use map	2
4	Preparation of watershed development proposal	3
5	Preparation of watershed evaluation and impact assessment report	2
6	Application of watershed models for evaluation of conservation treatments	2
7	Use of Remote Sensing and GIS in watershed management and modelling	2
	Total	**16**

X. Suggested Reading

- Dhaliwal GS Hansra BS and Ladhar SS. 1993. *Wetlands, their Conservation and Management*. Punjab Agricultural University, Ludhiana.
- Dhruvanarayana VV, Sastry G and Patnaik US. *Watershed Management*. Publ. and Inf. Dv., ICAR, Krishi Anusandhan Bhavan, New Delhi.
- Singh RV. 2000. *Watershed Planning and Management*. Second Edition Yash Publishing House, Bikaner.
- Suresh R. 2017. *Watershed Planning and Management*. Standard Publication and Distribution, Delhi.
- Tideman EM. 1999. *Watershed Management* (*Guidelines for Indian Conditions*). Omega Scientific Publishers, New Delhi.

I. Course Title : Flow Through Porous Media

II. Course Code : SWCE 506

III. Credit Hours : 2+0

IV. Aim of the course

To provide comprehensive knowledge to the students in aquifer and fluid properties, unsaturated flow theory and movement of groundwater in fractured and swelling porous media.

V. Theory

Unit I

Aquifer and fluid properties, forces holding water in soils, hydrodynamics in porous media and limitations of governing laws.

Unit II

Differential equations of saturated flow, initial and boundary conditions. Dupuit and Business approximations and linearization techniques.

Unit III

Stream functions, potential functions and flow net theory. Analysis of seepage from canals and ditches.

Unit IV

Unsaturated flow theory, Infiltration and capillary rise flux dynamics. Movement of groundwater in fractured and swelling porous media.

Unit V

Hydro-dynamic dispersion in soil-aquifer system. Velocity hydrograph, flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of seepage on stability of slopes, drainage methods for stability of slopes.

VI. Learning outcome

The students will be able to understand physical properties of flow through porous media. Competence on various laws governing dynamics of flow through porous media. Understanding of hydrodynamics in porous media, governing laws and boundary conditions.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Aquifer and its classification, properties of aquifers and fluids	1
2.	Forces responsible for holding water in soil and movement, hydrostatic pressure distribution	1
3.	Porosity, permeability and hydraulic conductivity: its importance in fluids flow	1
4.	Hydrodynamics in porous media: Continuum approach to porous media, Representative Elementary Volume (REV), linear and aerial porosity, velocity and specific discharge relationship in porous medium	3
5.	Generalization of Darcy Law in isotropic and anisotropic layered porous medium, deviation from Darcy Law and limitations of governing laws in flow through porous media	3
6.	Saturated flow: Differential equations for flow through saturated medium, initial and boundary conditions, types of boundary conditions, boundary and initial value problems	3
7.	Dupuit and Boussinesq approximations and linearization: Dupuit assumption and equation, Boussinesq linearization Techniques and solutions	3
8.	Unsaturated flow theory: Continuity and conservation equations for a homogeneous fluid in non-deforming medium and deforming medium, continuity equation for compressible fluid and moveable solid matrix	6
9.	Infiltration and capillary rise flux dynamics, movement of groundwater in fractured and swelling porous media	2
10.	Stream and potential functions: Stream functions in two and three dimensional flow, potential functions and flow net theory	3
11.	Analysis of seepage from canals and ditches	2
12.	Hydro-dynamic dispersion in soil-aquifer system: Hydro-dynamic dispersion, derivation of dispersion and diffusion equation	3
13.	Velocity hydrograph: Flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of seepage on stability of slopes, drainage methods for stability of slopes	3
	Total	**34**

X. Suggested Reading

- Bears J. 1972. *Dynamics of Fluids in Porous Media*. American Elsevier Publishing Co. Inc. New York.

- Bear J and Arnold V. *Modeling Groundwater Flow and Pollution*. D. Reidel Publishing Company.
- Collins RE. 1961. *Flow of Fluids through Porous Materials*. Reinhold publishing cooperation, New York.
- Core AT *Flow in Porous Media*.
- De Wiest Roger JM. 1969. *Flow through Porous Media*. Academic press, New York.
- Helmut K *Soil Physics*. pp. 7-79.
- Verruijt A. 1982. *Theory of Groundwater Flow*. 2nd Edn., Macmillan, London

I. Course Title : GIS and Remote Sensing for Land and Water Resource Management

II. Course Code : SWCE 507/IDE 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of land use, surface and ground water.

V. Theory

Unit I

Physics of remote sensing, electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platform, monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others, Indian Space Programme.

Unit II

Satellite Data analysis: Visual interpretation, digital image processing, image pre-processing, image enhancement, image classification and data merging.

Unit III

Definition: Basic components of GIS, map projections and co-ordinate system, spatial data structure-raster, vector, spatial relationship, topology, geodatabase models, hierarchical network, relational, object-oriented models, integrated GIS database-common sources of error–data quality: Macro, micro and usage level components, meta data, Spatial data transfer standards.

Unit IV

Thematic mapping, measurements in GIS: Length, perimeter and areas. Query analysis, reclassification: Buffering, neighbourhood functions, map overlay: Vector and raster overlay: Interpolation, network analysis, digital elevation modelling. Analytical Hierarchy Process, Object oriented GIS–AM/FM/GIS, Web Based GIS.

Unit V

Spatial data sources: 4M GIS approach water resources system, Thematic maps, rainfall runoff modelling, groundwater modelling, water quality modelling and flood inundation mapping and modelling. Drought monitoring, cropping pattern change analysis, performance evaluation of irrigation commands. Site selection for artificial recharge, reservoir sedimentation.

VI. Practical

Familiarization with the Remote sensing instruments and satellite imagery. Aerial

Photograph and scale determination with stereoscope. Interpretation of satellite imageries and aerial photographs. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

VII. Learning outcome

Students will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps. Able to integrate satellite data with GIS to undertake recourse mapping and planning studies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and brief history of RS and GIS, applications of RS and GIS	1
2.	Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation	1
3.	Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme	2
4.	Satellite data analysis. Visual interpretation.	1
5.	Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging.	3
6.	Basic components of GIS- Map projections and co-ordinate system.	2
7.	Spatial data sources,Thematic maps	1
7.	Spatial data structure: Raster, vector data, Spatial relationship-Topology	1
8.	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
9.	Data quality, Common sources of error, Macro, micro and Usage level components, Meta data and Spatial data transfer standards	2
10.	Measurement in GIS- Length, perimeter and areas	1
10.	Query analysis. Reclassification, Buffering and Neighbourhood functions	1
11.	Map overlay: Vector and raster overlay	1
12.	Interpolation and network analysis	1
13.	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS	3
14.	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling	2
15.	GIS approach to Groundwater modelling and water quality modelling	2
16.	Site selection for artificial recharge. Reservoir sedimentation	1
17.	Drought monitoring	1
18.	Performance evaluation of irrigation commands	1
19.	Cropping pattern change analysis	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization with the remote sensing instruments and satellite imagery	1
2.	Methods of establishing ground truth survey and Comparison between ground truth and remotely sensed data	2
3.	Aerial Photograph and scale determination with stereoscope	1
4.	Interpretation of satellite imagery and aerial photograph	1
5.	Determination of Parallaxes in images	1
6.	Demonstration on GPS; Provision of Ground Control by GPS in different mode	1
7.	Introduction to digital image processing software	1
8.	Introduction to GIS software	1
9.	Data input; Data editing and Topology creation -Digitization of point, line & polygon features	
10.	SRTM & CARTO DEM download from web and Georeferencing of an image	1
11.	Delineation of Watershed, DEM generation: slope, Aspect, flow direction, Flow accumulation, Drainage, network and morphometric analysis	2
12.	LULC by supervised classification and LULC by unsupervised classification	1
13.	Application of Remote Sensing data and GIS for water quality parameters	
14.	Temporal satellite data analysis for vegetation condition, crop water requirement calculation	1
15.	Erosion mapping using aerial and satellite Data	1
	Total	**17**

X. Suggested Reading

- Ian HS, Cornelius and Steve C. 2002. *An Introduction to Geographical Information Systems*. Pearson Education, New Delhi.
- James BC and Randolph HW. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lilles TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation*. John Wiley and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.
- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.

I. Course Title : Climate Change and Water Resources

II. Course Code : SWCE 508

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about the concept of climate change and its impact on surface and ground water resources. To understand adaptation and mitigation strategy under climate change scenario.

V. Theory

Unit I

The climate system: Definitions, climate, climate system, climate change. Drivers of climate change, characteristics of climate system components: Greenhouse effect, carbon cycle, wind systems. Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina– ENSO, teleconnections.

Unit II

Impacts of climate change: Observed and projected, global and Indian scenario, observed changes and projected changes of IPCC: Impacts on water resources, NATCOM Report, impacts on sectoral vulnerabilities, SRES, different scenarios, climate change impacts on ET and irrigation demand.

Unit III

Tools for vulnerability assessment: Need for vulnerability assessment, steps for assessment, approaches for assessment. Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models.

Unit IV

Adaptation and mitigation water: Related adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation), Adaptation, vulnerability and sustainable development.

Unit V

Sector specific mitigation: Carbon dioxide capture and storage (CCS), bio-energy crops, biomass electricity, hydropower, geothermal energy, energy use in buildings, land-use change and management, cropland management, afforestation and reforestation. Potential water resource conflicts between adaptation and mitigation. Implications for policy and sustainable development.

Case studies: Water resources assessment case studies: Ganga Damodar Project, Himalayan glacier studies, Ganga valley project. Adaptation strategies in assessment of water resources. Hydrological design practices and dam safety, operation policies for water resources projects. Flood management strategies, drought management strategies, temporal and spatial assessment of water for irrigation, land use and cropping pattern, coastal zone management strategies.

VI. Learning outcome

The students will be able to understand climate change concept particularly on surface and ground water. Students can have in depth knowledge about adaptation and mitigation strategies in respect of climate change.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Definitions- climate, climate system, climate change; Drivers of climate change	3
2.	Climate system and its components; wind systems, carbon cycle, Greenhouse effect, Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina– ENSO, teleconnections	3
3.	Climate scenarios- SRES, RCP, Scenario based observed and projected climate changes in Indian and global context	3

S.No.	Topic	No. of Lectures
4.	IPCC projected climate change impacts on water resources, NATCOM Report-impacts on ET and irrigation demand	3
5.	Vulnerability assessment: Need, steps for assessment, approaches for assessment	2
6.	Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models	4
7.	Adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation)	4
8.	Sector specific mitigation: Carbon dioxide capture and storage (CCS)	2
9.	Sector specific mitigation: bio-energy crops, biomass electricity, hydropower, geothermal energy, energy use in buildings	2
10.	Sector specific mitigation: land-use change and management, cropland management, afforestation and reforestation	2
11.	Potential water resource conflicts between adaptation and mitigation	2
12.	Implications for policy and sustainable development.	2
13.	Case studies- Ganga Damodar Project, Himalayan glacier studies, Ganga valley project	5
14.	Adaptation strategies in assessment of water resources- Temporal and spatial assessment of water for irrigation, land use and cropping pattern	2
15.	Adaptation strategies in assessment of water resources- Hydrological design practices and dam safety, operation policies for water resources projects	3
16.	Flood management strategies, coastal zone management strategies.	3
	Total	**45**

VIII. Suggested Reading

- Majumdar PP and Nagesh KD. *Floods in a Changing Climate: Hydrological Modelling*. Cambride University Press, New York.
- Pathak H, Agarwal PK and Singh SD. *Mitigation in Agriculture: Methodology for Assessment and Application*. Division of Environmental Sciences, IARI New Delhi.
- Rao YS, Zhang TC Ojha, Gurjar BR, Tyagi RD, Kao CM (eds). *Climate Change Modelling, Mitigation, and Adaptation*. American Society of Civil Engineers.
- Srinivasa RK and Nagesh KD. *Impact of Climate Change on Water Resources with Modelling Techniques and Case Studies*. Springer publications, New York.
- Tamim Y and Caitlin AG. *Climate Change and Water Resources*. Springer Publication.

I. Course Title : Numerical Methods in Hydrology

II. Course Code : SWCE 509

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint students about the concept of linear space, triangular and quadrilateral shape functions, isoparametric elements and transformation of coordinates.

V. Theory

Unit I

Review of finite difference operators. Concept of linear space and basis functions. Approximating from finite dimensional sub spaces.

Unit II

Variational and weighted residual methods. Langrange polynomials. Triangular and quadrilateral shape functions.

Unit III

Isoparametric elements and transformation of coordinates. Basis functions in three dimensions.

Unit IV

Galerkin finite element solution of Laplace, diffusion and dispersion-convection equations.

Unit V

Method of collocation, application in surface and sub surface hydrology.

VI. Learning outcome

The students are able to understand numerical methods in hydrology by having in-depth knowledge of linear space and finite element solution in surface and sub-surface hydrology.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Review of finite difference operators	2
2	Concept of linear space and basis functions	3
3	Approximating from finite dimensional sub spaces	3
4	Variational and weighted residual methods	2
5	Langrange polynomials	2
6	Triangular and quadrilateral shape functions	3
7	Isoparametric elements and transformation of coordinates.	3
8	Basis functions in three dimensions	3
9	Galerkin finite element solution of Laplace	3
10	Diffusion and dispersion-convection equations	3
11	Method of collocation	2
12	Application in surface and sub surface hydrology	3
	Total	**32**

VIII. Suggested Reading

- Bear J and Verruijt A. 1987. *Modeling Groundwater Flow and Pollution*. 414 pp. Dordrecht, Boston.
- Carr JR. 1995. *Numerical Analysis for the Geological Sciences*. 592 pp. Prentice-Hall, Englewood Cliffs NJ.
- George H and Patricia W. 2000. *Numerical Methods in the Hydrological Sciences*. American Geophysical Union, Florida Avenue, NW.
- Gerald CF and Wheatley PO. 1999. *Applied Numerical Analysis*. 6th ed., 768 pp, Addison-Wesley, Reading, MA.
- Middleton GV. 2000. *Data Analysis in the Earth Sciences using MATLAB* 260 pp., Prentice Hall, Saddle River NJ.

- Wang HF and Anderson MP. 1982. *Introduction to Groundwater Modeling: Finite Difference and Finite Element Methods*. 237 pp, W.H. Freeman and Co., San Francisco.

I. Course Title : Dryland Water Management Technologies

II. Course Code : SWCE 510

III. Credit Hours : 2+0

IV. Aim of the course

To provide detail knowledge about analysis of severity of drought assessment and various dry land water management technologies suitable for conservation, harvesting and enhancing productivity of rainfed areas.

V. Theory

Unit I

Drought severity assessment: Meteorological, hydrological and agricultural methods. Drought indices. GIS based drought information system, drought vulnerability assessment and mapping using GIS. DPAP programme, drought monitoring constraints, limiting crop production in dry land areas. Types of drought, characterization of environment for water availability, crop planning for erratic and aberrant weather conditions.

Unit II

Stress physiology and crop resistance to drought, adaptation of crop plants to drought, drought management strategies. Preparation of appropriate crop plans for dry land areas. Mid contingent plan for aberrant weather conditions.

Unit III

Land shaping and land development for soil moisture conservation. Improvement of tillage and soil management by implements and engineering practices. Soil and moisture conservation for rainfed lands through improved implements and engineering practices. Gel technology.

Ex-situ measures: Water harvesting-micro catchments. Design of small water harvesting structures: Farm Ponds, percolation tanks their types and design, recycling of runoff water for crop productivity.

Unit IV

Crops and cropping practices related to soil and moisture conservation. Fertility management in dryland farming. Planning and development of watersheds from engineering view point. Case studies.

Unit V

Application of aerial photography in surveys and planning of watersheds for rainfed agriculture.

Use of Remote Sensing in soil moisture estimation.

VI. Learning outcome

The students will be able to understand drought severity assessment techniques alongwith new and appropriate methods of rainwater conservation and harvesting technologies for rainfed areas.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Drought severity assessment: Meteorological, hydrological and agricultural methods	2
2.	Drought indices	1
3.	GIS based drought information system, drought vulnerability assessment and mapping using GIS	2
4.	DPAP programme, drought monitoring constraints, limiting crop production in dry land areas	2
5.	Types of drought: characterization of environment for water availability	1
6.	Types of drought: crop planning for erratic and aberrant weather conditions	1
7.	Stress physiology and crop resistance to drought	1
8.	Adaptation of crop plants to drought and drought management strategies	1
9.	Preparation of appropriate crop plans for dry land areas	2
10.	Mid contingent plan for aberrant weather conditions	1
11.	Land shaping and land development for soil moisture conservation	1
12.	Improvement of tillage and soil management by implements and engineering practices	2
13.	Soil and moisture conservation for rainfed lands through improved implements and engineering practices	2
14.	Introduction of Gel technology for conservation measures	1
15.	*Ex-situ* measures: Water harvesting-micro catchments	1
16.	Design of small water harvesting structures: Farm Ponds	1
17.	Design of small water harvesting structures: percolation tanks their types and design	2
18.	Recycling of runoff water for crop productivity	1
19.	Crops and cropping practices related to soil and moisture conservation	1
20.	Fertility management in dryland farming	1
21.	Planning and development of watersheds from engineering view point	2
22.	Planning and development of watersheds - Case studies	1
23.	Application of aerial photography in surveys and planning of watersheds for rainfed agriculture	1
24.	Use of Remote Sensing in soil moisture estimation	1
	Total	**32**

VIII. Suggested Reading

- Das NR. 2007. *Tillage and Crop Production*. Scientific Publishers.
- Dhopte AM. 2002. *Agro Technology for Dryland Farming*. Scientific Publ.
- Gupta US. 1995. *Production and Improvements of Crops for Drylands*. Oxford & IBH
- Singh RP. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh RP. 2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Publ.
- Singh RV. 2003. *Watershed Planning and Management*. Second Edition. Yash Publishing House, Bikaner.
- Singh SD. 1998. *Arid Land Irrigation and Ecological Management*. Scientific Publishers.

Course Title with Credit Load
Ph.D. in Soil and Water Conservation Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
*SWCE 601	Advances in Hydrology	2+1
*SWCE 602	Soil and Water Systems Simulation and Modeling	2+1
SWCE 603	Reservoir Operation and River Basin Modeling	2+1
SWCE 604	Modeling Soil Erosion Processes and Sedimentation	2+1
SWCE 605	Waste Water Treatment and Utilization	3+0
SWCE 606	Hydro-Chemical Modeling	2+0
	Total	**13+4**

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
IDE 603	Hydro-Mechanics and Ground Water Modeling	3+0
IDE 604	Soil-Water-Plant-Atmospheric Modeling	2+1
IDE 606	Multi Criteria Decision Making System	2+0
CSE 503	Neuro-Fuzzy Application in Engineering	2+1
CSE 506	Digital Image Processing	2+1
	Any other course(s) of other department can be taken as per recommendations of the students advisory committee	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics	1+1
	Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee.	

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

List of other Essential Requirements

Course Code	Course Title	Credit Hours
SWCE 691	Seminar-I	0+1
SWCE 692	Seminar-II	0+1
SWCE 699	Thesis Research	0+75

Course Contents
Ph.D. in Soil and Water Conservation Engineering

I. Course Title : Advances in Hydrology
II. Course Code : SWCE 601
III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge to the students about hydrologic models, flood frequency analysis and formulation of statistical models.

V. Theory

Unit I

Hydrologic models, processes and systems. Uncertainty in hydrological events. Statistical homogeneity.

Unit II

Probabilistic concept. Frequency analysis. Probability distribution of hydrological variables. Confidence intervals and hypothesis testing.

Unit III

Simple and multiple linear regressions, correlation, statistical optimization and reliability of linear regression models. Analysis of hydrologic time series and modeling. Auto–correlation, correlogram and cross-correlation analysis.

Unit IV

Markov processes, stochastic hydrologic models including Markov chain models. Generation of random variates. Hydrology of climate extremes. Area-duration-frequency curves. Regional flood frequency analysis.

Unit V

Formulation of various steps involved in formulation of statistical models and their application in hydrology.

VI. Practical

Parametric and non parametric test of time series data. Development of probabilistic and deterministic models for time series data of rainfall and runoff. Development of hydrologic models and frequency analysis for specified data set using SPSS and other software used in hydrologic modeling.

VII. Learning outcome

The students will be able to develop the hydrologic modeling and find out their trend as well as periodic component. To develop the stochastic and deterministic models for forecasting precipitation for prediction of floods and droughts.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Hydrologic models, processes and systems	1
2.	Uncertainty in hydrologic events risks, uncertainty	1
3.	Statistical homogeneity in hydrologic processes	1
4.	Probability, total probability theorem, Bayes theorem	2
5.	Moment generating function, statistical parameters	1
6.	Probability distribution of hydrologic variables	2
7.	Confidence interval one sided, two sided, Hypothesis testing test statistics	2
8.	Regression analysis, simple regression, confidence interval on regression coefficient, regression line, inference on regression	3
9.	Multiple linear regression	2
10.	Optimization of regression coefficients, Statistical optimization and reliability of linear regression models	3
11.	Time series analysis, components, stationarity, Auto correlation, correlograms, Cross correlation analysis	3
12.	Generating processes, Markov process- first order, higher order	2
13.	Statistical principles and techniques for time series modeling	2
14.	Markov chain models, Examples of Markov chain models in hydrology	2
15.	Autoregressive models, Autoregressive modeling of annual time series, Examples of autoregressive modeling	3
16.	Hydrology of climate extremes. Area-duration-frequency curves. Regional flood frequency analysis	2
17.	Formulation of various steps involved in formulation of statistical models and their application in hydrology	2
	Total	**34**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of parametric and non parametric test of time series data	4
2.	Development of probabilistic models for time series data of rainfall and runoff	2
3.	Development of deterministic models for time series data of rainfall and runoff	2
4.	Development of hydrologic models for specified data set using SPSS and other software used in hydrologic modeling	2
5.	Development of frequency analysis for specified data set using SPSS and other software used in hydrologic modeling	2
6.	Development of the stochastic models for forecasting precipitation for prediction of floods and droughts	2
7.	Development of deterministic models for forecasting precipitation for prediction of floods and droughts	2
	Total	**16**

X. Suggested Reading

- Garg SK. 1987. *Hydrology and Water Resources Engineering*. Khanna Publications.
- Hann CT. *Advanced Hydrology*. Oxford Publications House.
- Linseley RK Jr, Kohler MA and Paulhus JLH. 1975. *Applied Hydrology*. McGraw Hill.
- Mutreja KN. 1986. *Applied Hydrology*. Tata McGraw Hill.
- Singh VP. 2010. *Hydrological Modelling*. Springer, New York.

I. Course Title : Soil and Water Systems Simulation and Modeling

II. Course Code : SWCE 602

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the rainfall-runoff models, sediment model, overland and channel flow simulation and decision support systems using simulation models.

V. Theory

Unit I

Models and their classification, simulation procedure. Rainfall-runoff models. Infiltration models, evapo-transpiration models, structure of a water balance model.

Unit II

Overland and channel flow simulation. Modeling approaches and parameters. Stream flow statistics. Surface water storage requirements.

Unit III

Flood control storage capacity and total reservoir capacity. Surface water allocations. Palaeo-channels. Ground water models.

Unit IV

Design of nodal network. General systems frame work. Description of the model. Irregular boundaries. Decision support system using simulation models. Monte-Carlo approach to water management.

Unit V

Stanford watershed model and input data requirements of various hydrologic modeling systems. Soil water assessment tool (SWAT). Groundwater modeling and solute transport.

VI. Practical

Rainfall-runoff models. Infiltration models. Stanford watershed model (SWM). Channel flow simulation problems. Stream flow statistics. Model parameters and input data requirements of various software's of surface hydrology and groundwater. Hydrologic modeling system. Soil water management model. Soil water assessment tool (SWAT). Catchments simulation hydrology model. Stream flow model and use of dimensionless unit hydrograph. Generalized groundwater models.

VII. Learning outcome

The students will be able to develop the model for overland and channel flow simulation, which can be used for watershed management and planning and also able to simulate the ground water and surface water by developing the ground water model and runoff models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Models and their classification, simulation procedure	2
2	Rainfall-runoff models	3
3	Infiltration models, evapo-transpiration models, structure of a water balance model	2

S.No.	Topic	No. of Lectures
4	Overland and channel flow simulation	2
5	Modeling approaches and parameters. Stream flow statistics	2
6	Surface water storage requirements	1
7	Flood control storage capacity and total reservoir capacity	2
8	Surface water allocations	1
9	Palaeo-channels	1
10	Ground water models	2
11	Design of nodal network	1
12	General systems frame work	1
13	Description of the model	1
14	Irregular boundaries	1
15	Decision support system using simulation models	2
16	Monte-Carlo approach to water management	2
17	Stanford watershed model and input data requirements of various hydrologic modeling systems	2
18	Soil water assessment tool (SWAT)	2
19	Groundwater modeling and solute transport	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Rainfall-runoff models	2
2.	Infiltration models	1
3.	Stanford watershed model (SWM)	1
4.	Channel flow simulation problems	1
5.	Stream flow statistics	2
6.	Model parameters and input data requirements of various software's of surface hydrology and groundwater	2
7.	Hydrologic modeling system. Soil water management model	2
8.	Soil water assessment tool (SWAT). Catchments simulation hydrology model	2
9.	Stream flow model and use of dimensionless unit hydrograph	1
10.	Generalized groundwater models	2
	Total	**16**

X. Suggested Reading

- Biswas AK. 1976. *Systems Approach to Water Management*. McGraw Hill.
- Cox DR and Mille HD. 1965. *The Theory of Stochastic Processes*. John Wiley & Sons.
- Eagleson PS. 1970. *Dynamic Hydrology*. Mc Graw Hill.
- Himmel Blau DM and Bischoff KB. 1968. *Process Analysis and Simulation Deterministic Systems*. John Wiley & Sons.
- Linsley RK, Kohler MA and Paulhus JLH. 1949. *Applied Hydrology*. McGraw Hill.
- Schwar RS and Friedland B. 1965. *Linear Systems*. McGraw Hill.
- Ven Te Chow, David R Maidment and Mays LW. 1998. *Applied Hydrology*. McGraw Hill.

I. Course Title : Reservoir Operation and River Basin Modeling

II. Course Code : SWCE 603

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge to the students about water management plans, demand analysis and water resources planning in river basins including stochastic and deterministic modeling.

V. Theory

Unit I

Water resources system analysis: Techniques, concept, objectives and applications.

Unit II

Identification and evaluation of water management plans. Demand analysis, policy formulation. Water resources planning objectives. Water resources planning under uncertainty.

Unit III

Definition of terminologies and basic concepts. Theories and principles of IRBM processes/phases in integrated river basin management. River basins, river functions. Human interventions and impacts. River basins in India, related case studies. Water resources planning in river basins. Operational management, tools and methods. Monitoring, acquisition and processing of water resource data.

Unit IV

Statistical methods. Decision support systems. Deterministic river basin modeling. Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis, single and multi-reservoir operation models. Economics and finance.

Unit V

Stochastic river basin modeling: Single reservoir design and operation, multisite river basin models, stochastic linear programming operation models.

VI. Practical

Development of regression models, stochastic models and deterministic models for river basin based on stream flow data. Estimation of reservoir storage and preparation of operation models.

VII. Learning outcome

The students will be able to develop the model for effective water resources planning for river basins, identification and evaluation of water management plans as well as in-depth knowledge of stochastic and deterministic modeling.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction–Concepts of Systems and Systems Analysis; Techniques, objectives and applications	2
	Applications of Water resources system analysis	1
2.	Identification and evaluation of water management plans-water demand analysis, Water resources planning objectives	2
3.	Water resource planning and management approaches-Top-Down Planning and Management; Bottom-Up Planning and Management Integrated Water Resources Management	1
4.	Water resource management policy formulation, Water resources planning under uncertainty	1

S.No.	Topic	No. of Lectures
5.	River basins, river functions, Theories and principles of IRBM processes/phases in integrated river basin management	1
6.	Human interventions and impacts in in integrated river basin management	1
7.	River basins in India- related case studies	1
8.	Water resources planning in river basins- Operational management, tools and methods	2
9.	Water resources planning in river basins - Monitoring, acquisition and processing of water resource data	2
10.	Economic Considerations in Water Resources Planning	1
10.	Deterministic river basin modeling-Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis	2
11.	Deterministic river basin modeling- Reservoir Sizing; Reservoir Operation – standard operating policy, optimal operating policy; multi-reservoir systems,	6
12.	Concept of Reliability	1
13.	Stochastic river basin modeling: Basic probability theory,	2
14.	Single reservoir design and operation-Chance constrained Linear Programming for reservoir operation and design	3
15.	Stochastic river basin modeling: multisite river basin models,	1
	Model Formulations and Case Studies- Conjunctive use of ground and surface water; Crop yield optimization, Multi-basin and multi-reservoir systems	3
	Total	**33**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Development of regression models	1
2.	Regression analysis	1
3.	Correlation analysis	1
4.	Simple Linear Regression and coefficient of determination	1
5.	Discrete and Continuous probability - Random Variable and Variate	1
6.	Deterministic models for river basin based on stream flow data	1
7.	Stochastic models for river basin based on stream flow data	1
8.	Stochastic river basin modeling	1
9.	Stochastic linear programming operation models	1
10.	Single and multi-reservoir operation models	1
11.	Evaluation of water management plans	1
12.	Evaluation of demand analysis	1
13.	Stream flow estimation	1
14.	Estimation of reservoir storage	1
15.	Preparation of operation models	1
16.	Deterministic river basin planning model	1
	Total	**16**

X. Suggested Reading

- Chaturvedi MC 1984. *System Approach to Water Resources Planning and Management*.
- Loucks DP *et al*. 1980. *Water Resources System Planning and Analysis*. Prentice Hall, NJ.
- Major DC and Lenton RL. 1979. *Applied Water Resources System Planning*. Prentice Hall Inc., New Jersey.

I. Course Title : Modeling Soil Erosion Processes and Sedimentation

II. Course Code : SWCE 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concept of modeling upland erosion, reservoir sedimentation and sediment yield models for estimation of soil erosion.

V. Theory

Unit I

Mechanics of soil erosion. Erosion-sedimentation systems of small watersheds. Overland flow theory and simulation. Basic theory of particle and sediment transport. Sediment deposition processes.

Unit II

Modeling upland erosion and component processes. Modes of transport and transport capacity concept and computation. Channel erosion. Erosion and sediment yield measurement and estimates.

Unit III

Reservoir sedimentation surveys and computation. Classification of models, structure and mathematical bases of sediment yield models. Nature and properties of sediment: Individual and group of particles. Critical tractive force, lift and drag forces. Shield's analysis.

Unit IV

Calibration and testing of models. Universal soil loss equation, its modification and revisions. Stochastic and dynamic sediment yield models.

Unit V

Evaluation of erosion control measures. Computer models used for hydrologic and/ or watershed modeling.

VI. Practical

Computation of soil erosion index. Estimation of soil erodibility factor. Design of erosion control structures. Computation of suspended load and sediment load using empirical formulae. Application of sediment yield models. Prediction of sediment loss. Computation of reservoir sedimentation, sounding method.

VII. Learning outcome

The students will be able to estimate the sediment from the particular watershed by using various instruments. Development of the common understanding of mechanics of sediment transportation process and remedies to reduce sedimentation of watersheds

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Mechanics of soil erosion	1
2.	Erosion-sedimentation systems of small watersheds	1
3.	Overland flow theory and simulation	2
4.	Basic theory of particle and sediment transport. Sediment deposition processes	2

S.No.	Topic	No. of Lectures
5.	Modeling upland erosion and component processes	2
6.	Modes of transport and transport capacity concept and computation	2
7.	Channel erosion	1
8.	Erosion and sediment yield measurement and estimates	1
9.	Reservoir sedimentation surveys and computation	2
10.	Classification of models, structure and mathematical bases of sediment yield models	2
11.	Nature and properties of sediment: Individual and group of particles	2
12.	Critical tractive force, lift and drag forces	2
13.	Shield's analysis	2
14.	Calibration and testing of models	2
15.	Universal soil loss equation, its modification and revisions	2
16.	Stochastic and dynamic sediment yield models	2
17.	Evaluation of erosion control measures	2
18.	Computer models used for hydrologic and/or watershed modeling	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Computation of soil erosion index	2
2.	Estimation of soil erodibility factor	2
3.	Design of erosion control structures	4
4.	Computation of suspended load and sediment load using empirical formulae	2
5.	Application of sediment yield models	2
6.	Prediction of sediment loss	2
7.	Computation of reservoir sedimentation, sounding method	2
	Total	**16**

X. Suggested Reading

- Garde RJ and Ranga Raju KG. 1977. *Mechanics of Sediment Transport and Alluvial Stream Problems*.Wiley Eastern Ltd.
- Morgan RPC (Ed. D A Davison). 1986. *Soil Erosion and Conservation*. ELBS.
- Longman USDA. 1969. *A Manual on Conservation of Soil and Water*. Oxford & IBH.
- Tripathi RP and Singh HP. 1993. *Soil Erosion and Conservation*. Publisher- New Age International, New Delhi.

I. Course Title : Waste Water Treatment and Utilization

II. Course Code : SWCE 605

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint students about types of waste water and the various treatment measures alongwith the utilization of waste water in agriculture and other sectors.

V. Theory

Unit I

Types of waste water, causes of pollution, analysis of pollutants in the waste effluents, Biological wastewater treatment, biological sludge treatment. Biological systems: Fundamentals of microbiology and biochemistry, bioenergetics and metabolism, kinetics of biological growth. Process analysis: Reaction rates, effect of temperature on reaction rate, enzyme reaction and kinetics, effect of temperature on reaction rate. Reactor analysis, residence time distribution.

Unit II

Sewerage system: Domestic wastewater characteristics, flow equalization, population equivalent, treatment flow chart. Primary, secondary and tertiary treatment of domestic wastewater. Downstream wastewater treatment for reuse and recycle. Need for downstream processing. Guidelines for wastewater recycling. Small and package plants for wastewater treatment.

Unit III

Activated sludge process: Substrate utilization and biomass growth, Monod's kinetics, estimation of kinetic parameters. Process Description and its Modification, Process design, process performance evaluation, trouble shooting. Nitrogen removal-Biological nitrification and denitrification.

Unit IV

Activated sludge process design for nutrient removal. Process operation: (F/M), mean cell residence time, oxygen requirement. Biological and chemical phosphorus removal, Sedimentation of activated sludge. Advanced activated sludge process-Sequencing Batch reactor, Oxidation ditch and membrane bioreactors.

Unit V

Biofilm process: Trickling filter, biotower, rotational biological contactor, integrated activated sludge and biofilm processes. Stabilization ponds and aerated lagoons: Types and their description, design, operation and maintenance. Anaerobic processes: Process description, process design, operation and maintenance, sludge digestion. Sludge treatment-thickening, dewatering-mechanical and sludge drying beds. Utilization of waste water in agriculture and other sectors.

VI. Learning outcome

Students will be able to have in-depth knowledge about waste water treatment methods, sewerage system, activated sludge process, biofilm process. The student will also expose to use of waste water in agriculture and other sectors.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Status of wastewater in India, Sources of contamination and characterization of urban and rural wastewater for irrigation	2
2.	Water quality: Physical, chemical and biological parameters of wastewater	2
3.	Wastewater quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses.	2
4.	Different types of wastewater, pollutants and contaminants.	1
5.	Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.	2
6.	Key drivers of wastewater use in agriculture and existing approaches for regulating wastewater reuse in agriculture	2

S.No.	Topic	No. of Lectures
7.	Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for irrigation	3
8.	Health Risks Associated with the Use of Wastewater for Irrigation	1
9.	Wastewater treatment methods: Physical, chemical and biological.	3
10.	Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation	2
11.	General water treatments: Wastewater recycling, constructed wetlands, reed bed system.	2
12.	Carbon foot prints of wastewater reuse. Environmental standards.	2
13.	Management of health and environmental risks of wastewater irrigation	1
14.	Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts.	3
15.	Impact on groundwater resources and soil health, EIA process, Stages of EIA-monitoring and auditing. Environmental clearance procedure in India	3
16.	Economics of wastewater irrigation	1
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study on physical, chemical and biological parameters of wastewater	1
2.	Determination of EC and pH of wastewater	1
3.	Determination of BOD of wastewater	1
4.	Determination of COD of wastewater	1
5.	Determination of TSS and TDS of wastewater	1
6.	Determination RSC of wastewater	1
7.	Determination of e-coli in the wastewater	1
8.	On field demonstration of wastewater use for the irrigation	1
9.	Determination of nutrient (N, P and K) concentration in wastewater	2
10.	Field demonstration of impact of waste water on eco-system and human health.	1
11.	Study on various wastewater treatment methods	2
12.	Study on effect of wastewater on contamination of ground water	1
13.	Visit of village pond treatment nearby area	1
14.	Visit of sewerage treatment plant nearby area	1
	Total	**16**

IX. Suggested Reading

- Droste RL. 1997. *Theory and Practice of Water and Wastewater Treatment*. John Wiley.
- Metcalf and Eddy. 2003. *Wastewater Engineering*. 4th Ed., McGraw Hill.
- Qasim SR. 1999. *Wastewater Treatment Plants – Planning, Design and Operation*. CRC Press, Florida.
- Ramalho RS. *Wastewater Treatment*. Wiley.

I. Course Title : Hydro-Chemical Modeling

II. Course Code : SWCE 606

III. Credit Hours : 2+0

IV. Aim of the course

To provide comprehensive knowledge to the students about hydrodynamics of flow through porous media and development of analytical, statistical and numerical models.

V. Theory

Unit I

Review of hydrodynamics in flow through porous media. Miscible displacement, physical processes.

Unit II

Breakthrough curves and mathematical models for miscible displacement. Hydrodynamic dispersion convection equations and its solutions.

Unit III

Statistical models for dispersion. Gaseous (CO_2 and O_2) diffusion equation.

Unit IV

Heat flow through soil by conduction. Concept of adsorption in solute transport.

Unit V

Analytical and numerical models of contaminant transport in unsaturated soil profile and groundwater aquifers.

VI. Learning outcome

Students will be able to demonstrate understanding of hydrodynamics of fluid transport through modeling and will be able to do water quality analysis of lakes and reservoir based physical and chemical characteristics. Develop water reclamation and water reuse plans for irrigation and industries.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Review of hydrodynamics in flow through porous media	7
2.	Miscible displacement, physical processes, breakthrough curves	2
3.	Mathematical models for miscible displacement	5
4.	Hydrodynamic dispersion convection equation and its solutions	4
5.	Heat flow through soil by conduction	2
6.	Concept of adsorption in solute transport	2
7.	Analytical and numerical models of contaminant transport in unsaturated soil profile and groundwater aquifers.	6
8.	Statistical models for dispersion	3
9.	Gaseous (CO_2 and O_2) diffusion equation.	3
	Total	**34**

VIII. Suggested Reading

- Larry W Mays 1996. *Water Resources Handbook*. Mc Graw Hill.
- Metcalf and Eddey 1994. *Wastewater Treatment Engineering and Reuse*. John Wiley.
- Soli J Arceivala 1998. *Wastewater Treatment for Pollution Control*. Tata Mc Graw-Hill.

Details of Minor Courses
Department of Electrical Engineering and Information Technology

I. Course Title : Big Data Analytics

II. Course Code : CSE 501

III. Credit Hours : 2+1

IV. Aim of the course

To understand principles of analyzing and mining big data and to use simple tools to extract useful information from big data sets.

V. Theory

Unit I

Data analysis, data matrix attributes. Data: Algebraic and geometric view, probabilistic view.

Unit II

Basics of data mining and CRISP-DM, organizational and data understanding, purposes, Intents and limitations of data mining, database, data warehouse, data mart and data set, types of data, privacy and security, data preparation, collation and data scrubbing.

Unit III

Data mining models and methods, correlation, association rules, k-means, clustering understanding of concept, preparation and modelling.

Unit IV

Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling.

Unit V

Decision trees, neural networks, understanding, preparation and modeling.

VI. Practical

Introduction to OpenOffice and RapidMiner in data analytics and mining. Preparing RapidMiner, Importing data, handling missing data, data reduction, handling Inconsistent data, attribute reduction. Performing different analysis using RapidMiner or suitable software.

VII. Learning outcome

Capability to understand the principles behind analysis of big data and apply the same using simple tools.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Data analysis, data matrix attributes	2
2.	Algebraic and geometric view, probabilistic view.	4

S.No.	Topic	No. of Lectures
3.	Basics of data mining and CRISP-DM	2
4.	Organizational and data understanding	3
5.	Intents and limitations of data mining, database, data warehouse, data mart and data set	4
6.	Types of data, privacy and security, data preparation, collation and data scrubbing.	4
7.	Data mining models and methods, correlation, association rules	6
8.	K-means, clustering understanding of concept, preparation and modelling.	5
9.	Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling.	5
10.	Decision trees, neural networks, understanding, preparation and modeling.	5
	Total	**40**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Working of OpenOffice and RapidMiner	3
2.	Preparing RapidMiner Dataset	3
3.	Handling the inconsistent data, missing data, attribute reduction	4
4.	Performing analysis on dataset using RapidMiner	3
	Total	**13**

X. Suggested Reading

- Dr Matthew *North Data Mining for the Masses A Global Text Project Book* ISBN: 0615684378ISBN-13: 978-0615684376.
- Mohammed J Z, Troy and Wagner M Jr. *Data Mining and Analysis: Fundamental Concepts and Algorithms*. Universidade Federal de Minas Gerais, Brazil. Cambridge University Press ISBN 978-0-521-76633-3 Hardback.

I. Course Title : Artificial Intelligence

II. Course Code : CSE 502

III. Credit Hours : 2+1

IV. Aim of the course

To introduce students with techniques and capabilities of artificial intelligence (AI) and enable them to do simple exercises.

V. Theory

Unit I

Definitions of intelligence and artificial intelligence. What is involved in intelligence? Disciplines important to AI. History of development of AI. Different types of AI. Acting humanly, Turing test. AI systems in everyday life. Applications of AI.

Unit II

Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining. Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems.

Unit III

Problem solving using AI, search techniques, breadth first search, depth first search, depth limited search, bidirectional search, heuristic search, problems and examples. Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.

Unit IV

Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, the Chinese room problem, emergence of consciousness, technological singularity, Turing test.

Unit V

Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network, N-tuple network, evolutionary computing, genetic algorithms, agent methods, agents for problem solving, software agents, multi agents, hardware agents.

VI. Practical

Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. Using structures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures. Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.

VII. Learning outcome

Ability to understand and apply principles of AI in solving simple problems to enable them to get insight into working of AI based systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Definitions of intelligence and artificial intelligence. Disciplines important to AI. History of development of AI.	2
2.	Different types of AI. Acting humanly, Turing test. AI systems in everyday life. Applications of AI.	2
3.	Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining.	3
4.	Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems.	3
5.	Problem solving using AI, search techniques, breadth first search, depth first search	4
6.	Depth limited search, bidirectional search, heuristic search, problems and examples.	4
7.	Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.	3
8.	Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment,	2
9.	Chinese room problem, emergence of consciousness, technological singularity, Turing test.	3
10.	Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network,	3
11.	N-tuple network, evolutionary computing, genetic algorithms,	2
12.	Agent methods, agents for problem solving, software agents,	2
13.	Multi agents, hardware agents.	1
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic.	4
2.	Using structures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures.	5
3.	Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.	5
	Total	**14**

X. Suggested Reading

- GNU PROLOG *A Native Prolog Compiler with Constraint Solving over Finite Domains* Edition 1.44, for GNU Prolog version 1.4.5 July 14, 2018.
- Ivan Bratko, *Prolog Programming for Artificial Intelligence*.
- Warwick K. 2012. *Artificial Intelligence: The Basics* ISBN: 978-0-415-56482-3 (hbk).

I. Course Title : Neuro-Fuzzy Application in Engineering

II. Course Code : CSE 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn the basic concept of neural network models and fuzzy logic based models and apply fuzzy reasoning and fuzzy inference to solve various agricultural engineering problems

V. Theory

Unit I

Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.

Unit II

Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions. Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T- conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling. Applications of fuzzy reasoning and modelling in engineering problems.

Unit III

Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods. Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks, recurrent networks, hopfield networks, hebbian learning, self organizing networks, unsupervised learning, competitive learning.

Unit IV

Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.

Unit V

Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling.

VI. Practical

Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks. Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees, data clustering algorithms like k-means, fuzzy c-means, mountain and subtractive clustering, rule based structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks.

VII. Learning outcome

The students will be able to have the basic concept of neural network models and fuzzy logic-based models and will be in a position to apply fuzzy reasoning and fuzzy inference for various problems of agricultural engineering. They will also learn to develop different types of neural network models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.	3
2.	Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions.	3
3.	Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T- conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling.	4
4.	Applications of fuzzy reasoning and modelling in engineering problems.	3
5.	Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods.	3
6.	Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks	3
7.	recurrent networks, hopfield networks, hebbian learning, self-organizing networks, unsupervised learning, competitive learning.	4
8.	Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.	3
9.	Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling.	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks	5
2	Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees,	5

S.No.	Topic	No. of Lectures
3	data clustering algorithms like k-means, fuzzy c-means, mountain and subtractive clustering, rule based structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks	6
	Total	**16**

X. Suggested Reading

- Jang, JS R, Sun C Tand Mizutan E 1997. *Neuro-Fuzzy and Soft Computing*. Prentice Hall
- Simon Haykin NJ. 1994. *Neural Networks. A Comprehensive Foundation*. McMillan College Publishing Company.
- Klir George J and Forger TA. 1995. *Fuzzy Sets, Uncertainty and Information*. Prentice Hall of India, Pvt. Ltd, New Delhi.
- Kosko B. 1997. *Neural Networks and Fuzzy Systems*. Prentice Hall of India Pvt. Ltd, New Delhi.
- Rao V and Rao H. 1996. *C++ Neural Networks and Fuzzy Logic*. BPB Publications, New Delhi.

I. Course Title : Soft Computing Techniques in Engineering

II. Course Code : CSE 504

III. Credit Hours : 2+1

IV. Aim of the course

To learn the basic concepts of soft computing techniques like neural networks, genetic algorithms and fuzzy systems and apply these techniques for real time problem solving.

V. Theory

Unit I

Introduction to control techniques, need of intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule based systems, the artificial intelligence approach. Knowledge representation and expert systems. Data pre-processing: Scaling, Fourier transformation, principle component analysis and wavelet transformations.

Unit II

Concept of artificial neural networks (ANN) and basic mathematical model, network structures, activation function, back propagation, network size and pruning McCulloch-Pitts neuron model, simple perceptron, adaline and madaline neural networks, feed-forward multi-layer perceptron. Learning and training the neural network. Networks: Hopfield network, self-organizing network and recurrent network. Neural network based controller. Case studies: Identification and control of linear and nonlinear dynamic systems.

Unit III

Genetic algorithm (GA): Basic concept and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using GA. Concept of other search techniques like tabu search and ant-colony search for solving optimization problems.

Unit IV

Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to Fuzzy logic modelling and control of a system. Fuzzification, inference and defuzzification. Fuzzy knowledge and rule bases.

Unit V

Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control. Implementation of fuzzy logic controller. Stability analysis of fuzzy control systems. Intelligent control for SISO/MIMO nonlinear systems. Model based multivariable fuzzy controller.

VI. Practical

To work on data transformations, brief review on statistical criteria for termination of epochs, deciding the input output and hidden layers and neutrons for ANN problems, working on different algorithms of ANN to different problems in agricultural engineering, working with different fuzzy relations, propositions, implications and inferences, working with defuzzification techniques and fuzzy logic controllers, concept of coding, selection, crossover, mutation and application of genetic programming for global optimization, use of available software for application of soft computing techniques.

VII. Learning outcome

To enable students to apply modern engineering techniques which are useful for solving nonlinear and complex functions and to develop application of different soft computing techniques like genetic algorithms, fuzzy logic, neural networks and their combination to real world problems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to control techniques, need of intelligent control. Architecture for intelligent control.	3
2.	Symbolic reasoning system, rule based systems, the artificial intelligence approach.	3
3.	Knowledge representation and expert systems.	2
4.	Data pre-processing: Scaling, Fourier transformation, principle component analysis and wavelet transformations.	2
5.	Concept of artificial neural networks (ANN) and basic mathematical model, network structures, activation function, back propagation, network size and pruning McCulloch-Pitts neuron model	3
6.	Simple perceptron, adaline and madaline neural networks, feed-forward multi-layer perceptron. Learning and training the neural network.	3
7.	Networks: Hopfield network, self-organizing network and recurrent network. Neural network based controller. Case studies: Identification and control of linear and nonlinear dynamic systems	3
8.	Genetic algorithm (GA): Basic concept and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using GA.	3
9.	Concept of other search techniques like tabu search and ant-colony search for solving optimization problems.	2
10.	Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning.	2

S.No.	Topic	No. of Lectures
11.	Introduction to Fuzzy logic modelling and control of a system. Fuzzification, inference and defuzzification.	2
12.	Fuzzy knowledge and rule bases.	2
13.	Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control.	2
14.	Implementation of fuzzy logic controller. Stability analysis of fuzzy control systems.	2
15.	Intelligent control for SISO/MIMO nonlinear systems. Model based multivariable fuzzy controller.	2
	Total	**36**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	To work on data transformations, brief review on statistical criteria for termination of epochs, deciding the input output and hidden layers and neutrons for ANN problems,	3
2.	Working on different algorithms of ANN to different problems in agricultural engineering, working with different fuzzy relations,	2
3.	propositions, implications and inferences, working with defuzzification techniques and fuzzy logic controllers, concept of coding,	3
4.	selection, crossover, mutation and application of genetic programming for global optimization, use of available software for application of soft computing techniques.	4
	Total	**12**

X. Suggested Reading

- David EG. *Genetic Algorithms*.
- Rajasekaran S and Vijayalakshmi Pai GA. 2017.*Neural Networks, Fuzzy Logic and Genetic Algorithm, Synthesis and Applications*. PHI Learning Pvt. Ltd.
- Ross TJ. 1997. *Fuzzy Logic with Fuzzy Applications*. McGraw Hill Inc.
- Simon H. 2003. *Neural Networks: A Comprehensive Foundation*. Pearson Edition.
- Sivanandam SN and Deepa SN. 2011. *Principles of Soft Computing*. Wiley India Pvt. Ltd., 2nd Edition.
- Sivanandam SN and Deepa SN. 2013. *Principles of Soft Computing*. Wiley India.

I. Course Title : Digital Image Processing

II. Course Code : CSE 506

III. Credit Hours : 2+1

IV. Aim of the course

To give an overview of digital image processing including visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation and morphological image processing.

V. Theory

Unit I

Digital image fundamentals, elements of visual perception, light and the electromagnetic spectrum, image sensing and acquisition, image sampling and quantization, basic relationships between pixels, linear and nonlinear operations.

Unit II

Image enhancement in the spatial domain, basic gray level transformations, histogram processing, basics of spatial filtering, smoothing spatial filters, sharpening spatial filters.

Unit III

Color image processing, color fundamentals, color models, pseudo color image processing, basics of full-color image processing, color transformations, smoothing and sharpening, color segmentation.

Unit IV

Image segmentation, detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds.

Unit V

Morphological image processing, dilation and erosion, opening and closing, extensions to gray-scale images.

VI. Practical

To write program to read and display digital image, image processing program using point processing method, program for image arithmetic operations, program for image logical operations, program for histogram calculation and equalization, program for geometric transformation of image, understand various image noise models and to write programs for image restoration and to remove noise using spatial filters. Brief outline of image processing tools.

VII. Learning outcome

This course introduces digital image processing. It focuses on the theory and algorithms underlying a range of tasks including acquisition, formation, enhancement, segmentation and representation.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and Fundamentals, Motivation and Perspective, Applications, Components of Image Processing System,	3
2.	Element of Visual Perception, A Simple Image Model	1
3.	Sampling and Quantization.	2
4.	Light and the electromagnetic spectrum, image sensing and acquisition	2
5.	Basic relationships between pixels, linear and nonlinear operations	2
6.	Image Enhancement in Spatial Domain	2
7.	Introduction; Basic Gray Level Functions	2
8.	Histogram Specification	2
9.	Basics of spatial filtering, smoothing spatial filters, sharpening spatial filters	2
10.	Color image processing, color fundamentals	1
11.	Color models, pseudo color image processing	1
12.	Color transformations, smoothing and sharpening, color segmentation.	2
13.	Image segmentation, detection of discontinuities	1

S.No.	Topic	No. of Lectures
14.	Edge linking and boundary detection, thresholding, region-based segmentation	2
15.	Segmentation by morphological watersheds	1
16.	Morphological image processing, dilation and erosion	2
17.	Opening and closing, extensions to gray-scale images	2
	Total	**30**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	Display digital image, image processing program using point processing method, program for image arithmetic operations	3
2.	Program for image arithmetic operations, image logical operations, histogram calculation and equalization	4
3.	Program for geometric transformation of image, understand various image noise models	4
4.	Programs for image restoration and to remove noise using spatial filters	4
5.	Brief outline of image processing tools	1
	Total	**16**

X. Suggested Reading

- Jayaraman S, Esakkirajan S and Veerakumar T. *Digital Image Processing*. Tata McGraw Hill Publication.
- Rafael CG and Richard EW. *Digital Image Processing*. Third Edition, Pearson Education.
- Sridhar S. *Digital Image Processing*. Oxford University Press.

Department of Civil Engineering

I. Course Title : Dimensional Analysis and Similitude

II. Course Code : CE 501

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students with importance of analysis of dimensions and similitude principles in structuring mathematical/simulation models of various processes under different constraint variables.

V. Theory

Unit I

Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter, Methods of dimensional analysis: Rayleigh's method, Buckingham-Pi theorem, Choice of variables, Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic.

Unit II

Model studies, Model classification, Dimensionless numbers: Reynolds model, Froude's model, Euler's Model, Webber's model, Mach model, Scale effects, Distorted models, Model laws.

Unit III

Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws. Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect. Numerical problems on Reynolds's and Froude's Model.

Unit IV

Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables.

VI. Learning outcome

The students will be able to analyze complex problems using dimensional analysis and to develop rules for experiments with scale models and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating mathematical models.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter	2

S.No.	Topic	No. of Lectures
2.	Methods of dimensional analysis: Rayleigh's method, Buckingham-Pi theorem, Choice of variables	3
3.	Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic	2
4.	Model studies, Model classification, Dimensionless numbers: Reynolds model	3
5.	Froude's model, Euler's Model, Webber's model, Mach model, Scale effects	3
6.	Distorted models, Model laws.	2
7.	Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws	3
8.	Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect	3
9.	Numerical problems on Reynolds's and Froude's Model	3
10.	Use and scope of mathematical modeling, Principles of model formulation	2
11.	Role and importance of steady-state and dynamic simulation	2
12.	Classification of models, Model building, Modeling difficulties	2
13.	Degree-of-freedom analysis, Selection of design variables	2
	Total	**32**

VIII. Suggested Reading

- Barenblatt GI. 1987. *Dimensional Analysis*. Gordon and Breach Science, New York.
- Langhar HL. 1951. *Dimensional Analysis and the Theory of Models*. Wiley, New York.
- Murphy G. 1950. *Similitude in Engineering*. The Ronald Press Company, New York.
- Zohuri Bahman. *Dimensional Analysis and Self-Similarity Methods for Engineers and Scientists*. Springer Publications, New York.

I. Course Title : Water Quality and Pollution Control

II. Course Code : CE 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquire in-depth knowledge of water quality parameters, water quality standards, source of water pollution and multiple use of water.

V. Theory

Unit I

Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality (Physical, Chemical and Bacteriological) investigation, Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference, Software packages. Water quality indices. Water quality for irrigation. Salinity and permeability problem, saline water irrigation root zone salinity, interaction of irrigation and drainage.

Unit II

Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources. NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands.

Unit III

Multiple uses of water. Reuse of water in agriculture. Low cost waste water treatment technologies Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation.

Unit IV

Principles of water quality, water quality classification, water quality standards, water quality indices, TMDL Concepts. Water quality models. Soil crop and other practices for use of poor quality water.

VI. Practical

Determination of pH, total solids, dissolved and suspended solids, chlorides, sulphates, turbidity, dissolved oxygen, hardness. Preparation of water quality map of watershed in GIS environment. Visit of water polluted site of nearby area.

VII. Learning outcome

The students will be able to understand water quality standards which are quite important for drinking and irrigation purposes. They will also be exposed to source and type of pollution along with multiple uses of water.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality (Physical, Chemical and Bacteriological) investigation	3
2.	Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference	3
3.	Software packages. Water quality indices. Water quality for irrigation	2
4.	Salinity and permeability problem, saline water irrigation root zone salinity, interaction of irrigation and drainage	3
5.	Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources	3
6.	NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands	3
7.	Multiple uses of water. Reuse of water in agriculture. Low cost waste water treatment technologies	3
8.	Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation	3
9.	Principles of water quality, water quality classification	3
10.	water quality standards, water quality indices	2
11.	TMDL Concepts. Water quality models	2
12.	Soil crop and other practices for use of poor quality water	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Determination of pH, total solids, dissolved and suspended solids	4
2.	Determination of chlorides, sulphates, turbidity	3

S.No.	Topic	No. of Practicals
3.	dissolved oxygen, hardness	4
4.	Preparation of water quality map of watershed in GIS environment	4
5.	Visit of water polluted site of nearby area	1
	Total	**16**

X. Suggested Reading

- Abbasi T and Abbasi SA. *Water Quality Indices.* Elsevier Publications, New York.
- Chin and David A. 2006. *Water Quality Engineering in Natural Systems.* Wiley – Interscience.
- Claude E. Boyd. *Water Quality an Introduction*. Springer Publications.
- Eaton AD, Clesceri LS, Rice EW and Greenburg AE (eds). 2005. *Standard Methods for the Examination of Water and Wastewater*. 21st edn. American Public Health Association, Washington, DC.
- Thomann RV and Mueller JA. 1987. *Principles of Surface Water Quality Modelling and Control*. Harper and Row Publishers.
- Wesley W, Wallender PE and Kenneth K. Tanji, Sc.D. *Agricultural Salinity Assessment and Management*. ASCE Press.

I. Course Title : Experimental Stress Analysis

II. Course Code : CE 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with importance of analysis of stress, analysis of strain, stress-strain relationship under different constraint conditions in 2-D plane as well as 3-D plane.

V. Theory

Unit I

Strain and stress – strain relationship. Generalized Hook's Law. Strain Gauges-Mechanical, optical, electrical, acoustical and pneumatic etc and their use.

Unit II

Different types of electrical resistance strain gauges. Semi-conductor strain gauges. Rosette analysis. Strain gauge circuits. Strain measurements at high temperatures.

Unit III

Two dimensional and three dimensional photo-elastic method of strain analysis. Bifringent coatings and scattered light in photo-elasticity.

Unit IV

Brittle coating methods. Moiré's method of strain analysis. Grid method of strain analysis. Photo elastic strain gauges.

VI. Learning outcome

The students will be able to analyze stress, strain and their interrelationships when they are subjected to different end conditions in two dimensional and three dimensional planes and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating for stress and strain.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Strain and stress – strain relationship. Generalized Hook's Law	3
2.	Strain Gauges- Mechanical, optical, electrical, acoustical and pneumatic etc.	3
3.	Use of different strain gauges. Types of electrical strain gauges.	3
4.	Semi-conductor gauges. Rosette analysis. Strain gauge circuits.	32
5.	Strain measurements at high temperatures.	2
6.	Two dimensional photo-elastic method of strain analysis.	3
7.	Three dimensional photo-elastic method of strain analysis.	3
8.	Bifringent coatings and scattered light in photo-elasticity.	3
9.	Brittle coating methods	3
10.	Moir's method of strain analysis.	2
11.	Grid method of strain analysis. Photo elastic strain gauges.	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Cementing of an electrical resistance strain gage on a structural member	1
2.	To find the gage factor for a resistance type strain gage.	1
3.	To measure strain at centre of bream when loaded at greater points by making use of two strain gages one at top surface and 2nd at bottom both along longitudinal direction and fixing both in first and second arm of the bridge.	3
4.	To measure the modulus of elasticity of the beam making use of four strain gages, two on top and two on bottom, one on longitudinal and one in transversal direction on each face of the beam.	3
5.	Deter mine the tension produced in a circular shaft by using strain gages cemented perpendicular to each other.	1
6.	Determine the bending moment produced in a circular shaft by using a rectangular shaft.	1
7.	To align the circular polariscope.	1
8.	Study the plane polariscope and circular polariscope with different light field arrangements.	1
9.	Study of Moiré fringe apparatus and its applications in analysis of structures.	2
10.	Calibrate the photoelastic material by use of rectangular beam under pure bending.	2
	Total	**16**

IX. Suggested Reading

- Srinath LS, Raghavan MR, Lingaiah K, Gargesha G, Pant B and Ramachandra K. Experimental Stress Analysis, McGraw-Hill.
- Dally JW and Riley WF. *Experimental Stress Analysis*, McGraw-Hill.
- Singh S. *Experimental Stress Analysis*, Khanna Publishers.

Department of Mechanical Engineering

I. Course Title : Mechatronics and Robotics in Agriculture
II. Course Code : ME 501
III. Credit Hours : 2+0

IV. Aim of the course

To introduce the fundamentals of mechatronics and the concepts behind designing mechatronic systems and their subsystems and its application in automation in agriculture.

V. Theory

Unit I

Introduction to mechatronics: Basic definitions, key elements of mechatronics, historical perspective, the development of the automobile as a mechatronic system. Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems.

Unit II

System interfacing, instrumentation, and control systems.Input/output signals of a mechatronic system, signal conditioning, microprocessor control, microprocessor numerical control, microprocessor input/output control.

Unit III

Microprocessor based controllers and microelectronics: Introduction to microelectronics, digital logic, overview of control computers, microprocessors and microcontrollers, programmable logic controllers, digital communications.

Unit IV

Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system, sensors, electronics, algorithms and software. Servo motor drives types and applications. Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area.

Unit V

Application of robots in agriculture: Harvesting and picking, weed control, autonomous mowing, pruning, seeding, spraying and thinning, phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture.

VI. Learning outcome

Ability to understand agricultural machinery that is built on concepts of mechatronics and ability to use robotic machinery in agriculture.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to Mechatronics: Basic definitions, key elements of mechatronics,	2
2.	Historical perspective, the development of the automobile as a mechatronic system	1
3.	Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems.	3
4.	System interfacing, Instrumentation, and control systems	2
5.	Input/output signals of a mechatronic system, signal conditioning	2
6.	Microprocessor control, microprocessor numerical control, microprocessor input/output control	2
7.	Microprocessor based controllers and microelectronics	2
8.	Introduction to microelectronics, digital logic, overview of control computers	2
9.	Microprocessors and microcontrollers, programmable logic controllers, digital communications.	3
10.	Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system	2
11.	sensors, electronics, algorithms and software. Servo motor drives types and applications	2
12.	Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area.	2
13.	Application of robots in agriculture: Harvesting and picking, weed control	2
14.	autonomous mowing, pruning, seeding, spraying and thinning	2
15.	phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture.	3
	Total	**32**

VIII. Suggested Reading

- Alciatore DG and Histand MB. 2002. *Introduction to Mechatronics and Measurement System*. McGraw Hill Pvt Limited, New Delhi.
- Robert HB. 2002. *Mechatronic Hand Book*. CRC Press.
- Shakhatreh and Fareed. 2011. *The Basics of Robotics*. Lahti University of Applied Sciences Machine and Production Technology.

I. Course Title : Refrigeration Systems

II. Course Code : ME 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquire the skills required to model, analyse and design different refrigeration processes and components.

V. Theory

Unit I

Reversed Carnot cycle, Carnot, Brayton and aircraft refrigeration systems.

Unit II

Vapour compression refrigeration systems: Use of p-h chart, effect of pressure changes on COP, sub cooling of condensate on COP and capacity, super heating, single stage, multi-stage and cascade systems.

Unit III

Vapour absorption systems: Theory of mixtures, temperature-concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process, ammonia water and water lithium-bromide systems.

Unit IV

Thermoelectric refrigeration systems: Advantages, comparison with vapour compression system. Vortex tube refrigeration system and its thermodynamic analysis. Ultra low temperature refrigeration. Ejection refrigeration. Water refrigeration: Centrifugal and steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration.

VI. Practical

Numerical on air refrigeration cycle, Study of vapour compression refrigeration systems, Determination of the coefficient of performance of the refrigeration system, Study of vapour absorption (electrolux) refrigeration systems, Study and application of P-V, T-s and P-h chart in refrigeration, Study and performance testing of domestic refrigerator, Study of domestic water cooler, Study of actual and theoretical COP of Cascade Refrigeration System, Visit to cold storage plants.

VII. Learning outcome

After studying this course, students shall be able to analyse air and vapour compression refrigeration cycle, and perform thermodynamic analysis of absorption, steam jet, thermoelectric and vortex tube refrigeration systems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Reversed Carnot cycle, Carnot cycle	2
2.	Brayton refrigeration systems	2
3.	Aircraft refrigeration systems	4
4.	Vapour compression refrigeration systems, Single stage vapour compression refrigeration, Use of p-h chart	3
5.	Effect of pressure changes on COP, sub cooling of condensate on COP and capacity, super heating	2
6.	Multi-stage vapour compression refrigeration systems	3
7.	Cascade vapour compression refrigeration systems	2
8.	Vapour absorption systems: Theory of mixtures, temperature-concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process,	3
9.	Ammonia water vapour absorption systems.	1
10.	Water lithium-bromide vapour absorption systems.	1
11.	Thermoelectric refrigeration systems: Advantages, comparison with vapour compression system.	1
12.	Vortex tube refrigeration system and its thermodynamic analysis.	1
13.	Ultra low temperature refrigeration.	3
14.	Water refrigeration, Centrifugal refrigeration	1
15.	Ejection refrigeration, Steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler	

S.No.	Topic	No. of Lectures
	efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Numerical on air refrigeration cycle	2
2.	Study of vapour compression refrigeration systems	1
3.	Determination of the coefficient of performance of the refrigeration system	1
4.	Study of vapour absorption (electrolux) refrigeration systems	2
5.	Study and application of P-V, T-s and P-h chart in refrigeration	3
6.	Study and performance testing of domestic refrigerator,	2
7.	Study of domestic water cooler	1
8.	Study of actual and theoretical COP of Cascade Refrigeration System	2
9.	Visit to cold storage plants.	2
	Total	**16**

X. Suggested Reading

- Ahmadul A. *Refrigeration and Air Conditioning*. PHI India.
- Arora CP. *Refrigeration and Air Conditioning*. McGraw-Hill India Publishing Ltd.
- Arora R. *Refrigeration and Air Conditioning*. Prentice Hall of India.
- Crouse and Anglin. *Automobile Air Conditioning*. McGraw Hill Publications.
- Dossat RJ. *Principles of Refrigeration*. Pearson Education.
- Jordon and Prister. *Refrigeration and Air Conditioning*. Prentice Hall of India Pvt. Ltd.
- Prasad M. *Refrigeration and Air Conditioning*. New Age International Publisher.
- Stocker WF and Jones JW. *Refrigeration and Air Conditioning*. McGraw-Hill.

I. Course Title : Mechanism Analysis and Synthesis

II. Course Code : ME 503

III. Credit Hours : 2+1

IV. Aim of the course

The objective of the course is to understand the analysis and synthesis of mechanisms and to learn the graphical and analytical techniques commonly used in the synthesis of mechanisms.

V. Theory

Unit I

Kinematics of mechanisms, analysis and synthesis, mobility, systematic of mechanisms, deriving other mechanisms from linkages, Relative motion, instantaneous center method, Kennedy's theorem. Graphical and analytical methods of kinematic analysis.

Unit II

Computer - Aided analysis of mechanisms. Synthesis of linkages for path generation, function generation, Graphical techniques. Relative pole method and method of inversion. Analytical kinematics synthesis of linkages, Freudenstein's method, Loop closure equations based on complex variable approach,

Unit III

Gears and their motion-Analysis and Synthesis of epicyclic gear trains.

Unit IV

Cams-follower system; standard follower motions and combinations, importance of follower acceleration in cam system dynamics, terms related to cam design - their importance. Cam synthesis - graphical cam profile layout for a desired follower motion. Analytical determination of cam profile co-ordinates for disc cam operating common types of follower.

VI. Practical

Graphical solutions of mechanisms relating to velocity and acceleration. Problems on computer-aided analysis and synthesis of mechanisms. Analysis and design problems of gear trains, cam profile design.

VII. Learning outcome

The Student will be able to design mechanisms for better accuracy and productivity. The student will Get familiar with design process of the mechanisms for functional requirements.

VIII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Introduction & basic concepts.	2
2.	Kinematics of mechanisms, analysis and synthesis, mobility, systematic of mechanisms, deriving other mechanisms from linkages	3
3.	Determination of velocity and acceleration using graphical method and analytical methods (relative velocity and acceleration, instantaneous centers), Kennedy's theorem. Graphical and analytical methods of kinematic analysis	4
4.	Computer - Aided analysis of mechanisms. Synthesis of linkages for path generation, function generation, Graphical techniques. Relative pole method and method of inversion	3
5.	Analytical kinematics synthesis of linkages, Freudenstein's method, Loop closure equations based on complex variable approach	5
6.	Introduction to spur, helical, spiral, bevel and worm gears, law of gearing, nomenclature, velocity of sliding between two teeth in mesh.	3
7.	Gears and their motion-Analysis and Synthesis of epicyclic gear trains	4
8.	Cams-follower system; standard follower motions and combinations, importance of follower acceleration in cam system dynamics, terms related to cam design	4
9.	Cam synthesis - graphical cam profile layout for a desired follower motion. Analytical determination of cam profile co-ordinates for disc cam operating common types of follower.	4
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Graphical solutions of mechanisms relating to velocity and acceleration (4 different mechanisms to be studied)	4
2.	Problems on computer-aided analysis and synthesis of mechanisms	4

S.No.	Topic	No. of Practicals
3.	Analysis and design problems of gear trains	5
4.	Cam profile design	3
	Total	**16**

X. Suggested Reading

- Erdman A, Sandor G and Kota S. 2001. *Mechanism Design: Analysis and Synthesis* Pearson India Pvt Ltd, New Delhi.
- Sandor GI, Erdman AG. 1984. *Advanced Mechanism Design: Analysis and Synthesis* Pearson. Facsimile edition.
- Ballaney PL. 2003. *Theory of Machines*. - Khanna Publishers, New Delhi.
- Rattan. SS. 2014. *Theory of Machines*, McGraw Hill Pvt Ltd, New Delhi.
- Khurmi RS and Gupta 2020. *Theory of Machines*. Eurasia Publishing House (P) Ltd, New Delhi.

I. Course Title : Vibrations

II. Course Code : ME 504

III. Credit Hours : 3+0

IV. Aim of the course

To enable the students to design vibration control sytem,and balancing of rotating and reciprocating masses.

V. Theory

Unit I

Vibration motion and its terminology. Undamped free vibrations, equations of motion- natural frequency. Energy method, Rayleigh method; effective mass principle of Virtual work. Equivalent spring stiffness in parallel and in series. Harmonic analysis and Fourier Series

Unit II

Damping - viscous, solid, coulomb equivalent dampers. Viscosity damped free vibrations, Logarithmic decrement. Forced vibrations with harmonic excitation and rotating unbalance. Energy dissipated by damping

Unit III

Forced vibration with damping, Vibration isolation and force and motion transmissibility. Two degree of freedom systems. Principal modes of vibration, co-ordinate coupling. Vibration absorbers

Unit IV

Free vibration equation of motion for multi-degree of freedom systems. Influence coefficients and Maxwell's reciprocal theorem, stiffness coefficients. Numerical methods for finding natural frequencies for multi-degree of freedom systems.

Unit V

Vibration of lumped parameter systems and continuous systems. Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups, Accelerometer and frequency measuring instruments. Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines, design of vibration isolators.

VI. Learning outcome

The student will be able to understand the concept of vibrations, analyze the mathematical modeling of the multidegree freedom systems and able to design vibration isolators.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Vibration motion and its terminology.	2
2.	Undamped free vibrations, equations of motion- natural frequency.	2
3.	Energy method, Rayleigh method; effective mass principle of Virtual work.	2
4.	Equivalent spring stiffness in parallel and in series.	1
5.	Harmonic analysis and Fourier Series.	2
6.	Damping - viscous, solid, coulomb equivalent dampers.	3
7.	Viscosity damped free vibrations, Logarithmic decrement	3
8.	Forced vibrations with harmonic excitation and rotating unbalance	2
9.	Energy dissipated by damping. Forced vibration with damping,	3
10.	Vibration isolation and force and motion transmissibility.	2
11.	Two degree of freedom systems. Principal modes of vibration co-ordinate coupling	3
12.	Vibration absorbers,	2
13.	Free vibration equation of motion for multi-degree of freedom systems.	2
14.	Influence coefficients and Maxwell's reciprocal theorem, stiffness coefficients.	3
15.	Numerical methods for finding natural frequencies for multi-degree of freedom systems.	3
16.	Vibration of lumped parameter systems and continuous systems.	3
17.	Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups	3
18.	Accelerometer and frequency measuring instruments.	2
19.	Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines	3
20.	Design of vibration isolators.	2
	Total	**48**

VIII. Suggested Reading

- V.P. Singh.2014. *Mechanical Vibrations*. Dhanpat Rai and Comopany, New Delhi
- Rao S S. 2010.*Mechanical Vibrations*. Pearson Education, Delhi
- Srinivas P.1983. *Mechanical Vibration Analysis*. Tata McGraw Hill Company
- Limited, New Delhi
- Daniel J Inman.2013. *Engineering Vibration*. Prentice Hall, New Jersey

I. Course Title : Fatigue Design

II. Course Code : ME 507

III. Credit Hours : 2+1

IV. Aim of the course

The course provides an understanding on fatigue design considerations of mechanical components. The causes of fatigue in brittle and ductile materials are taught with focus on crack initiation, propagation and fracture.

V. Theory

Unit I

Theories of failure, maximum normal stress, maximum shear stress and distortion energy theory, failure of ductile materials, failure of brittle materials.

Unit II

Stress concentration and its evaluation, stress concentration of ductile and brittle materials under static loading and under dynamic loading, determining geometric stress concentration factors, designing to avoid stress concentration.

Unit III

Fatigue of machine components, mechanism of fatigue failure, fatigue failure models and their considerations in design of machine elements, fatigue loads. Fatigue testing and presentation of fatigue data. Influence of stress conditions on fatigue strength/endurance limit of metals. Low and high cycle fatigue

Unit IV

Cumulative fatigue damage. Designing for finite and infinite life. Improving fatigue resistance of machine elements. Stress corrosion. Corrosion fatigue.

Practical Fatigue tests on testing machine(s) for specimens of different materials having different discontinuities/stress raisers and various surface conditions. Determination of correlation between fatigue limit and ultimate strength of material. Problems in fatigue design of common machine component.

VI. Learning outcome

The students is able to understand technical aspects and principles of fatigue design. The student can design the engineering product having good durability and long fatigue life

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Introduction to cyclic loading and Fatigue Design	1
2	Types of Loads and Stresses, Different theories of Failure like maximum normal stress, maximum shear stress and distortion energy theory etc.	3
3	Determining stress concentration based on geometric stress concentration factors, Design considerations to avoid stress concentration of ductile and brittle materials.	3
4	Mechanical failure. Macroscopic failure modes, Behavior of brittle and ductile materials in fatigue and stress concentration. Fracture in brittle and ductile materials, characteristics of fracture surfaces, inter-granular and intra-granular failure.	4
5	Cleavage and micro-ductility, growth of fatigue cracks, The ductile/brittle fracture transition, temperature for notched and unnotched components. Fracture at elevated temperature.	3
6	Fatigue of machine components, mechanism of fatigue failure. Low and high cycle with examples mean stress R ratio, strain and load control. S-N curves.	4
7.	Goodman's rule and Miners rule. Micro-mechanisms of fatigue damage, fatigue limits and initiation and propagation control, leading to a consideration of factors enhancing fatigue resistance.	3

S.No.	Topic	No. of Lectures
8.	Fatigue loads and mathematical models. Fatigue testing and presentation of fatigue data, Influence of stress conditions on fatigue strength/endurance limit of metals.	3
9.	Total life and damage tolerant approaches to life prediction. Fatigue failure models and their considerations in design of machine elements. Cumulative fatigue damage and Designing for finite and infinite life	2
10.	Methods to improve fatigue resistance of machine elements. Improvement of fatigue strength by chemical/metallurgical processes such as nitriding, flame hardening, case carburizing. Fatigue strength enhancement by mechanical work, cold rolling, peening, shot peening.	3
11.	Environmental Assisted Cracking: Stress corrosion cracking, Hydrogen embrittlement, Corrosion fatigue. Creep: Creep curves, Mechanisms of creep, Stress rapture test, Life prediction, High temperature alloys.	3
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Load measurement using Load indicator, Load Cells	1
2.	Strain measurement using Strain Gauge	1
3.	Stress measurement using strain rosette	1
4.	Determination of Fatigue strength measurement of S45C or alike material under same loading condition for different stress concentrations factors (like holes, notches, sharp corners for at least 5 different samples). Comparison to be listed.	5
5.	Study to improvement Fatigue Design based on at least 5 different processes like flame hardening, case carburizing, nitriding, shot peening, peening etc or alike processes.	5
6.	Determination of correlation between fatigue limit and ultimate strength of commercially available S45C material for three different samples	3
	Total	**16**

IX. Suggested Reading

- Lessells, J.M. 1955. *Strength and resistance of metals*. John Wiley & sons, Michigan.
- T.L. Anderson. 2005. *Fracture Mechanics Fundamentals and Applications*. CRC press, Boca Raton.
- Bhandari V.B.2019. *Design of Machine Elements*. Mcgraw Hill Education Pvt Ltd, New Delhi
- Peterson, R.E. 1953 *Stress Concentration Design Factors*. John Wiley & Sons, New York.
- Meguid, S.A.1989 Engineering *Fracture Mechanics*. John Wiley & Sons, New York
- Kare Hellan.1985. *Introduction to Fracture Mechanics*. Mc Graw Hill Book Co, New York.

I. Course Title : Computer Aided Design

II. Course Code : ME 515

III. Credit Hours : 2+1

IV. Aim of the course

The **course** provides an understanding on computer aided design. It provides in depth knowledge about 2-d drawing, 3-D Modeling and finite element analysis for optimum product design.

V. Theory

Unit I

Introduction to computer aided design, scope of computer aided machine design, design process and design environments. Geometric modeling and interactive graphic, engineering analysis, design review and automated drafting, modeling, viewing,

Unit II

3-D solid modeling, boundary representation, constructive solid geometry, feature based modeling. Computer aided analysis and synthesis of common mechanical components, a bar, a beam and a shaft, comparison with analytical results.

Unit III

Application of numerical methods and optimization techniques to machine design problems, Computer aided selection of standard mechanical components. Introduction to FEM. FEA using two dimensional and three dimensional elements; plain strain and plain stress problems, finite element mesh, automatic meshing techniques, limitations of FEM.

Practical Computer aided design problems for machine components, use of standard software, CAD models for other applications. Development of FEM models for analysis of a bar, beam and a shaft. Practice in using an FEM software on other real life problems like spanners, connecting rods.

VI. Learning outcome

The students can design a product having better accuracy, less errors, increased productivity and shorter lead times with the help of CAD.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Introduction to Engineering Design, design steps and computer aided design.	2
2	Software and workstation selection for CAD. Design process with and without CAD	3
3	Input and output devices, Display devices; GKS, IGES and STEP; Modeling and viewing, Application areas of CAD.	3
4	Wireframe model, solid modeling, Boundary Representation (B-rep), Constructive Solid Geometry (CSG).	3
5	Mass, volumetric properties calculations; surface modeling, concepts of hidden-line removal and shading: Mechanical Assembly Kinematics analysis and simulation	3
6	Parametric Modeling Technique. Non-parametric and parametric representation of curves.	2
7	Parametric representation of Hermite Cubic, Beizer and B-spline curves; Surface and its analysis. Representation of Analytical and synthetic surfaces.	2
8	Numerical methods and optimization techniques to engineering design problems	3
9	Overview of FEM, Advantages and applications, recent advance in FEM, FEA software Basic principles and general procedure of FEM	3
10	Analyzing simple machine elements and comparing with analytical results of simple machine elements like bar, beam and a shaft.	4

S.No.	Topic	No. of Lectures
11	Simple Project. Mathematical modelling and design calculations of machines.	4
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Introduction to 2-D drawing. Use of any relevant software	2
2.	Study of drawings in First angle and third angle projections	1
3.	2-D assembly drawing and generation of BOM	1
4.	3-D Modeling. GKS, IGES and STEP; Modeling and viewing. Use of relevant software	3
5.	Assembly Design	2
6.	Introduction to FEA software. Mesh generation (Nodes and elements). Use of any other relevant software for FEA	3
7.	Practice on Boundary conditions like loads and constraints.	2
8.	Study of static and dynamic loading conditions. Study of Machine elements like bars, beams and shafts or other machine elements.	2
	Total	**16**

IX. Suggested Reading

- Mikell P. Groover, Emory W. Zimmers.2000 *CAD/CAM Computer Aided Design and Manufacturing*, PHI,
- Zeid Ibraham.1991. *CAD/CAM - Theory and Practice*, Tata McGraw Hill, New Delhi
- Chandandeep Grewal & Kuldeep Sareen.2007. *CAD/CAM Theory and Concepts*. S.Chand, New Delhi
- P.N Rao.2010. *CAD/CAM*. Tata McGraw Hill, New Delhi

Department of Maths, Statistics and Physics

I. Course Title : Finite Element Methods

II. Course Code : MATH 501

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction. Historical background, Stress equilibrium, boundary condition,stress strain relation, potential energy and equilibrium. Rayleigh-Ritz method. Galerkin method.

Unit II

coordinates and shape functions, potential energy approach,element stiffness matrix,Galerkin approach, assembly of global stiffness matrix. The finite element equation, boundary conditions.

Unit III

Trusses: Two dimensional problems, modeling by constant strain triangle, two dimensional iso-parametric elements, the four-node quadrilateral.

Unit IV

Scalar field problems, steady state heat transfer, torsion, potential flow, seepage and fluid flow index, dynamic analysis, principles.

V. Practical

Use of simple FEM software for FEM software for understanding, principles of FEM. Working out simple problems using LISA or any simple software with understanding of operation. Solving one dimensional problem. Solution to planar and spatial trusses, solving simple two-dimensional problems, Axisymmetric problems, solution of problems with two dimensional iso-parametric elements,solving simple beams and frames, three dimensional problems, solution to heat transfer problems and flow problems.

Learning outcome

Ability to formulate problems based on use of FEM and solve them using software tools.

VI. Lecture Schedule

S.No.	Topic	No.of Lectures
1.	Introduction. Historical background, Stress equilibrium, boundary condition	4
2.	Stress strain relation, potential energy and equilibrium, Rayleigh-Ritz method, Galerkin method.	4
3.	coordinates and shape functions, potential energy approach,element stiffness matrix	3

S.No.	Topic	No.of Lectures
4.	Galerkin approach, assembly of global stiffness matrix, The finite element equation, boundary condition	3
5.	Trusses: Two dimensional problems,	3
6.	modeling by constant strain triangle	3
7.	two dimensional iso-parametric elements, the four-node quadrilateral.	3
8.	Scalar field problems, steady state heat transfer	3
9.	torsion, potential flow,	3
10.	seepage and fluid flow index, dynamic analysis, principles.	3
	Total	**32**

VII. List of Practicals

S.No.	Topic	No.of Practicals
1.	Use of simple FEM software for FEM software for understanding, principles of FEM.	3
2.	Working out simple problems using LISA or any simple software with understanding of operatio	3
3.	Solving one dimensional problem, Solution to planar and spatial trusses	2
4.	Solving simple two-dimensional problems, Axisymmetric problems	2
5.	Solution of problems with two dimensional iso-parametric elements	2
6.	Solving simple beams and frames	2
7.	Three dimensional problems, solution to heat transfer problems and flow problems.	2
	Total	**16**

VIII. Suggested Reading

- Tirupathi R, Patla C and Belegundu AD. 1999. *Introduction to Finite Element in Engineering*. Prentice Hall of India Pvt. Ltd, New Delhi
- Singiresu RaoS. 2001. *The Finite Element Method in Engineering*. Butter worth Heinemann, New Delhi.
- Rajasekaran S 1999. *Finite Element Analysis in Engineering Design*. Wheeler Publishing, Division of A.h.Wheeler and Co. Ltd, Allahabad.
- *Tutorials and Reference Guide*, LISA Finite Element Analysis Software Version 8.0.0 2013

I. Course Title : Numerical Methods for Engineers

II. Course Code : MATH 502

III. Credit Hours : 2+1

IV. Aim of the course

To expose students to various numerical methods for solving algebraic equations, ordinary and partial differential equations.

V. Theory

Unit I

Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection, false position, iteration, Newton Raphson, Secant methods. Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan, LU decomposition methods, ill-conditioned systems.

Unit II

Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method, RK class and predictor corrector class methods. Stiff ODE's and Gear's methods. Boundary Value Problem, Shooting methods, finite difference method. Use of Method of weighted residuals and orthogonal collocation and Galerkin technique to solve BVP in ODEs

Unit III

Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method, all eigenvalues by Fadeev-Leverrier method. Introduction to diagonalization and QR Factorization.Approximation Theory.

Unit IV

Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms, linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.

Unit V

Solution of Partial Differential Equations: Classification of PDEs(Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five pointsformula, diagonal five-point formula. Solution of Laplace equation by Liebman's iteration method.Poisson's equation and its applications.Solution of parabolic equations by Bender–Schmidt method, Bender-Schmidt recurrence equation, Crank-Nicholson difference method.

VI. Practical

Use of EXCEL Sheet and MATLAB: Application of EXCEL Sheet and MATLAB to solve the Engineering problems

VII. Learning outcome

Ability to solve algebraic equations, ordinary and partial differential equations coming across in Agricultural Engineering problems using various numerical methods, ability to use latest software's towards numerical problems.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection method.	2
2.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using false position methods.	1
3.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration.	1
4.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods.	1
5.	Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan method.	2

S.No.	Topic	No. of Lectures
6.	Solution of linear simultaneous equations: LU decomposition methods, ill-conditioned systems.	2
7.	Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method	2
8.	Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear's methods.	1
9.	Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method.	2
10.	Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method	2
11.	Introduction to diagonalization and QR Factorization. Approximation Theory.	2
12.	Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms.	2
13.	Finite difference formulae: linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.	2
14.	Solution of Partial Differential Equations: Classification of PDEs (Parabolic, elliptical and hyperbolic equation)	2
15.	Elliptical equations, standard five pointsformula, diagonal five-point formula.	2
16.	Solution of Laplace equation by Liebman's iteration method. Poisson's equation and its applications.	2
17.	Solution of parabolic equations by Bender–Schmidt method	2
18.	Solution of parabolic equations by Bender-Schmidt recurrence equation, Crank-Nicholson difference method.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection method.	1
2.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using false position methods.	1
3.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration.	1
4.	Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods.	1
5.	Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan method.	1
6.	Solution of linear simultaneous equations: LU decomposition methods, ill-conditioned systems.	1
7.	Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method	1
8.	Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear's methods.	1

S.No.	Topic	No. of Lectures
9.	Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method.	1
10.	Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method	1
11.	Introduction to diagonalization and QR Factorization. Approximation Theory.	1
12.	Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms.	1
13.	Finite difference formulae: linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.	1
14.	Solution of Partial Differential Equations: Classification of PDEs (Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five points formula, diagonal five-point formula.	1
15.	Solution of Laplace equation by Liebman's iteration method. Poisson's equation and its applications.	1
16.	Solution of parabolic equations by Bender–Schmidt method, Bender-Schmidt recurrence equation, Crank-Nicholson difference method.	1
	Total	**16**

X. Suggested Reading

- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers*. John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

I. Course Title : Numerical Analysis

II. Course Code : Math 506

III. Credit Hours : 2+1

IV. Aim of the course

To provide understanding and application of basic numerical techniques for evaluation and approximation of roots of polynomials, solution of differential equations, numerical differentiation and integration.

V. Theory

Unit I

Computational errors, absolute and relative errors, difference operators, divided differences, interpolating polynomials using finite differences, Hermite interpolation, piecewise and spline interpolation, bivariate interpolation.

Unit II

Numerical solution of algebraic and transcendental equations by bisection, secant and Newton-Raphson's Methods, solution of polynomial equations by Birge-Vieta's, Bairstow's and Graffe's root squaring methods.

Unit III

Numerical differentiation based on interpolation, finite differences and undetermined coefficients. Numerical integration using methods based on interpolation and undetermined coefficients.

Unit IV

Numerical solution of ordinary differential equations of first order and first degree by Runge -Kutta method and predictor-corrector methods. Solution of linear system of equations, Gaussian elimination method, pivoting and scaling, factorization method, iterative techniques, inverse of a matrix, computation of eigen values and eigen vectors.

VI. Practical

Tutorials on: divided differences, Hermite and spline interpolation, bivariate interpolation, roots of algebraic and transcendental equations by Newton-Raphson's method, bisection method, Birge-Vieta's method, Bairstow's and Graffe's root squaring methods for polynomial equations, numerical evaluation of derivatives and integral, Runge-Kutta and predictor- corrector methods, Gaussian elimination method, factorization method, iterative techniques, inverse of a matrix, eigen values and eigen vectors.

VII. Learning outcome

To understand basic numerical methods and apply them to solve higher engineering problems.

VIII. Lecture Schedule

S.No.	Topic	No. of lectures
1.	Computational errors, absolute and relative errors	1
2.	Difference operators,	2
3.	Divided differences	2
4.	Interpolating polynomials using finite differences	2
5.	Hermite interpolation	2
6.	Piecewise interpolation	2
7.	Spline interpolation	2
8.	Bivariate interpolation.	1
9.	Bisection Method, secant method	2
10.	Newton-Raphson's method,Birge-Vieta's, method	2
11.	Bairstow's and Graffe's root squaring methods.	2
12.	Numerical differentiation based on interpolation, finite differences and undetermined coefficients.	2
13.	Numerical integration using methods based on interpolation and undetermined coefficients	2
14.	Numerical solution of ordinary differential equations of first order and first degree by Runge -Kutta method	2
15.	Predictor-corrector method	1
16.	Gaussian elimination method, pivoting and scaling	1
17.	Factorization method, iterative techniques	2

S.No.	Topic	No. of Practicals
18.	Inverse of a matrix, computation of eigen values and eigen vectors	2
	Total	**32**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	Divided differences	1
2.	Hermite Interpolation	1
3.	Spline interpolation	1
4.	Bivariate interpolation	1
5.	Bisection method	1
6.	Bivariate interpolation	1
7.	Secant Method	1
8.	Newton-Raphson's method	1
9.	Birge-Vieta's method	1
10.	Bairstow's Method	1
11.	Graffe's root squaring methods	1
12.	Numerical evaluation of derivatives and integral	1
13.	Runge-Kutta method	1
14.	Predictor- corrector methods	1
15.	Gaussian elimination method, factorization method,	1
16.	Iterative techniques, inverse of a matrix, eigen values and eigen vectors	1
	Total	**16**

X. Suggested Reading

- Gerald CF and Wheatley PO. 2003. *Applied Numerical Analysis,* Pearson, 7th Edition,
- Jain MK, Iyengar SRK and Jain RK. 2012. *Numerical Methods for Scientific and Engineering Computation*, New Age International Publishers, 6th edition.
- Chappra SC. 2014. *Numerical Methods for Engineers*, McGraw-Hill Higher Education; 7th edition.
- Mathew JH, *Numerical Methods for Mathematics*, Science and Engineering, Prentice Hall, (1992) 2nd edition,
- Burden RL and Faires JD. 2004. *Numerical Analysis*, Brooks Cole, 8th edition.
- Atkinson K and Han W. 2004. *Elementary Numerical Analysis*, John Willey & Sons, 3rd Edition.

I. Course Title : Numerical Methods for Ordinary and Partial Differential Equations

II. Course Code : Math 507

III. Credit Hours : 2+1

IV. Aim of the course

To provide understanding and application of basic numerical techniques for evaluation and approximation of ordinary and partial differential equations.

V. Theory

Unit I

Interpolation, Approximation, least square and uniform approximation.

Unit II

Numerical differentiation and integration, Numerical solution of ordinary differential equations by single step and multi-step methods

Unit III

Various difference schemes for solutions of partial differential equations of parabolic, elliptic and hyperbolic types

Unit IV

Solution of differential equations by finite element methods

VI. Practical

Tutorials on: evaluation of derivatives and integrals by numerical methods, single step and multistep methods for solution of ordinary differential equations, solution of parabolic, hyperbolic and elliptic equations by finite difference methods. Finite element methods

VII. Learning outcome

To understand basic numerical techniques and apply them to solve ordinary and partial differential equations.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Interpolation	3
2.	Approximation	3
3.	Least square approximation	2
4.	Uniform approximation	2
5.	Numerical differentiation	3
6.	Numerical integration	3
7.	Numerical solution of ordinary differential equations by single step method	3
8.	Numerical solution of ordinary differential equations by multi-step method	3
9.	Various difference schemes for solutions of partial differential equations of parabolic type	2
10.	Various difference schemes for solutions of partial differential equations of elliptic type	2
11.	Various difference schemes for solutions of partial differential equations of hyperbolic type	2
12.	Solution of differential equations by finite element methods	4
	Total	**32**

IX. List of Practical

S.No.	Topic	No. of Practicals
1.	Evaluation of derivatives by numerical methods	2
2.	Evaluation of integrals by numerical methods	2
3.	Single step method for solution of ordinary differential equation	2
4.	Multistep method for solution of ordinary differential equation	2
5.	Solution of parabolic equations by finite difference method	2
6.	Solution of hyperbolic equations by finite difference methods	2
7.	Solution of elliptic equations by finite difference methods	2
8.	Finite Element methods	2
	Total	**16**

X. Suggested Reading

- Gerald CF and Wheatley PO. 2003. *Applied Numerical Analysis*, Pearson, 7th Edition.
- Jain MK, Iyengar SRK and Jain RK. 2012. *Numerical Methods for Scientific and Engineering Computation*, New Age International Publishers, 6th edition.
- Chappra SC. 2014. *Numerical Methods for Engineers*, McGraw-Hill Higher Education; 7th edition.
- Mathew JH. 1992. *Numerical Methods for Mathematics*, Science and Engineering, Prentice Hall, 2nd edition,
- Burden RL and Faires JD. 2004. *Numerical Analysis*, Brooks Cole, 8th edition.
- Atkinson K and Han W. 2004. *Elementary Numerical Analysis*, John Willey & Sons, 3rd Edition.

I. Course Title : Statistical Methods for Research Workers

II. Course Code : STAT 501

III. Credit Hours : 2+1

IV. Aim of the course

To expose students to various statistical techniques for analysis of data and interpretation of results.

V. Theory

Unit I

Probability and probability distributions. Principle of least squares. Linear and non-linear regression. Multiple regression. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of mean and proportion.

Unit II

Hypothesis testing. Concept of p-value. Student's t-test. Large sample tests. Confidence intervals. ANOVA and testing of hypothesis in regression analysis. Analysis of variance for one way and two way classification (with equal cell frequency).Transformation ofdata.

Unit III

Advantages and disadvantages of nonparametric statistical tests. Scales of measurements. Run-test. Sign test. Median test. Wilcoxon-Mann Whitney test. Chi-square test. Kruskal-Walli's one way and Friedman's two way ANOVA by ranks. Kendall's Coefficient of concordance.

VI. Practical

Fitting of distributions. Sample and sampling distributions. Correlation analysis. Regression analysis (Multivariate, quadratic, exponential, power function, selection of variables, validation of models, ANOVA and testing of hypothesis). Tests of significance (Z-test, t-test, F-test and Chi-square test). Analysis of variance. Non-parametric tests.

VII. Learning outcome

The students will be able to understand different techniques for analyzing the data of their research work.

VIII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Elementary statistics	
2.	Probability theory	2
3.	Probability distributions (Binomial, Poisson and Normal)	3
4.	Sampling techniques, Determination of sample size	2
5.	Sampling distribution of mean and Proportion	1
6.	Hypothesis testing concept of p-value	1
7.	Large sample (mean, proportion)	1
8.	Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test	3
9.	Analysis of variance (one way and two way), Transformation of data	2
10.	Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation)	2
11.	Multiple linear regression and model validation	2
12.	Testing of coefficient of determination and regression coefficient	2
13.	Selection of variables in regression (forward substitution method and step-wise regression)	1
14.	Non-Linear regression (Quadratic, exponential and Power)	2
15.	Introduction to Non-parametric and scales of measurements	1
16.	Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances)	2
17.	One Sample test (Sign test, Median test, Run rest,)	2
18.	Two sample test (Wilcoxon Sign test, Mann Whitney test, Chi square test for two independent samples)	1
19.	K-Sample (Kruskal-Walli's test and Friedman's two way ANOVA)	2
20.	Kendall's coefficient of concordance	1
	Total	**33**

IX. List of Practicals

S.No.	Topics	No. of Practicals
1.	Elementary statistics	1
2.	Probability distributions (Binomial, Poisson and Normal)	1
3.	Sampling techniques, Determination of sample size, Sampling distribution of mean and Proportion	1
4.	Large sample (mean, proportion)	1
5.	Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test	1
6.	Analysis of variance (one way and two way), Transformation of data	2
7.	Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation)	1
8.	Multiple linear regression and model validation	1
9.	Testing of coefficient of determination and regression coefficient	
10.	Selection of variables in regression (Forward substitution method and step-wise regression)	1
11.	Non-Linear regression (Quadratic, exponential and Power)	2
12.	Introduction to Non-parametric and scales of measurements	
13.	Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances)	2
14.	One Sample test:Sign test, Median test, Run rest, Two sample test: Wilcoxon Sign test, Mann Whitney test, X^2 test for two independent samples	1

S.No.	Topic	No. of Practicals
15.	K-Sample: Kruskal-Walli's test and Friedman's two way ANOVA, Kendall's coefficient of concordance	1
	Total	**16**

X. Suggested Reading

- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers*. John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

I. Course Title : Experimental Designs

II. Course Code : Stat 502

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with the basic principles of theory of designs and analysis of experiments.

V. Theory

Unit I

Basic principles of experimental designs. Uniformity trials. Completely randomized design, randomized block design and latin square designs. Multiple comparison tests.

Unit II

Missing plot techniques. Analysis of covariance. Factorial experiments:2^2, $2^3$and 3^2. Split plot design. Strip plot design. Factorial in split plot design.

Unit III

Crossover designs. Balanced incomplete block design. Response surface designs. Groups of experiments.

VI. Practical

Uniformity trials. Completely randomized design. Randomized block and latin square designs. Missing plot and analysis of covariance Split plot designs. Factorial in split plot design. Strip plot designs. Cross over and balanced incomplete block designs. Groups of experiments.

VII. Learning outcome

The students will be able to plan and design the experiments for their research.

They will also be exposed to statistical software for the analyzing the data pertaining to designs of this course.

VIII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Basic principles of experimental designs,	1
2.	Completely randomized design	1
3.	Randomized block design	1
4.	Latin square design	1
5.	Multiple comparison tests	1
6.	Missing plot techniques	1
7.	Analysis of covariance	1
8.	Factorial experiments	2
9.	Split plot design	1
10.	Strip plot design	1
11.	Factorial in split plot design	1
12.	Crossover designs	1
13.	Balanced incomplete block design	1
14.	Response surface designs	1
15.	Groups of experiments	1
	Total	**16**

IX. List of Practicals

S.No.	Topics	No. of Practical
1	Completely randomized design	1
2	Randomized block design	1
3	Latin square design	1
4	Multiple comparison tests	1
5	Missing plot techniques	1
6	Analysis of covariance	1
7	Factorial experiments	3
8	Split plot design	1
9	Strip plot design	1
10	Factorial in split plot design	1
11	Crossover designs	1
12	Balanced incomplete block design	1
13	Response surface designs	1
14	Groups of experiments	1
	Total	**16**

X. Suggested Reading

- Cochran WG and Cox GM 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean AM and Voss D 1999. *Design and Analysis of Experiments*. Springer.
- Design Resources Server: www.iasri.res.in/design.
- *Examination of Theory and Practice*. John Wiley.
- Federer WT 1985. *Experimental Designs*. MacMillan.
- Fisher RA 1953. *Design and Analysis of Experiments*. Oliver & Boyd.
- Montogomery 2013. *Design and analysis of experiments*. John Wiley & Sons.
- Nigam AK and Gupta V K 1979. *Handbook on Analysis of Agricultural Experiments*. IASRI Publ.
- Pearce SC 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice*. John Wiley & Sons

ANNEXURE I

List of BSMA Committee Members for Agricultural Engineering

Name and designation	Address	Specialization
1. **Dr J K Singh** Dean (Retd),	G.B. Pant University of Agriculture and Technology, Pantnagar	Chairman
2. **Dr Jaskarn Singh Mahal** Director of Extension Education Former Dean	College of Agricultural Engg. and Technology),	Convener
3. **Dr T B S Rajput** Emeritus Scientist	Indian Agricultural Research Institute, New Delhi	Member
4. **Dr A K Mehta** Professor & Head	College of Technology and Engineering, MPUAT, Udaipur	Member
5. **Dr S K Jha** Principal Scientist	Division of Post-Harvest Technology, New Delhi	Member
6. **Dr D Manohar Jesudas** Professor & Head	Department of Agricultural Machinery & Research Centre, TNAU, Coimbatore	Member
7. **Dr P K Singh** Professor	Department of Soil and Water Engineering, MPUAT, Udaipur	Member
8. **Dr Atul Mohod** Head, Department of Agricultural Engineering	Dr B.S. Konkan Krishi Vidyapeeth, Dapoli	Member

ANNEXURE II

Consultantion Process

Details of BSMA Committee Meeting Held

S. No.	Date	Organizing Institute
1.	Oct 22, 2018	PAU Ludhiana
2.	Feb 4-5, 2019	PAU Ludhiana
3.	March 25-26, 2019	TNAU, Coimbatore
4.	June 3-4, 2019	AAU, Anand Gujarat

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 4

Food Technology

- Processing Technology
- Process Engineering
- Safety and Quality

Contents

Acknowledgements
(Food Technology)

The teaching and processing of food on commercial scale is of much recent origin and the number of teaching institutions and of research are countable on fingers. Like, dairy processing, food processing technology also started on the same pattern about two decades back. Indian Council of Agricultural Research recommended a 4 year undergraduate programme through its Dean's committee in year 2016 for different agriculture and allied fields. On completion of the exercise of Deans committee the next step of improving and developing Masters and Doctoral program by constituting Broad Subject Matter Area (BSMA) Committees for revision and uniformity in curricula and regulations. The narration in this manuscript is the outcome of BSMA on Food Technology meetings held at various locations and feedback from various institutions and invited specialists from other institutions and the industry.

During the course of this exercise, two meeting and two workshops were held at different institutions of the country with a view to obtain the status as well as the experiences of the faculty across the institutions and then deliberate on them with all enabling the committee to synthesize and make suitable recommendations to be used while framing the course titles and contents and decide the teaching weightage in terms of credits. Subsequently, the formation of course contents were assigned to a specialist group from amongst the committee members. These groups took the assignments to their respective places for completion. Such assignments were first presented in the next meeting/workshop for discussion and further moderations in view of some additional inputs received from other scientists. In this way the whole exercise took place for master's as well as Doctoral courses. Though, the work was vast but with due diligence and vigil by all of us, the matter reached to the desired stage of satisfactory completion. For all to happen, a word of gratefulness and gratitude to all need complements individually as well as combinedly.

First of all the Committee is beholden to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR, for reposing faith in the Committee and giving opportunity and guidance to examine, revise, and update the post graduate and doctoral curricula to build quality human resources and to fortify academic standards in our vitally important agriculture sector. The Committee is deeply indebted to Dr N.S. Rathore, and to his predecessor Dr R.C. Agrawal, Deputy Director General (Edn.), ICAR, New Delhi for their indulgence and guidance. Sincere gratitude to Dr G. Venkateshwarlu, Assistant Director General (EQR) for his humble and precise approach to support in numerous ways, along with Dr K.L. Khurana, Retired Principal Scientist, Education Division, Indian Council of Agricultural Research New Delhi to work as a bridge between the BSMA and ICAR.

Due recognition and gratefulness is to Dr Arvind Kumar Hon'ble Vice Chancellor, Rani Laxmibai Central Agricultural University, Jhansi who provided initial guideline as a Chairman of the core group and continued directives during the process of developing the syllabus.

The Committee would like to place on record its gratitude to all the Vice-Chancellors/ Director of Institutes, Deans and other stakeholders for their tremendous support in completing this challenging task.

Committee express deep sense of gratitude towards Dr S.Patil, Hon'ble Vice Chancellor, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Dr N.C.Patel, Hon'ble Vice Chancellor, Anand Agricultural University, Anand; Dr, Partha Pratim Chakraborty, Director, Indian Institute of Technology, Kharagpur and Dr Chindi Vasudeva, Hon'ble Vice Chancellor of National Institute of Food Technology and Entrepreneurship Management, Kundali, Sonipat for kind permission to conduct meeting/workshop in their institute primarily and later providing institutional support to the members and hospitality. Valuable introductory remarks and permission for participation to the faculty of their faculty is also greatly acknowledged.

The committee express its indebtedness to Dr D C Joshi former Dean, College of Food Processing Technology and Bio Energy (CFPTBE), Anand Agricultural University, Anand, Dr R F Suthar, Dean, CFPTBE, Dr J.B. Prajapti, Dean, SMC Dairy Science College, Dr A.R. Sawate Assoc. Dean and Principal of College of Food Technology Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Dr Raj Bala Grewal Director, Centre of Food Science and Technology, Choudhary Charan Singh Hissar Agricultural Uuniversity, Hisaar, Dr Poonam Aggarwal Sachdev, Professor, Department of Food Science & Technology, Panjab Agricultural University, Ludhiyana and Dr H. Pandey, Prof & Head Food Process Technology, CFPTBE, AAU, Anand.

Very special thanks to Dr A.K.Sharma, Professor and Head Food Process Engineering, AAU, Anand and Dr Narayan Singh Thakur, Professor (PHT), Department of Food Science and Technology, College of Horticulture, Dr YS Parmar University of Horticulture & Forestry, Solan for their whole hearted support and efforts in preparing the syllabus.

Thanks, are also expressed to the participants of industry at different locations and sharing the training and skill needs of human resource for the future food processing industry.

Our heart core feelings to all the staff of Education Division ICAR and staff of different institutes who supported in organization of meetings/workshop and development of course for their support like a fraternity.

Prof. V. B. Singh
Chairman BSMA-FST
Former Vice Chancellor
Maharan Pratap University of Agriculture and Technology, Udaipur
Prof. Sudhir Uprit
Convener BSMA- FST
Dean College of Dairy Science and Food Technology,
Chhattisgarh Kamdhenu Vishwavidyalaya, Raipur
Discipline: Processing Technology

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Vol. 4

Food Technology
– Processing Technology

Preamble

The efficient use of resources is the growing concern for all involved in food production, processing, distribution and retailing. The unique features of the raw materials of the food processing industries such as seasonality, perishability and variability in conjunction with sophistication required for processing to maintain high quality standards, necessitates special attention towards focused availability of qualified technical manpower, effective technologies and efficient machinery. The food industries in the country need modernization to face the challenges of the globalization. Government of India is also paying special attention to this important sector and associated stakeholders. Efficient utilization of resources will definitely help in manufacturing of nutritious and healthy food but also help in fostering economic development and therefore, improving livelihoods by promoting access to domestic, regional and international markets.

Over the years significant growth in processing technology have resulted in development of various value-added processed food products of very high quality and improvement in existing manufacturing processes. This motivated the BSMA committee for Food Science and Technology to enrich the content and syllabus of the MTech and PhD programmes in the area of Food Processing Technology. This will hopefully produce competent food technologists to handle resources from farm-to-factory-to-consumers and cater the various sectors of food processing industries.

The content and course are developed by keeping in mind the development and advancement in food technology globally. New techniques and advancement in food processing technology and new packaging techniques are introduced. Moreover, a new course is introduced named as Industrial Manufacturing of food and beverage which gives exposure to understand raw material quality, processing and production of food and beverage on industrial scale. Many new courses are introduced, viz. Frozen and Concentrated Foods, Aseptic Processing and Packaging, Traditional Foods, Technologies of Convenience Foods, Food Powders and Premixes, Food Business Management. A new subject Global Food Laws and Regulations is introduced which helps the food industry to export the food product to the world as per their specifications and regulations. New courses like Novel Technologies for Food Processing and Shelf Life Extension, Food Manufacturing Technology, Formulation of Standards of Food Products, Packaging and Labeling are introduced in PhD programme through which the students will develop and formulate new product, new technology and helps in developing the regulations of different food products.

The proposed curricula and quality measures should render Food Technology as an intellectually more stimulating discipline and an economically rewarding profession to attract talent and investment.

Course Title with Credit Load
M.Tech. in Processing Technology

Major Courses

Course Code	Course Title	Credit Hours
FPT 501	Emerging Technologies in Food Processing*	2+1
FPT 502	Emerging Technologies in Food Packaging*	2+1
FPT 503	Industrial Manufacturing of Food and Beverages*	2+1
FPT 504	Food Material and Product Properties	2+1
FPT 505	Cocoa and Chocolate Processing Technologies	2+1
FPT 506	Spices, Herbs and Condiments	2+0
FPT 507	Meat, Poultry, Fish and Egg Processing	2+1
FPT 508	Nutraceuticals and Specialty Foods	2+1
FPT 509	Frozen and Concentrated Foods	1+1
FPT 510	Aseptic Processing and Packaging	2+1
FPT 511	Traditional Foods	2+1
FPT 512	Technologies of Convenience Foods	2+1
FPT 513	Food Powders and Premixes	2+1
FPT 514	Food Ingredients and Additives	2+1
FPT 515	Flavour Chemistry and Technology	2+1
FPT 516	Bioprocessing and Separation Technology	2+1
FPT 517	Enzymes in Food Processing	2+1
FPT 518	Food Process Automation and Modelling	2+0
FPT 519	Zero Waste Processing	2+0
FPT 520	Special Problem/ Summer Internship	0+2

*Compulsory Rest of the courses will be decided by the students advisory committee keeping the minimum limits set for award of degree.

Minor Courses

Course Code	Course Title	Credit Hours
FPE 502	Engineering Properties of Food Materials	3(2+1)
FPE 504	Bioprocessing and Down Stream Engineering	3(2+1)
FPE 506	Numerical Technique and Stimulation	2(1+1)
FPE 508	Food Safety and Storage Engineering	3(2+1)
FSQ 503	Advanced Food Chemistry	3(2+1)
FSQ 504	Global Food Laws and Regulations	2(2+0)
FSQ 506	Process and Products Monitoring for Quality Assurance	2(2+0)
FSQ 508	Management of Food By-products and Waste	3(2+1)

Supporting Courses

Course Code	Course Title	Credit Hours
BSH 501	Research Methodology	2+0
BSH 502	Food Informatics	1+1
FBM 501	Post-Harvest Management	2+1
FBM 502	Food Business Management	2+0
FBM 503	Food Processing Entrepreneurship and Start up	0+1
FPE 505	Energy Management and Auditing in Food Industry	2+1
FSQ 521	Food Safety Management Systems and Certification	2+1
FSQ 523	Quality Concepts and Chain Traceability	2+0
FPE 510	Operation Research	2+1

Common Courses

S. No.	Course Title	Credit Hours
1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1
5.	Agricultural Research, Research Ethics and Rural Development Programmes	1

These courses are available in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

Seminar

Course Code	Course Title	Credit Hours
1	Seminar	1+0

Course Contents
M.Tech. in Processing Technology

I. **Course Title** : **Emerging Technologies in Food Processing**
II. **Course Code** : **FPT 501**
III. **Credit Hours** : **2+1**

IV. **Theory**

Unit I

Membrane Technology: Pressure activated membrane processes: MF, UF, NF and RO and their industrial application. Membrane distillation. Supercritical fluid extraction: Concept, property of super critical fluids SCF, extraction methods, application in food processing.

Unit II

Microwave and radio frequency processing: Advantages, mechanism of heat generation, application in food processing: microwave blanching, sterilization and finish drying. Hurdle technology: Concept and Principle, Preservation techniques as hurdles and their principles, hurdle tech foods.

Unit III

High Pressure processing: Concept, equipment for HPP treatment, mechanism of microbial and enzyme inactivation and its application in food processing, effect on food constituents.
Ultrasonic processing: Properties of ultrasonic, types of equipment, application of ultrasonic as processing technique.

Unit IV

Newer techniques in food processing: principle and application of High intensity light, pulse electric field, ohmic heating, IR heating, inductive heating, cold plasma, and pulsed X-rays in food processing and preservation, Cryo-processing of foods Nanotechnology: Principles and applications in foods.

V. **Practical**

- To evaluate the characteristics of treated water using RO system
- To study production and characteristics of treated water using, microfiltration, UF, NF and RO system
- To study the effect of ultrafiltration process on fruit juices quality
- To study suitability and production of fruit juices using ultrafiltration
- To study the effect of microfiltration process on milk quality
- To study super critical fluid extraction system and to carry out extraction of bioactive compound from selected samples
- To carry out extraction of lycopene from tomato using SCFE system
- To study microwave system and to evaluate the effect of different power on drying characteristics of selected vegetable products

- To study microwave blanching of vegetable and determination of blanching efficacy
- To study the ultrasonicator and evaluate the effect of ultrasonication on micro-organism in sample
- To study the ultrasonicator and to evaluate the effect of ultrasonication on extracted juice yield from fruit pomace
- To evaluate the different pre-treatment on oil yield from oil seed cake
- To prepare nano emulsion and study of their characteristics
- To study ohmic heating system and to study the processing of fruit pup using ohmic heating system
- To visit food industries utilizing advance food processing techniques
- To study the effect of different drying techniques/ hybrid drying techniques on fruits and vegetables.

VI. Suggested Reading

- Gould GW, 2000. *New Methods of Food Preservation*, CRC Press.
- Barbosa-Canovas, 2002. *Novel Food Processing Technologies*, CRC Press.
- Dutta AK &Anantheswaran RC. 1999. *Hand Book of Microwave Technology for Food Applications*, CRC Press.
- Sun DW, 2015. *Emerging Technologies for Food Processing*, Elsevier Ltd.
- Kudra T and Mujumbar AS, 2009. *Advanced Drying Technologies*, CRC Press.
- Nema PK, Kaur BP and Mujumdar AS, 2018. *Drying Technologies for Foods: Fundamentals and Applications*, CRC Press

I. Course Title : Emerging Technologies in Food Packaging

II. Course Code : FPT 502

III. Credit Hours : 2+1

IV. Theory

Unit I

Active and intelligent packaging: Active Packaging Techniques and intelligent Packaging Techniques, current use of novel Packaging Techniques, consumers and novel Packaging Oxygen, ethylene and other scavengers: Oxygen scavenging technology, selecting right types of oxygen scavenger, ethylene scavenging technology, carbon dioxide and other scavengers.

Antimicrobial food packaging: Antimicrobial agents, constructing antimicrobial packaging systems, factors affecting the effectiveness of antimicrobial packaging.

Unit II

Non-migratory bioactive polymers (NMBP): Advantages of NMBP, Inherently bioactive synthetic polymers: types and application, Polymers with immobilized bioactive compounds and their applications.

Time Temperature labels and indicators (TTIs): Defining and classifying TTIs, Requirements for TTIs, development of TTIs, Maximizing the effectiveness of TTIs, Application of TTIs- to monitor shelf-life, and optimization of distribution and stock rotation, leakage indicators, oxygen indicators, micro indicators etc.

Freshness indicator in packaging: Compounds indicating the quality of packaged food products, freshness indicators, pathogen indicators, other methods for spoilage detection.

Self-heating/rehydrating packages.

Unit III

Packaging-flavour interaction: Factors affecting flavor absorption, role of food matrix, role of differing packaging materials, flavour modification and sensory quality, Study of packaging materials compatibility with foods.

Developments in modified atmosphere packaging (MAP): Permeability properties of polymer packaging, measurement of permeability – water and gases. Selection criteria of packaging films, Novel MAP gas, testing novel MAP applications, applying high oxygen MAP.

Recycling packaging materials: Recyclability of packaging plastics, improving the recyclability of plastics packaging, testing safety and quality of recycled materials, uses of recycled plastics in packaging.

Unit IV

Green plastics for food packaging: Problems of plastic packaging wastes, range of biopolymers, developing novel biodegradable materials.

Edible Films and Coatings: Properties, types, sources, applications, advantages, disadvantages, theories of plasticization, challenges and opportunities.

PFS machine, seal and closures.

Safety and legislative aspects of packaging: Regulatory considerations, plastic, metal, paper and glass packaging.

V. Practical

- Determination of WVTR in different packaging materials
- Determination of GTR in different packaging materials.
- Study of different ethylene scavengers and their analysis
- Study of different oxygen scavengers systems and their analysis
- Application of anti-microbial packaging for moisture sensitive foods
- Evaluation of chemical residue migration from package to food
- Application of MAP packaging in selected foods
- Study of TTI label, leakage indictors etc.
- Determination of oxidative changes in packaged foods
- Comparative evaluation of flexible and rigid packages for fragile foods
- Packaging of foods under inert atmosphere.
- To study textural characteristics of selected fruit/ vegetable under MAP storage
- Shelf life evaluation and mode up of packaged food product.
- Determination of oil and grease resistant test for packaging films
- Determination of respiration rate in fresh fruits and vegetables
- Determination of shelf life of fresh fruits and vegetables by using edible coating and films.
- Effect of edible coating and films on respiration behaviour, chemical, physical and sensory characteristics of fresh fruits and vegetables.
- Visit to food packaging material manufacturing industry

VI. Suggested Reading

- Ahvenainen R, 2001. *Novel Food Packaging Techniques*, CRC Press.
- Robertson GL, 2012. *Food Packaging*, CRC Press.
- Hanlon, JF, Kelsey RJ and Forcinio H. 1998. *Handbook of Package Engineering*, CRC Press.
- Painy FA, 1992. *A Handbook of Food Packaging*, Blackie.
- Rooney ML, 1988. *Active Food Packaging*, Chapman & Hall.
- Coles R and Kirwan M, 2011. *Food and Beverage Packaging Technology*, Wiley-Blackwell.
- Han J and Han J, 2005. *Innovations in Food Packaging*, Academic Press.

• Yam K and Lee D, 2012. *Emerging Food Packaging Technologies*, Woodhead Publishing.

I. Course Title : Industrial Manufacturing of Food and Beverages
II. Course Code : FPT 503
III. Credit Hours : 2+1

IV. Theory

Unit I

Grain products: Industrial manufacturing of grain based products: formulation, processes, machinery and material balance of baked, rolled, shredded, puffed, flaked, roasted products.
Extrusion technology: Importance and applications of extrusion in food processing; Pre and post extrusion treatments; Manufacturing process of extruded products; Change of functional properties of food components during extrusion. Breakfast cereals, RTE/RTC foods, instant premixes, functional foods.

Unit II

Fruit and vegetable products: Industrial manufacturing of fruit and vegetable based products: formulation, processes, machinery and material balance of minimally processed, Retorted products, IMF, high moisture stable foods, IQF; Machines and equipment for batch and continuous processing of fruit and vegetable products.

Unit III

Chocolates and candies: Coating or enrobing of chocolate (including pan-coating); Maintenance, safety and hygiene of bakery plants.
Fats and oils processing: Technology of refined oil, winterized oil, hydrogenated fat, texturized fat, by-products of fat/oil processing industries – oil seed protein isolates; Quality standards of fats and fatty foods; Antioxidants and its mechanism of application.

Unit IV

Beverages: Production technology of beer and wine
Non-alcoholic beverages: Carbonated beverages: carbonation equipment, -ingredients-preparation of syrups-Filling system-packaging-containers and closures. Non-carbonated beverage: Coffee bean preparation-processing-brewing-decaffeination- instant coffee, Tea types-black, green, Fruit juices and beverages,. Flash pasteurization, Aseptic Packaging of beverages Tea/coffee and cocoa beverages, Grain based and malted beverages.
Packaged drinking water: types, manufacturing processes, quality evaluation and raw and processed water, methods of water treatment, BIS quality standards of bottled water; mineral water, natural spring water, flavoured water, carbonated water.

V. Practical

- Preparation of cereals based fried snack foods
- Preparation of cereal, pulses based ready-to-eat snack food by extrusion cooking their quality evaluation
- Preparation of cereal grain based puffed products
- Development of instant food premixes
- Preparation of cereal and legume based roasted snack
- Preparation of flaked rice product

- To study the effect of roasting time and temperature on quality of pop-corn
- Determination of shelf-life and packaging requirements of snack food products
- Preparation of fruits/vegetable based ready to serve beverages and quality evaluation
- Heat classification of milk powders.
- Determination of degree of browning-chemical/physical methods.
- Determination of quality of packaged drinking water.
- Preparation of wine and beer
- Preparation of soy milk.
- Determination of quality of canned food.

VI. Suggested Reading

- Edmund WL, 2001. *Snack Foods Processing*, CRC Press.
- Gordon BR. 1990. *Snack Food*, Springer US.
- Frame ND, 1994. *Technology of Extrusion Cooking*, Springer US
- O'Brien RD, 2008. *Fats and Oils: Formulating and Processing for Application*, CRC Press.
- Davis B, Lockwood A, Alcott P and Pantelidis L, 2012. *Food and Beverage Management*, CRC Press.
- Kunze W, 2010. *Technology: Brewing and Malting*, VLB.
- Dhillon PS and Verma S, 2012. *Food and Beverage: Production Management for Hospitality Industry*, Abhijeet Publications.
- Bamforth CW, 2006. *Brewing: New Technologies*, Woodhead Pub.

I. Course Title : Food Material and Product Properties

II. Course Code : FPT 504

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Biomaterials and their properties in relation to processing and product development.

Physico-chemical characteristics: Shape, sphericity, size, volume, microstructure, density, porosity, surface area, coefficients of friction and angle of repose and influence of constituents on processing.

Unit II

Mechanical and rheological properties: Flow behaviour of granular and powdered food materials, rheological models, creep phenomenon, stress – strain - time effects and relationships, and techniques of model fitting, Elastic vs. textural characteristics and textural profile analysis of food products.

Unit III

Thermal, electrical and optical properties: Specific heat, thermal conductivity, phase transition, thermodynamics-basic principles and laws, Thermodynamic properties of moist air, kinetics of water absorption, heat capacity, thermal diffusivity, electrical resistance and conductance, dielectric constant, reflectivity, transmittivity and absorptivity of incident rays.

Food microstructure: Methods and systems for food microstructure, determination of light microscopy, transmission electron microscopy, scanning electron microscopy, other instrumentation and techniques, image analysis: image acquisition, image processing, measurement analysis.

Unit IV

Functional properties: Dextrinization, Gelatinisation, Crystallisation, gelation, foaming, coagulation, denaturation and syneresis, foaming, emulsification.
Sensory attributes: Sensory properties and correlation with objective indices, microstructure and its relation to texture from their mechanical models and its examination.
Sorption behaviour of food: sorption isotherm, modelling.

V. Practical

- To determine physical dimension and shape for suitability of processing and packaging of food materials
- To determine bulk, true density and porosity of samples
- To determine the angle of repose using rough and smooth surface
- Analysis of powder characteristics using powder flow analyser.
- To determine the mixing and strength characteristics of wheat flour using faringograph/ mixograph/ mixolab
- To determine the amylolytic activity using falling number of wheat flour
- Development of stress and strain curve and to study viscosity of Newtonian and non-Newtonian fluid
- Effect of temperature on viscosity profile of a food sample
- Texture profile analysis of foods samples.
- Effect of temperature on textural profile of food
- Determination of thermal properties of foods using DSC.
- To estimate dielectric constant of foods
- Organoleptic evaluation of food materials
- TEM and SEM, image analysis and image processing techniques
- To determine water activity of food
- To determine colour value of food, viz. Lab, whiteness index, yellow index, browning index

VI. Suggested Reading

- Rao MA and Rizvi SSH, 1986. *Engineering Properties of Foods*, Marcel Dekker.
- Aguilera JM & Stanley DW, 1999. *Microstructural Principles of Food Processing and Engineering*, Springer.
- Mohsenin NN, 1986. *Physical Properties of Plant and Animal Materials*, Gordon & Breach Science.
- Bourne MC, 1981. *Food Texture and Viscosity; Concept and Measurement*, Academic Press.
- Steffe JF, 1992. *Rheological Methods in Food Process Engineering*, Freeman Press.
- Aguilera JM, 1999. *Micro Structure: Principles of Food Processing Engineering*, Springer.
- Rahman MS, 2009. *Food Properties Handbook*, CRC Press.
- Serpil S & Sumnu SG, 2006. *Physical Properties of Foods*, Springer-Verlag.
- Pomeranz Y, 1991. *Functional Properties of Food Components*, Academic Press

I. Course Title : Cocoa and Chocolate Processing Technologies
II. Course Code : FPT 505
III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Cocoa, Occurrence, chemistry of the cocoa bean, analysis of cocoa beans, processing of raw bean, changes taking place during fermentation of cocoa bean

Cocoa processing: processing of cocoa bean- Cleaning, roasting, alkalization, cracking and fanning; Nib grinding for cocoa liquor, cocoa butter and cocoa powder; processing of roast bean; chemical changes during various stages of processing

Unit II

Chocolates: Types, ingredients, chemistry of chocolate manufacture, Mixing, Refining, Conching, Tempering, moulding etc. to obtain chocolate slabs, chocolate bars. Dark, milk and white chocolate and their manufacturing processes

Unit III

Enrobed and other confectionary products: Compound Coatings & Candy Bars, Tempering technology, Chocolate hollow figures, Chocolate shells, Enrobing technology, Manufacture of candy bars, Presentation and application of vegetable fats. Production of chocolate mass

Unit IV

Packaging, quality and storage of chocolates.

V. Practical

- Anatomical structure of cocoa beans
- Effect of fermentation on cocoa beans
- Roasting of cocoa beans
- Effect of roasting on cocoa beans
- Effect of packaging on quality of cocoa beans
- Production of cocoa liquor
- Production of cocoa butter
- Effect of crunching on chocolate
- Effect of tempering on chocolate
- Fat expulsion during chocolate storage
- Production of milk chocolate
- Production of dark chocolate
- Effect of packaging on quality of chocolate
- Effect of storage temperature on chocolate quality

VI. Suggested Reading

- Minifie, BW, 1999. *Chocolate, Cocoa and Confectionery Technology*. Springer Science & Business Media.

I. Course Title : Spices, Herbs and Condiments

II. Course Code : FPT 506

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction: Status and scope of spice processing industries in India; Spices, Herbs and seasonings: sources, production, selection criteria, classification on the basis of origin, physical characteristic.

Major spices: Post-Harvest Technology composition, processed products of following spices (1) Ginger (2) Chilli (3) Turmeric (4) Onion and garlic (5) Pepper (6) Cardamom

Unit II

Minor spices, herbs and leafy vegetables: All spice, Annie seed, sweet Basil, Caraway seed, Cassia, Cinnamon, Clove, Coriander, cumin, Dill seed, nutmeg, mint, Rose merry, saffron, sage

Processing technology of Spices: Chemical composition, processing methods, equipment's used; recent developments in processing

Unit III

Processing effect on spice quality: Effect of processing on spice quality, contamination of spices with micro-organisms and insects

Unit IV

Spice Essential Oils: methods of extraction, isolation, and encapsulation,
Spice Oleoresins: method of extraction, isolation, separation equipment
Spices quality evaluation: Criteria for assessment of spice quality

V. Suggested Reading

- Reineccius G. 2005. *Flavour Chemistry and Technology*. CRC Press.
- Heath HB, 1986. *Flavour chemistry and Technology*. AVI Publ.
- Piggott JR, Paterson A. 1994. *Understanding Natural Flavours*. Springer US

I. Course Title : Meat, Poultry, Fish and Egg Processing

II. Course Code : FPT 507

III. Credit Hours : 2+1

IV. Theory

Unit I

Meat Industry: Meat and meat products in India-an Industrial profile. Meat production and trade practices. Prospects and problems in production of fresh meat in India, Research and Development activities on meat, fish and poultry products. Gross and microstructure of muscle. Mechanism of muscle contraction and relaxation: Organization of skeletal muscle from gross structure to molecular level. Muscle Communication (sarcolemma, sarcoplasmic reticulum, Innervation). Muscle metabolism. Different types of connective tissues and their relevance to properties of meat. Myofilament proteins and their major functions. Nervous tissue, nerves and the nature of stimuli, membrane potential in nerve and muscle, Events that occur during relaxation and contraction.

Unit II

Cattle and beef, sheep and mutton, pig and pork and their fabrication: Breeds, Pre-slaughter care, ante and post mortem, slaughter, handling of offal (edible and inedible). Cuts of beef, pork and mutton.

Meat inspection and grading: Application and Enforcement of inspection laws, elements of inspection (sanitation, antemortem inspection, post-mortem inspection, condemnation, product inspection, laboratory inspection, labelling). Identification of inspected products, product inspection, types of grades, factors used to establish quality grades, conformation, fleshing and finish.

Unit III

Properties of fresh meat: Perception of tenderness, Factors effecting tenderness, connective tissue, collagen, sarcomere contractile state, Myofibrillar tenderness, marbling. Methods to improve tenderness (Electrical stimulation, aging, Meat colour, Pigments associated with colour, Chemical state of pigments, methods to improve meat colour. Water holding capacity (Net charge effect and stearic effect) Molecular Techniques in meat products, cultured meat etc.

Poultry meat: Kind of poultry, processing of poultry. Special poultry products, Breaded poultry, Smoked turkey, packagedprecooked chicken, Freeze dried poultry meat.

Egg and egg processing: Egg quality, egg preservation, egg powder production

Unit IV

Meat analogues and restructured meat products: Textured plant proteins, processes for preparation of meat analogues and restructured meat products.

Fish processing and fish products: Chemical/Nutritional composition of Fish, Fish in human diet: protein, carbohydrates, lipids, vitamins etc. Selection of raw material for processing of streaking and filleting of fish; production of fish paste, fish oils, sauce, fish protein concentrates. Irradiation of fish and fisheries products, packaging of fish products, quality control and quality assurance. Allergens, toxins and infectious diseases from meat, poultry and fish products.

V. Practicals

- To study the effect of low and high oxygen atmosphere on meat colour.
- To study the chemistry of myoglobin as it relates to the colour of the molecule.
- To understand and compare the action of two meat tenderizing enzymes by applying the technique of electrophoresis.
- To study the structure of the muscle under compound microscope.
- Perform the slaughtering of the poultry birds.
- Identification of different internal organs of poultry birds and their utilization for product preparation.
- Dressing of Fish.
- Determination of total volatile acids in fish,
- Determination of buffering capacity of fish muscle.
- Rapid estimation of hypoxanthine concentration in chill stored fish.
- Determination of glycine in fish muscle.
- Determination of protein fractions in fresh fish.
- Cut out test for canned fishery products.
- Determination of glycogen in fish muscle.
- Industrial visit to meat industry.

VI. Suggested Reading

- Henricksons. 1978. *Meat Poultry and Sea Food Technology*/ Prentice Hall
- Robert RJ. 2012. *Fish Technology*/ Wiley-Blackwell
- Mountney GJ. 1988. *Poultry Meat and Egg Production*/ Springer, Netherlands
- Kerry J, Kerry J. 2002. *Meat Processing*/ Woodhead Publishing and David Ledwood
- Levie A. 1979. *Meat Hand Book*, Avi Pub
- Weiss GH. 1971. *Poultry Processing*. Noyes Data Corporation
- Wheaton FW and Lawson TB. 1985. *Processing of Aquatic Food Products* John Wiley & Sons.
- Mead G. 2004. *Poultry meat processing and quality* Woodhead Publishing
- Sinha R. 2017. *HACCP in Meat, Poultry and Fish Processing*/ Random Publications
- Sahoo J and Chatli MK. 2015. *Textbook on Meat, Poultry and Fish Technology*/ Daya Pub. House.

- Badapanda KC. 2012. *Basics of Fisheries Science*/ Narendra Publishing House
- Sahoo J, Sharma DK and Chatli MK. 2016. *Practical Handbook on Meat Science and Technology*/ Daya Pub. House

I. Course Title : Nutraceuticals and Specialty Foods

II. Course Code : FPT 508

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Defining nutraceuticals and functional foods. Nature, type and scope of nutraceutical and functional foods. Nutraceutical and functional food applications and their health benefits. Nutraceutical compounds and their classification based on chemical and biochemical nature, Innovations in Functional Food Industry for Health and Wellness, Development of biomarkers to indicate efficacy of functional ingredients.

Nutraceuticals and Functional foods: Nutraceuticals/ food components for specific disease such as cancer, heart disease, diabetes, obesity, anti-aging, arthritis, Prebiotics and probiotics; Omega 3 and omega 6 fatty acids, Isoflavones, phenolic compounds, catechins, lycopene, glucosinolates.

Unit II

Specialty Foods: Design of food for infants, children and old age.

Functional Beverage: Selection of ingredients, health benefits and production.

Extraction and delivery system: Non-thermal techniques, bioprocessing techniques, dehydration techniques, effect on bioactive ingredients. Delivery system and controlled release of nutraceuticals

Unit III

Packaging, Storage, labelling: Packaging requirements, storage and storage kinetics on quality of nutraceuticals, interactions of various environmental factors.

Marketing and safety aspects: Marketing and safety and regulatory issues for functional foods and nutraceuticals.

Unit IV

Nutrigenomics: concept of personalized medicine. Use of nanotechnology in functional food industry.

Biological functionality of cruciferous vegetables, tropical, subtropical and temperate fruits, herbs and spices.

V. Practical

- Determination of antioxidant activity of given food sample by different techniques, viz. DPPH, FRAP, ABTS, FRAP.
- Determination of total phenolic content of given food sample.
- Estimation of dietary fibres of given food sample.
- Estimation of lycopene in tomato.
- Estimation of carotenoids of given food sample.
- Determination of total flavonoid content of given food sample
- Effect of heat processing on ascorbic acid
- Determination of vitamins A.

- Estimation of pectic substances in plant sample
- Determination of beta carotene of given food sample.
- To determine gas chromatography for bioactive components analysis.
- To study the effect of drying on bioactive components of food sample
- To study the packaging requirement of functional foods.
- Determination and qualifications of some nutraceutical and functional food compounds by HPLC
- Estimation of â- glucan
- To study the storage kinetics of nutraceutical.
- Estimation of soluble/insoluble fibres of given food sample.

VI. Suggested Reading

- Chadwick R Henson S and Moseley B, 2003. *Functional Foods*, Springer-Verlag.
- Jeffrey Hurst W, 2008. *Methods of Analysis for Functional Foods and Nutraceuticals*, CRC Press.
- Shi J, Mazza G and Maguer M, 2002. *Functional Foods*, CRC Press.
- Wildman REC, 2006. *Handbook of Nutraceuticals and Functional Foods*, CRC Press.
- Vattem DA and Maitin V, 2016. *Functional Foods, Nutraceuticals and Natural Products*, DEStech publications.
- Grumezescu AM, 2016. *Nutraceuticals: Nanotechnology in the Agri-Food Industry*, Elsevier Inc
- Rizvi SSH, 2010. *Separation, Extraction and Concentration Processes in the Food, Beverage and Nutraceutical Industries*, Woodhead Publishing.
- Tomar SK, 2011. *Functional Dairy Foods Concepts and Applications*, Satish Serial Publishing House.
- Gupta RK, Bansal S and Mangal M, 2012. *Health Food Concept, Technology and Scope*, Biotech Books.

I. Course Title : Frozen and Concentrated Foods

II. Course Code : FPT 509

III. Credit Hours : 1+1

IV. Theory

Unit I

Freezing: Glass transitions in frozen foods and biomaterials, Microbiology of frozen foods, Thermo-physical properties of frozen foods, Freezing loads and Freezing time calculation, Innovations in freezing process, freezing methods and equipment. Facilities for the Cold Chain: Cold store design and maintenance, Transportation and storage of of frozen foods, Retail display equipment and management.

Unit II

Quality and safety of frozen foods: Quality and safety of frozen meat and meat product, poultry and poultry products, eggs and egg products, fish and shellfish, and related products, frozen vegetables and fruits, frozen dairy products, frozen ready meals and confectioners.

Unit III

Packaging of frozen foods: Selection of packaging materials, Plastic and paper packaging of frozen foods, Shelf-life prediction of frozen foods.

Unit IV

Concentrated milk: Production and quality of evaporated and condensed milk.

Concentrated juice products: Production and quality of fruits and vegetable juice concentrate, puree and paste, tomato juice concentrates, mango pulp etc.

V. Practical

- Measure the glass transition temperature of food
- Calculate freezing load of food sample
- Calculate freezing time of a frozen foods
- Effect of cold chain on quality of fruits and vegetables
- Effect of cooling on egg quality
- Effect of chilling on meat quality
- Effect of freezing on meat quality
- Production of concentrated milk and check its quality
- Production of evaporated milk and check its quality
- Effect of clarification n juice quality
- Effect of juice concentration on juice concentrate
- Effect of cold and hot break on tomato pulp quality
- Production tomato puree and paste and check its quality

VI. Suggested Reading

- Erickson MC & Hung YC, 1997. *Quality in Frozen Foods*, Springer.
- Hui YH, Legarretta IG, Lim, MH, Murrell KD & Nip WK, 2004. *Handbook of Frozen Foods*, CRC Press.
- Kennedy C J, 2000. *Managing Frozen Foods*, Elsevier.

I. Course Title : Aseptic Processing and Packaging

II. Course Code : FPT 510

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: present and future of aseptic processing, Advantages and disadvantages, processing of semi-solid and fluid and particulate foods.

Aseptic processing operations: pre-sterilization, loss of sterility, water-to-product and product-to-water separation, cleaning, control, CIP.

Unit II

Quality Assurance: Effect of aseptic processing on nutrients, microorganisms, in-process and post-process assurance, HACCP, regulatory aspects of processing and packaging, Shelf life modules.

Unit III

Sanitary design and Equipments requirements: Pumps, Heat exchangers, homogenizers, aseptic process and packaging system for retail and institutional packages.

Unit IV

Packaging of aseptic processed foods: Packaging materials characteristics, aseptic filling, sterilization of packaging materials, package design, aseptic packaging system, type of pack and equipments: Fill and seal, Form, fill and seal, Erect, fill and seal, Thermoform, fill, sealed, Blow mold, fill, seal; geometry, materials and size of retail and bulk package, seal and closures.

V. Practical

- Effect of aseptic processing on microbial quality of juice based beverage
- Effect of aseptic processing on vitamins in selected foods.
- Effect of aseptic processing on minerals in selected foods.
- Effect of aseptic processing on colour pigments in selected foods.
- Effect of aseptic processing on browning of milk
- Effect of aseptic processing on viscosity of milk
- Effect of aseptic processing on proteins in selected foods
- Effect of different chemical sterilant on microbial quality of packaging material
- To estimate chemical sterilant residue on packaging materials
- Estimation of package integrity and leakage
- Shelf life models and prediction.

VI. Suggested Reading

- Robertson GL, 2012. *Food Packaging: Principles and Practices*, CRC Press.
- David JRD, Graves RH and Szemplenski T, 2016. *Handbook of Aseptic Processing and Packaging*, CRC Press.
- Reuter H, 1993. *Aseptic Processing of Foods*, CRC Press.
- Willhoft EM, 1993. *Aseptic Processing and Packaging of Particulate Foods*, Springer.

I. Course Title : Traditional Foods

II. Course Code : FPT 511

III. Credit Hours : 2+1

IV. Theory

Unit I

Present status of traditional food products, Globalization of traditional food products; Plans and policies of the Government and developmental agencies.
Overview of heat-desiccated, coagulated, fried, fermented traditional food products
Process technology for Indian bread (chapatti), paratha, stuffed paratha, panipoori
Process technology for Indian fried foods- poori, samosa, sev, fafda, chorafali, Jalebi
Process technology for fermented traditional food and its improvement- pickle, idli, khaman, nan, dahi, dhokla, Spiced buttermilk etc.
Process improvement in production of Indian sweets (Halwasan, kajukatli, carrothalwa, Rabdi, chocolate burfi, Chikki etc).
Process improvement in production of puffed cereals and grains by microwave technique

Unit II

New products based on fruits, vegetables and cereals
Application of membrane technology; microwave heating, steaming, extrusion for industrial production of traditional food products (Shrikhand, Dhokla, wadi, murukku/chakri, Patra, Khandvi)
Utilization and scope of legumes and grains in India for novel food products development like- flour, ready to eat products, flour mixes etc (puranpoli, Idlimix,Wada mix, Gotamix)
Process technology for convenience traditional food products (ready to eat and serve -Curried vegetables, pulses and legumes), chutneys, paste
Use of natural and permitted synthetic preservatives and new packaging systems for traditional food products.

Unit III

Techno-economic aspects for establishing commercial units for traditional products. Introduction to traditional foods of India, composition and nutritive values, microbial and biochemical diversity, quality and food safety challenges Processing& Preservation methods of Sweets & Desserts**:** Kulfi, Falooda, Kheer, khurchan, khoa/mawa, Rabri,jalebi, imarti, Gulab jamun, Peda, petha, rewdi, gajak, milk cake, balushahi, bal mithai, singoni, Ras-malayi,Gulqand, ghevar, rasgolla, chamcham, son halwa, son papri, several varieties of halwa, laddu, barfi & rasgolla.

Unit IV

Traditional fermented foods: Idli, dosa, Vada, khamman dhokla, Dahi (Curd), Srikhand.Processing & Preservation methods of Snacks**:** Gujiya, kachauri, samosa, mirchibada, kofta, potato chips, banana-chips, mathri, bhujiya, fried dhals, bhujia, shakarpara, pakora, vada.

Processing & Preservation methods of Baked Products: Biscuits, Toast, Candies, Cookies, Breads, Roti, Naan, Tandoori Roti, parantha, kulcha, puri, bhatura.

Processing & Preservation methods of Preserves & Beverages: Murabba, sharbat, pana, aampapad, sharbat,

Coconut water, milk (khas, rose), Alcoholic Beverages

Industrialization, Socioeconomic Conditions and Sustainability of Traditional Foods.

V. Practical

- To study the effect of different combination of salt and oil in quality of traditional fermented food product (pickle)
- To study the effect of different starter culture on taste and texture of idli
- To evaluate the shelf life of stuffed paratha under different storage conditions
- To study the effect of time and temperature on quality of fried food products (poori/ panipoori etc.
- To study effect of sugar and Artificial sweeteners in the preparation of kajukatli
- To study the microwave heating in drying of khaman/ dhokla
- To study the effect of cold extrusion on mixing of vermicelli
- To prepare instant carrot halwa mix
- To study the effect of different packaging material on shelf life of traditional Indian food products
- To study the effect of different natural food preservatives in traditional sweets
- Preparation of spiced buttermilk
- Preparation of puffed cereals and grains
- Preparation and quality evaluation of Instant Premixes (Puranmix)
- Preparation of quality evaluation of dried malted moth bean powder
- Preparation of Indian traditional confections (chikki)
- Visit to ethnic food industry (Instant mixes/Pickle making)

VI. Suggested Reading

- Steinkrus KH. 1995. *Handbook of Indigenous Fermented Foods*. CRC Press
- Wickramasinghe P. 2007. *The Food of India OM Book Service*
- Aneja RP, Mathur BN, Chandan RC and Banerjee AK. 2002. *Technology of Indian Milk Products*, India Year Book Publications
- Mangal R. 2013. *Fundamentals of Indian Cooking: Theory and Practice*

I. Course Title : Technologies of Convenience Foods

II. Course Code : FPT 512

III. Credit Hours : 2+1

IV. Theory

Unit I

Overview of grain-based snacks: whole grains – roasted, toasted, puffed, popped and flakes

Coated grains- salted, spiced and sweetened

Flour based snack– batter and dough-based products; *savoury* and *farsans*;formulated chips and wafers, papads.

Fruit and vegetable-based snacks: chips, wafers, papads etc.

Coated nuts – salted, spiced and sweetened products- *chikkis, fried groundnut pakora,*

Unit II

Technology of ready- to- eat baked food products, drying, toasting, roasting and flaking, coating, chipping

Extruded snack foods: Formulation and processing technology, flavouring and packaging

Unit III

Ready-to-cook food products- different puddings and curried, Vegetables, meat and meat food products etc. Technology of instant cooked rice, carrot and other cereals-based food products

Technology of ready to eat instant premixes based on cereals, pulses etc.

Technology for RTE puffed snack- sand puffing, hot air puffing, explosion puffing, gun puffing etc.

Unit IV

Equipment for frying, baking and drying, toasting, roasting and flaking, popping, blending, coating, chipping.

V. Practical

- Preparation of cereals based fried snack foods
- Preparation of legume based fried snack foods
- Preparation of cereal, pulses based ready-to-eat snack food by extrusion cooking and their quality evaluation
- Preparation of cereal grain based puffed products
- To study the effect of frying time and temperature on potato chips
- Development of instant food premixes
- Preparation of cereal and legume based roasted snack
- Preparation of flaked rice product
- To study the effect of roasting time and temperature on quality of pop-corn
- Determination of shelf-life and packaging requirements of snack food products
- Preparation of cereal and legume based roasted snack foods by vacuum frying
- Visit to industries manufacturing snack foods.

VI. Suggested Reading

- Edmund WL 2001. *Snack Foods Processing*. CRC Press
- Frame ND 1994. *Technology of Extrusion Cooking*, Blackie Academic.

- Gordon BR 1997. *Snack Food* AVI Publ.
- Samuel AM. 1976. *Snack Food Technology*. AVI Publ.
- Manley D. 2000. *Technology of Biscuits, Crackersand Cookies* CRC Press
- Deny AV and Dobraszczyk BJ. 2001. *Cereals and Cereal Products*, Aspen Publishers
- Ram S and Mishra B. 2010. *Cereals: Processing and Nutritional Quality*, New India Publishers

I. Course Title : Food Powders and Premixes
II. Course Code : FPT 513
III. Credit Hours : 2+1
IV. Theory

Unit I

Food powder properties: Particle size, shape, particle size distribution, density, Crystalline and amorphous microstructure of powders, cohesive forces in powders, adhesive forces and surface energies, stickiness of powders, surface structure of powders, fluidity of powders, compressibility of powders, mixing property of powders, segregation of powder particles, flow and packing properties
Handling of food powders: Basic flow patterns in storage vessels, storage vessel design, mass-flow operation, the Jenike silo design method, the flow-no flow criterion, Powder conveying: Belt, screw, chain, pneumatic

Unit II

Size reduction and enlargement: Principles, equipment, criteria for selecting comminution process, aggregation and agglomeration, instantization
Encapsulation: Principles, methods of encapsulation, viz. spray drying, coacervation, extrusion, co-crystallization

Unit III

Powder Production: Spray, drum and freeze-drying process and equipments
Undesirable properties: Attrition, segregation, caking, dust explosion hazards, laboratory testing to assess explosion characteristics of dust clouds, safety from dust cloud explosion hazards
Food powder rehydration: Principles of powder rehydration- wettability and sink ability, dispersibility, solubility, improvement of rehydration properties
Surface composition of food powders: Microscopy and spectroscopy techniques for analysing the surface of food powder, factors affecting food powder surface composition, impact of powder surface composition on powder functionality.

Unit IV

Packaging and Storage: Packaging requirements, design of package, effect of environmental factors on quality of food powders, shelf life test and prediction
Food Premix: Formulation, processing and packaging of Vitamin premix, mineral premix, fibres premix for food supplements

V. Practical

- Estimation of bulk properties: bulk density, true density, porosity
- Estimation of reconstitution powder properties: wettability, dispersibility, solubility
- Effect of moisture on lump formation and caking
- Estimate flowability of food powders
- Estimate hygroscopicity of powder

- Estimate glass transition and sticky point temperature of food powder
- Effect of bulk properties on packaging
- Measurement of particle size using particle size analyser
- Measurement of surface properties of food powder using SEM
- Packaging of food powders
- Effect of storage on quality of food powders
- Production of various vitamin premix and its application
- Production of various mineral premix and its application

VI. Suggested Reading

- Hong Yan. 2005. *Food Powders: Physical Properties, Processing, and Functionality*/ Springer US.
- Bhandari BS, Bansal N, Zang M, Schuck P. 2013. *Handbook of Food Powders-Process and Properties*/ Woodhead Publishing
- Yasuo Arai. 1996. *Chemistry of Powder Production* Springer Netherlands
- Masuda H, Higashitani K and Yoshida H. 2006. *Powder Technology: Fundamentals of Particles, Powder beds, and Particle Generation*/ CRC Press

I. Course Title : Food Ingredients and Additives

II. Course Code : FPT 514

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Role of food ingredients and additives in food processing, functions, classification, intentional and unintentional food additives, toxicology and safety evaluation of food additives, beneficial effects of food additives, food additives generally recognized as safe (GRAS), tolerance levels and toxic levels in foods-LD 50 values of food additives.

Preservatives: General mechanism of action; basis of selection; classes; Chemical preservatives: characteristics, antimicrobial spectrum, mechanism of action, toxicology, regulations, application in food.

Unit II

Antioxidants: Characteristics, types/classes/groups, mechanism of action/ working of antioxidants, functions, sources, application in food, limits and toxic effects of synthetic antioxidants, synergistic effects of antioxidants, role of free radicals in human body, Natural antioxidants.

Flavouring agents: Flavour functions, selection; forms; sources; process of flavour creation; natural and synthetic flavouring; extractions methods; production process; application in food.

Emulsifiers and Stabilizers: Characteristics/ functional properties; functions; basis of selection; types; mechanism of emulsion formation; mechanisms of emulsion stabilization and destabilization; application in food.

Unit III

Hydrocolloids: Definition: function and functional properties: sources; application in food.

Sweeteners: Characteristics; classification/types; applications in food; Limits and toxicology of non-nutritive sweeteners.

Colouring agents: Properties; functions; classification; sources of natural and synthetic colours: extraction; applications in food, levels of use, misbranded colours, colour stabilization.

Unit IV

Starch, protein, and lipids, fibres and fructo-oligosaccharides: As functional ingredients; their isolation, modification, specifications, functional properties and applications in foods.

Humectants, clarifying agents, Stabilizers and thickeners, Bleaching and maturing agents, Humectants, Sequestrants/ chelating agents, Anti-caking agents, Buffering agents, Acidulants: definition; characteristics; sources; functions and their application in food processing.

V. Practical

- Determination of benzoic acid in food samples
- Estimation of sulphur dioxide in food samples
- Estimation of sorbic acid in cheese and yoghurt
- Determination of nitrate and nitrites in foods
- Detection and determination of aspartame by thin layer chromatography
- Liquid chromatographic determination of caffeine, benzoate and saccharin in soda beverage
- Identification of natural colours
- Isolation, identification and estimation of synthetic food colours
- TLC detection of antioxidants in fats and oils
- TLC detection of emulsifiers
- Detection of alginates in foods (chocolate, ice cream)
- GC determination of menthol in mentholated pan masala
- Isolation and modifications of protein, starch, lipids, fibres from the raw and processed food samples
- Estimation of various additives mentioned in unit IV

VI. Suggested Reading

- Branen AL, Davidson PM and Salminen S. 2001. Food Additives, Marcel Dekker.
- George AB. 1996. *Encyclopaedia of Food and Colour Additives*, CRC Press.
- Nakai S and Modler HW. 2000. *Food Proteins: Processing Applications*, Wiley VCH.
- Gerorge AB. 2004. *Fenaroli's Handbook of Flavour Ingredients*, CRC Press.
- Branen AL, Davidson PM, Salminen S and Thorngate JH, 2001. *Food Additives*, Marcel Dekker.
- Madhavi DL, Deshpande SS and Salunkhe DK. 1996. *Antioxidants: Technological, Toxicological and Health Perspective*, Marcel Dekker.
- Stephen AM. 2006. *Food Polysaccharides and Their Applications*, CRC Press.
- Smith J and Shum LH. 2011. *Food Additives Data Book*, Wiley-Blackwell.
- Baines D and Seal R. 2012. *Natural Food Additives, Ingredients and Flavorings,* Woodhead Publishing

I. Course Title : Flavour Chemistry and Technology

II. Course Code : FPT 515

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: classification of food flavour, chemical compounds responsible for flavours, difficulties of flavour chemistry research. Anatomy of chemical senses. Chemical compounds classes and their flavour response. Flavour intensifiers: Flavour intensifiers and their effects, Chemistry and technology of various flavour intensifiers.

Flavour Extraction: Methods of flavour extraction, isolation, separation and equipments.

Unit II

Flavour development during biogenesis: Flavour Compounds from Carbohydrates and Proteins, Lipid oxidation. Flavour formulation: Creating and formulating flavour, Synthetic flavours, Blended flavouring, flavour, creation for new products, Delivery of flavours from food matrices.

Flavouring compounds during food processing: Volatile and non-volatile flavouring compounds, non-enzymatic browning reactions.

Unit III

Flavour analysis: Sensory evaluation, discrimination analysis, descriptive analysis, Instrumental analysis (Absorption Spectroscopy (W/VIS), chromatography, mass spectrometry)

Food Flavours in different food products: Principal components and properties, baked products, cheese, milk, meat, fish, wine, coffee, tea, chocolate, fruit and vegetable products and fermented foods

Unit IV

Flavour encapsulation and stabilization: Principles and techniques of flavour encapsulation, types of encapsulation, factors affecting stabilization of encapsulated flavour and their applications in food industry, Packaging and flavour compounds interaction, packaging and storage

V. Practical

- Qualitative identification of different flavouring compounds
- Extraction of essential oil/ flavouring compound of basil leave by hydro distillation
- Extraction of essential oil/ flavouring compound of basil leave by SCFE
- Comparison of the quality of flavouring component obtained by hydro distillation and SCFE
- Extraction of essential oil/ flavouring compound of ginger by SCFE
- Effect of storage conditions on flavouring compound of ginger
- Preparation of flavour emulsions and their stability
- To study effects of staling on food flavours and its adverse effects
- Separation, purification and identification of some flavouring compounds by GC/ MS.
- Sensory evaluation of different flavours
- To check effect of cooking on flavour of food sample
- To check effect of fermentation on food flavour
- To study sugar caramelization reaction for flavour development
- Development of blended food flavour-based products
- To study effects of storage conditions on food flavour
- Encapsulation of flavouring compounds
- To study effects of overdoses of flavours
- To study flavour development on roasting/ baking

VI. Suggested Reading

- Reineccius G. 2005. *Flavour Chemistry and Technology*/ CRC Press
- Heath HB. 1986. *Flavour Chemistry and Technology*/ AVI Publ.
- Piggott JR, Paterson A. 1994/ *Understanding Natural Flavours*. Springer US
- Morton ID, Macleod AJ. 1990. *Food Flavour* Elsevier Science
- Ashurst PR. 1994. *Food Flavourings* Blackie
- Taylor AJ and Linforth RST. 2010. *Food Flavour Technology*/ Blackwell Publishing Ltd
- Hui YH. 2010. *Handbook of Fruit and Vegetable Flavours* Wiley & Sons, Inc
- Bruckner B and Wyllie SG. 2008. *Fruit and vegetable flavour: Recent advances and future prospectus* CRC Press.
- Ferreira V and Lopez R. 2013. *Flavour Science* Academic Press

I. Course Title : Bioprocessing and Separation Technology

II. Course Code : FPT 516

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction to various separation processes, Gas-Liquid, Gas–Solid, Liquid-Liquid, Liquid-Solid separation; Concept of phase equilibrium, Stage equilibrium, Stage efficiency, Equilibrium concentration; Single stage contact equilibrium, counter-current multiple contact stages, Concept of equilibrium line and operating line, Determination of optimum number of contact stages by analytical and graphical method; Rate of extraction, Rate of gas absorption, Individual and over all mass transfer coefficient; Calculation of tower height for gas absorption for both dilute and concentrated solution. Construction and working mechanism of different extraction equipments like single stage extraction, Multiple stage static bed system, Bollmann extractor, Hildebrandt extractor, Rotocell extractor.

Unit II

Various separation processes Solid Separation Process, Introduction, Concept of size, Shape, Cut-size, Sieving, Magnetic separation, Eddy-current separation, Wet separation, Ballistic separation, Colour separation, Wet Separation Process, liquid-solid and liquid- liquid separation by hydro cyclones, Surface velocity classifier, Elutriators, Impingement separator, Electrostatic precipitation, Distillation: Introduction, boiling point diagram, differential or simple distillation, Flash or equilibrium distillation, Continuous rectification with and without reflux, Reflux ratio, Optimum reflux ratio, Batch distillation, Application of distillation in food processing.

Unit III

Membrane Separation Technology: Introduction to micro-filtration, Ultrafiltration, Reverse osmosis, Electro dialyses, dialyses, physical characteristics of membrane separation, Factors affecting reverse osmosis process, Concentration polarization, Design of reverse osmosis and ultra-filtration systems, Operation layout of the modules, Electrodialysis, per vaporization, Fabrication of membranes, Application of membrane technology in food industry.

Unit IV

Powder Technology: Classification of powder, Separation of powder, Sieving, Air classification, Factors affecting air classification, Cyclone application, Air separation, Particle size distribution,

Supercritical Fluid Extraction: Introduction, Properties of SCF, Food application, Application of SCFE in analytical technique, Pharmaceutical application.

V. Practical

- Determination of contact equilibrium in counter current and multiple contact model systems.
- Determination of rate of extraction in gas-liquid, gas-solid, liquid-liquid and liquid-solid systems.
- Study of working mechanisms of different extraction equipments.
- Evaluation of physical separation techniques based on size, shape and densities, magnetic, eddy current, ballistic and colour separation,
- Use of air classification, hydyocyclones, electrostatic and distillation techniques for fractionation and separation, application studies on Microfiltration, Ultrafiltration, reverse osmosis and dialysis.

VI. Suggested Reading

- Saravacos GD and Maroulis ZB. 2011. *Food Process Engineering Operations* CRC Press
- Smith PG. 2011. *Introduction to Food Process Engineering* Springer

I. Course Title : Enzymes in Food Processing

II. Course Code : FPT 517

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: General Characteristics of Enzymes, Classes and Nomenclature of Enzymes, Enzymatic Reactions, Factors affecting enzyme activity, Enzyme Kinetic, Enzyme Inhibition

Enzyme Production: Selection and sources of commercial Enzymes, Advantages of microbial enzymes, rDNA in enzyme engineering, Problems of scale up, Enzyme extraction and purification

Unit II

Immobilization: Techniques, Advantages and disadvantages, use of immobilized biocatalysts in food processing

Enzymes for protein modification (hydrolysates and bioactive peptides), Enzymes for Lipid modification

Enzymes in cereal processing: Application of enzymes in process of malting, brewing, milling, baking (fungal –amylase for bread making; maltogenic – amylases for anti-staling xylansandpentosanes as dough conditioners; lipases or dough conditioning; oxidases as replacers of chemical oxidants; synergistic effect of enzymes), production of high fructose corn syrup, glucose syrups

Unit III

Enzymes in fruit processing: Applications of enzyme in fruit juice clarification, removal of haziness and bitterness, Uses of enzymes in wine production

Enzymes in meat, fish and milk processing: Meat tenderization and flavour development, fish processing (De-skinning, collagen extraction etc.,) Egg processing, Cheese processing,

Unit IV

Flavour production: Role of enzymes (enzyme-aided extraction of plant materials for production of flavours, production of flavour enhancers such as nucleotides, MSG; flavours from hydrolysed vegetable/animal protein)

Enzymes in the processing of fats and oils: specificity, stability and application of lipases and related enzymes Role of enzymes in hydrolysis of triglycerides, interesterification and randomization. Enzyme allergy.

V. Practical

- To investigate some of the kinetic properties of invertase
- To study time course of the reaction catalysed by alkaline phosphatase.
- To investigate the thermal stability of horseradish peroxidase
- Quantitative estimation of endoglucanase
- Quantitative estimation of exoglucanase
- Quantitative estimation of â galactosidase
- Quantitative estimation of Pectinase
- Quantitative estimation of Protease
- Quantitative estimation of Lipase
- Immobilization of amylase by sodium alginate and comparative evaluation with native enzyme
- To immobilize yeast cells and demonstrate its biological activity by invertase assay
- To carry out amylase fermentation
- To carry out protease fermentation
- To carry out lipase fermentation

VI. Suggested Reading

- Palmer T. 2008. *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry*. East West
- Laskin AI. 2007. *Enzymes and Immobilized Cells in Biotechnology Benjamin*/ Cummings Pub. Co.
- Mansi ME and Bryce C. 2011. *Fermentation Microbiology and Biotechnology* CRC Press
- Price NC and Stevens L. 2000. *Fundamentals of Enzymology* Oxford University Press
- Reed G. 2007. *Enzymes in Food Processing* Academic Press
- Whitehurst RJ and Oort MV. 2010. *Enzymes in Food Technology* Blackwell Publ
- Bayindirli A. 2010. *Enzymes in Fruit and Vegetable Processing: Chemistry and Engineering Applications* CRC Press.

I. Course Title : Food Process Automation and Modelling

II. Course Code : FPT 518

III. Credit Hours : 2+0

IV. Theory

Unit I

Principles of modelling: Linear programming-concepts, graphical and algebraic solution; Simplex method; Duality theory; Post-optimality analysis; Sensitivity analysis; Transportation and assignment models; Computer applications to LP, queuing theory; Project scheduling and management by PERT-CPM; Integer programming; Non-linear programming; Simulation; Goal programming; Decision theory; Markov chains; Sequencing problem.

Food process modelling: The principles of modelling, kinetic modelling, the modelling of heat and mass transfer; introduction diffusion equation, the Navier-stokes equations, heat and mass transfer in porous media Luikov's equation. Modelling thermal processes: cooling and freezing, modelling product heat load during cooling & freezing. Modelling foods with complex shapes, numerical solution of the heat conduction equation with phase change. Modelling thermal processes: heating, introduction, processing of packed and solid foods, continuous heating and cooling processes, Modelling food quality and microbiological safety. Case Studies in Modelling, Control in Food Processes.

Unit II

Food process equipment design: Design considerations of agricultural and food processing equipment. Design of food processing equipment, Dryers, design of dryers. Determination of heat and air requirement for drying grains. Types of heat exchanger. Design of heat exchangers and evaporators. Design of material handling equipment like belt conveyor, screw conveyor, bucket elevator and pneumatic conveyors.

Digital image processing: digital representation of image, morphological image processing – dialation, erosion, opening and closing, line and edge detection, thresholding, segmentation, techniques for finding length, breadth, perimeter, surface area, eccentricity and surface roughness of solids. Machine Vision-Based Measurement Systems for Fruit and Vegetable Quality Control in Postharvest.

Genetic algorithm optimization: traditional optimization techniques and their limitations, non-traditional method, fitness function in biological evolution, computational procedure for optimization of independent parameters using Genetic algorithm.

Artificial neural network modelling: Developing predictive model between independent and dependent parameters by using Artificial neural network –Neural network architecture, weights and bias values of neurons, least square method for NN parameters optimization, matrix representation and computation of the values of NN parameters.

Unit III

Automation in different unit operations of food processing: Raw food material sorting, grading, size reduction, mixing and agitation, thermal processing, dehydration, packaging, CIP, quality control. Bottle Washing Machine Automation, Bottling Plant Drive System, Demineralization Plant Control System, Labelling Machine Control system, Charger level automation, Reverse Osmosis plant automation, Thermal plant automation, Dehydration and freezing plant automation.

V. Suggested Reading

- Najim K. 1989. *Process Modeling and Control in Chemical Engineering* - CRC Press
- Das H. 2005. *Food Processing Operations Analysis*. Asian Books Private Limited
- Ahmed J and Rahman S. 2012. *Handbook of Food Process Design*.Wiley-Blackwell
- Tijskens LMM, Hertog MLATM and Nicolai BM. 2001. *Food Process Modelling*. Woodhead Publishing
- Bernd H. 2017. *Measurement, Modeling and Automation in Advanced Food Processing*. Springer International Publishing
- Moreira RG. 2001. *Automatic Control for Food Processing Systems* Aspen publishers

I. Course Title : Zero Waste Processing

II. Course Code : FPT 519

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction: Food processing waste and by-product, ISO 14000 for environmental management system, biochemical and nutritional aspects of food processing by-products. Waste minimization: Chain management issues and good housekeeping Procedures, minimise energy use in food Processing, minimise water use in food processing.

Unit II

Food waste separation: microbiological risk management, Effects of postharvest changes in quality on the stability of plant co-products, Separation technologies for food wastewater treatment and product recovery.

Unit III

Co-product recovery techniques: Enzymatic extraction and fermentation for the recovery of food processing products, Supercritical fluid extraction and other technologies for extraction of high-value food processing co-products, Membrane and filtration technologies, recovery of nutraceuticals, micronutrients, functional ingredients, Natural dyes.

Unit IV

Waste management and co-product recovery: Meat, cereal, dairy, fish, fruit and vegetable, vegetable oil, plantation crops processing, waste management of food packaging. Food processing waste water treatment and gas production from solid food processing

V. Suggested Reading

- Waldron K. 2009. *Handbook of Waste Management and Co-product Recovery in Food Processing* Woodhead Publishing
- Arvanitoyannis IS. 2007. *Waste Management for the Food Industries* Academic Press
- Nout MJR and Sarkar PK. 2013. *Valorisation of Food Processing By-Products* CRC Press

Course Title with Credit Load
Ph.D. in Processing Technology

Major Courses

Course Code	Course Title	Credit Hours
FPT 601	Novel Technologies for Food Processing and Shelf Life Extension	3+0
FPT 602	Food Packaging	3+0
FPT 603	Food Manufacturing Technology	3+0
FPT 604	Plant Food Products	3+0
FPT 605	Food Process Modeling and Scale up	3+0
FPT 606	Animal Food Products	3+0
FPT 607	Special Problem	0+2

Minor Courses

Course Code	Course Title	Credit Hours
FPE 601	Concentration and Drying Engineering	3+0
FPE 603	Food Handling and Storage Engineering	3+0
FSQ 603	Quality Assurance in Food Supply Chain	3+0
FSQ 604	Formulation of Standards of Food Products, Packaging and Labeling	2+0

Supporting

Course Code	Course Title	Credit Hours
FPE 605	Food Analytical Techniques	1+2
FSQ 607	Sensory Evaluation of Foods	2+0

Seminar

Course Code	Course Title	Credit Hours
FPT 698	Seminar I	1+0
FPT 699	Seminar II	1+0

Course Contents
Ph.D. in Processing Technology

I. Course Title : Novel Technologies for Food Processing and Shelf Life Extension

II. Course Code : FPT 601

III. Credit Hours : 3+0

IV. Theory

Recent advances in novel food processing technology; Membrane processing, Supercritical fluid extraction, Microwave and radio frequency processing, High Pressure processing, Ultrasonic processing, Ozonization, Plasma Technique, Novel drying techniques. Various techniques to increase shelf life and shelf life prediction.

V. Suggested Reading

- Gould GW. 2000. *New Methods of Food Preservation*, CRC Press.
- Barbosa-Canovas, 2002. *Novel Food Processing Technologies*, CRC Press.
- Dutta AK and Anantheswaran RC, 1999. *Hand Book of Microwave Technology for Food Applications*, CRC Press.
- Sun DW. 2015. *Emerging Technologies for Food Processing*, Elsevier Ltd.
- Kudra T and Mujumbar AS. 2009. *Advanced Drying Technologies*, CRC Press.
- Kilkast D and Subramanium P. 2000. *The Stability and Shelf Life of Food*. CRC Press.
- Doona C J and Feeherry F E. 2007. *High Pressure Processing of Foods*. Blackwell Publishing Ltd.

I. Course Title : Food Packaging

II. Course Code : FPT 602

III. Credit Hours : 3+0

IV. Theory

Recent advances in active and intelligent packaging like Antimicrobial food packaging, Non-migratory bioactive polymers, Freshness indicator, Recycling, biodegradable packaging, Edible Films and Coatings, aseptic packaging, self heating and hydrate packages.

V. Suggested Reading

- Ahvenainen R. 2001. *Novel Food Packaging Techniques*, CRC Press.
- Rooney ML. 1988. *Active Food Packaging*, Chapman & Hall.
- Coles R and Kirwan M. 2011. *Food and Beverage Packaging Technology*, Wiley-Blackwell.
- Han J and Han J. 2005. *Innovations in Food Packaging*, Academic Press.
- Yam K and Lee D. 2012. *Emerging Food Packaging Technologies*, Woodhead Publishing.
- Mihindukulasuriya SDF and Lim LT. 2014. *Nanotechnology Development in Food Packaging-a Review. Trends in Food Science and Technology*, 149-167.
- Souza VGL and Fernando L. 2016. *Nano-particles in Food Packaging-Biodegradibility and Potential Migration to Food – A Review. Food Packaging and Shelf Life*, 63-70.

I. Course Title : Food Manufacturing Technology

II. Course Code : FPT 603

III. Credit Hours : 3+0

IV. Theory

Manufacturing resource planning, Inventory control, Production planning, Production scheduling, Material requirement planning, Resource planning, Capacity requirement planning. Job scheduling,

V. Suggested Reading

- Badiru AB. 2015. *Global Manufacturing Technology Transfer: Africa-USA Strategies, Adaptations, and Management*, CRC Press.
- Hitomi K. 1996. *Manufacturing Systems Engineering: A Unified Approach to Manufacturing Technology, Production Management and Industrial Economics*, CRC Press.
- Yamane Y and Childs T. 2013. *Manufacturing Technology Transfer: A Japanese Monozukuri View of Needs and Strategies*, CRC Press.

I. Course Title : Plant Food Products

II. Course Code : FPT 604

III. Credit Hours : 3+0

IV. Theory

Post-harvest handling of fresh fruits and vegetables, Minimally processed fruits and vegetables, advances in chilling, freezing, and drying, Alcoholic and non-alcoholic beverages; Dough quality measurements; bakery, RTE, RTC products; Hydrogenation, fractionation, winterization, inter-esterification etc. Process for obtaining tailor-made fats and oils; Speciality fats and designer lipids for nutrition and dietetics, Textured Plant proteins.

V. Suggested Reading

- Rodrigues S and Fernandes FAN, 2016**.** Advances in Fruit Processing Technologies, CRC Press.
- Smith DS, Cash JN, Nip WK and Hui YH. 1997. *Processing Vegetables: Science and Technology,* CRC Press.
- Chakraverty A and Singh RP. 2016. *Postharvest Technology and Food Process Engineering*, CRC Press.
- Frame ND. 1994. *Technology of Extrusion Cooking*, Springer US
- O'Brien RD. 2008. *Fats and Oils: Formulating and Processing for Application*, CRC Press.
- Davis B, Lockwood A, Alcott P and Pantelidis L. 2012. *Food and Beverage Management*, CRC Press.
- Dhillon PS and Verma S. 2012. *Food and Beverage: Production Management for Hospitality Industry*, Abhijeet Publications.

I. Course Title : Food Process Modeling and Scale-up

II. Course Code : FPT 605

III. Credit Hours : 3+0

IV. Theory

Recent advances in modeling of high and low temperature processing;Kinetic modeling of microbial growth and its destruction, enzyme inactivation, nutrient retention, Scale up of food processing.

V. Suggested Reading

- Tijskens LMM, Hertog MLATM and Nicolai BM. 2001. *Food Process Modelling*, Woodhead Publishing.
- Ozilgen M. 2011. *Handbook of Food Process Modeling and Statistical Quality Control*. CRC Press.
- Bernd H. 2017. *Measurement, Modeling and Automation in Advanced Food Processing*, Springer.
- Valentas KJ, Clark JP and Levin L. 1990. *Food Processing Operations and Scale-up*. CRC Press.

I. Course Title : Animal Food Products

II. Course Code : FPT 606

III. Credit Hours : 3+0

IV. Theory

Research and development activities on meat, fish and poultry products. gross and microstructure of muscle, Pre-slaughter care, ante and post mortem, slaughter, handling of offal (edible and inedible). Methods to improve tenderness,

Special poultry products, Breaded poultry, packaged precooked chicken, Freeze dried poultry meat. egg preservation, egg powder production. Meat analogues and restructured meat products, production of fish paste, fish oils, sauce, fish protein concentrates. Irradiation of fish and fisheries products, packaging of fish products, quality control and quality assurance. Allergens, toxins and infectious diseases from meat, poultry and fish products.

V. Suggested Reading

- Nollet ML. 2012. *Handbook of Meat, Poultry and Seafood Quality*, Wiley-Blackwell.
- Mountney GJ. 1988. *Poultry Meat and Egg Production*, Springer.
- Robert RJ. 2012. *Fish Technology*, Wiley-Blackwell.
- Mead G. 2004. *Poultry Meat Processing And Quality*, Woodhead Publishing.
- Sahoo J, Sharma DK and Chatli MK. 2016. *Practical Handbook on Meat Science and Technology*, Daya Pub. House.
- Pearson AM and Gillet TA. 1996. *Processed Meat*, Springer.
- Kerry JP, Kerry JF and Ledwood D. 2002. *Meat Processing*, Elsevier.
- Wheaton FW and Lawson TB. 1985. *Processing of Aquatic Food Products*, John Wiley & Sons.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Food Technology
– Process Engineering

Preamble
(Food Process Engineering)

"Food Process Engineering" is a relatively young discipline covering not only factories, equipment and processes but also understanding the product and developing innovative products and packages to satisfy the consumer's needs and wishes. The complexity of the food product and hygienic food production with suitable packaging, compared to chemicals or textile, calls for increasing reliance on the computer in food process research and development. Simulation and modeling constitute an essential step in food process research and development. "Virtualization" becomes a legitimate approach in food engineering research for equipment, mechanization, integrated processing system and hygienic plant design. Further, recent technologies such as Internet of Things, Artificial Intelligence, Nanomaterials, 3D printing, 3D scanning, soft gripping, nondestructive and online/quick analyzing have been found useful for suitable equipment and machineries manufacturing for sustainable food production.

Over the years Food Process Engineering studies emerged as a scientific and industrial discipline describing equipment and means for proper plant operations and environment control considering engineering properties of materials, transport phenomenon, computer aided design, simulation, project engineering and management, post-harvest engineering, storage engineering, additives and preservatives, reaction kinetics, and so on, in ways that preserve value of food and prevent any illness. This was well realized by the 5th Deans' Committee while they chose to have 'Food Process Engineering' as one of the departments at College of Food Technology under Agricultural University setup in the country. Food Process Engineering has been an area of priority for the food industries, processing plants, plant designers, equipment and plant manufacturers, bulk material handling systems, cold storage, supply chain systems and manufacturers, mega kitchen equipment, analytical instruments, ingredient/chemical producers, consumers, retailers, manufacturers, national and international agencies and regulators. Further, need for mechanization of selected indigenous food products and automation has been felt.

To meet the compliances for efficient use of resources, related equipment, instrumentation, plant and building design, establishment and operation for sustainable food manufacturing; competent human resources at various levels such as process engineers, plant engineers, equipment engineers, service engineers, service in-charges, plant in-charge, auditors, designated officers, equipment and instrument handlers, safety officers etc. Development of trained human resource in this scientific and industrial sector is essential for the future growth of food processing and national – international trade from it.

All above requirement of the eco system in an around food sector motivated the BSMA Committee for Food Science and Technology to come up with a new stream of M.Tech. and Ph.D. programme in the area of Food Process Engineering.

Present M. Tech. Food Technology (Process Engineering) course frame work has its parity with national frame work with credit distribution among the different course types core and optional subject with due credits to seminar, research and industrial exposure. Present curriculum at UG level offers adequate introduction on the basic principles of engineering (fluid mechanics, heat transfer, and mass transfer), math, and science (biology, chemistry, and physics) with basics in food chemistry, microbiology, food processing operations, engineering design, analytical techniques, plant sanitation and HACCP. For advancement of knowledge and core competence courses on food engineering operations, engineering properties of food materials and transport phenomenon, computer aided design of food plant machinery and equipment, numerical techniques and simulation etc are kept as compulsory. The course content also offer opportunity to learn testing, inspection, statistical and quality aspect of material and food products for robust knowledge on associated equipment and risk assessment.

Here besides theory teaching practical hands on exposure is also a focus. Other core courses may be selected as per the resources and need analysis which are related to global regulatory and certification requirements, toxicology, food informatics etc. Future researchers as per their interest may find and opportunity to opt for a formal learning on research methodology and advanced food science. Course structure also provides scope for learning across the PG departments. Master students of food process engineering will also have option to study post-harvest management, food processing entrepreneurship and start up, global food laws and regulations, food safety management systems and certification, quality concepts and chain traceability etc.

PhD programme in Food Process Engineering is to assess and design food machinery and associated utilities, AI based automation and robotics, novel process, packaging systems, separation, concentration of required materials etc. So far limited work in this area is taking place in the country and that to under general food technology programmes. The major highlights of PhD programme are a formal course structure focused on the discipline of process engineering with an opportunity to sharpen the assessment, design of machinery, equipment and/or instrument for online/offline quick quality assessment at laboratory or field or in plant. The researchers will be exposed to advances in process engineering, process and equipment validation, food quality and safety assessment, toxicology and risk assessment etc along with food law making process nationally and at international front.

Thus, the M.Tech. programme is intended to offer the industry ready professionals for food processing sector on one hand while they would be given training so that they can ponder upon the industry problems to offer solution either through deep scientific research or problem-solving approach for quick industry solution and immediate response. The programme will also be good for who enjoy quality food production, processing, distribution and retailing or interested in strengthening their proficiency in design and assessment of production management systems.

The programme shall also open new vista for entrepreneurs who intend to diversify in Food Process Engineering aspects. While PhD programme is envisaged to begin a new era of food process engineering research. While proposing this programme it is believed that this programme will also cover research gap in the area and will provide primary data from the country to be used in best quality indigenous equipment and production system manufacturing with compliance to applicable international/ reputed standards and codes which has been lacking in the past. The committee also has taken care that course should also offer knowledge opportunity matching to contemporary global scenario in the field. The committee hopes that the course will meet the expectations of different stakeholders of the sector and learners.

Course Titles with Credit Load
M.Tech. in Process Engineering

Major Courses

Course Code	Course Title	Credit Hours
FPE 501	Emerging Food Engineering Operations*	2+1
FPE 502	Engineering Properties of Food Materials*	2+1
FPE 503	Transport Phenomenon*	2+1
FPE 504	Bio Processing and Down Stream Engineering	2+1
FPE 505	Energy Management and Auditing in Food Industry	2+1
FPE 506	Numerical Techniques and Simulation	1+1
FPE 507	Computer Aided Design of Food Plant Machinery and Equipment	1+2
FPE 508	Food Safety and Storage Engineering	2+1
FPE 509	Equipment, Machine and System Design for Indigenous Food Product	0+2
FPE 510	Operation Research	2+1
FPE 511	Process Control in Food Industries	2+1
FPE 512	Project Engineering and Management	2+1
FPE 513	Food Process Automation and Robotics	2+0
FPE 514	Water and Waste Management	2+1
FPE 515	Special problem/ Summer internship	0+2

*Compulsory Rest of the courses will be decided by the students advisory committee keeping the minimum limits set for award of degree.

Minor Courses

Course Code	Course Title	Credit Hours
FPT 502	Emerging Technologies in Food Packaging	2+0
FPT 503	Industrial Manufacturing of Food and Beverages	2+1
FPT 504	Food Material and Product Properties	2+1
FPT 510	Aseptic Processing and Packaging	2+1
FSQ 503	Advanced Food Chemistry	2+1
FSQ 504	Global Food Laws and Regulations	2+0
FSQ 506	Process and Products Monitoring for Quality Assurance	2+0
FSQ 508	Management of Food By-products and Waste	2+1

Supporting Courses

Course Code	Course Title	Credit Hours
BSH 501	Research Methodology	2(2+0)
BSH 502	Food Informatics	2(1+1)
FBM 501	Post-Harvest Management	3(2+1)
FBM 502	Food Business Management	2(2+0)
FBM 503	Food Processing Entrepreneurship and Start up	1(0+1)
FSQ 505	Food Safety Management Systems and Certification	3(2+1)
FSQ 507	Quality Concepts and Chain Traceability	2(2+0)

Common Courses

S. No.	Course Title	Credit Hours
1	Library and Information Services	1
2	Technical Writing and Communications Skills	1
3	Intellectual Property and its Management in Agriculture	1
4	Basic Concepts in Laboratory Techniques	1
5	Agricultural Research, Research Ethics and Rural Development Programmes	1

These courses are available in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

Seminar

Course Code	Course Title	Credit Hours
FPE 526	Seminar	1(0+1)

Course Contents
M.Tech. in Process Engineering

I. Course Title : Emerging Food Engineering Operations
II. Course Code : FPE 501
III. Credit Hours : 2+1
IV. Theory

Unit I

Ionizing and non-ionizing radiation processing system operations: types of radiations, generation, microwave assisted processing systems, IR assisted processing systems, radio frequency systems, O_3, UV and x-ray assisted processing systems, gamma irradiations systems, e-beam radiation systems and applications.

Unit II

Pulse electric field (PEF) generation system and applications, cold plasma generation systems and applications, high pressure processing systems and applications, ultrasonic processing systems and applications.

Unit III

Extrusion systems, batch and continuous ohmic heating systems and applications, inductive heating systems and applications, applications of nanotechnology.

Unit IV

Drying systems: superheated steam drying, refractance window drying, heat pump drying, freeze drying, spray drying, foam bed drying, microwave drying, instant pressure drop (DIC) drying and hybrid drying systems.

Unit V

Membrane processing systems: UF, MF, NF, reverse osmosis and vapour permeation, pervaporation, membrane distillation. Supercritical fluid extraction: concept, property of near critical fluids (NCF), extraction methods. Cryoprocessing-cryogens properties, systems and their different applications.

V. Practical

- To evaluate the characteristics of treated water and selected liquid foods using membrane systems (NF, UF, RO, etc)
- To study super critical fluid extraction system and application
- To study microwave system and microwave assisted food processing
- To study efficacy of hot water, steam, microwave, ultrasound blanching of selected fruits and vegetables
- To study the ultrasonicator and applications
- To study cryogenic processing applications
- To prepare Nano emulsion and study of their characteristics
- To study ohmic/inductive heating systems applications
- To study cold plasma applications

- To study gamma irradiation applications
- To study drying kinetics using different drying systems
- To study operations in 3 D printing
- Solving problems in food processing and case studies
- Visits of food industries utilizing advance food processing systems.

VI. Suggested Reading

- Datta AK. 2001. *Handbook of Microwave Technology for Food Application*. CRC Press.
- Purkait MK and Singh R. 2018. *Membrane Technology in Separation Science*. CRC Press Taylor and Francis Group.
- Frame ND. 1994. *The Technology of Extrusion Cooking*. Blackie.
- Gould GW. 2012. *New Methods of Food Preservation*. Springer Science & Business Media.
- Berk Z. 2018. *Food process engineering and technology*. Academic press.
- Nema PK, Kaur BP and Mujumdar AS. 2019. *Drying technologies for foods: Fundamentals and applications*. CRC Press
- Meredith RJ. 1998. *Engineers' Handbook of Industrial Microwave Heating* (No. 25). Iet.
- Arvanitoyannis IS. 2010. *Irradiation of food commodities: techniques, applications, detection, legislation, safety and consumer opinion*. Academic Press.
- Yanniotis S. 2008. *Solving problems in food processing and case studies*. Springer

I. Course Title : Engineering Properties of Food Materials

II. Course Code : FPE 502

III. Credit Hours : 2+1

IV. Theory

Unit I

Physical characteristics of different food grains, fruits and vegetables; shape and size, volume and density, porosity, surface area, water activity. Thermal properties: Specific heat, thermal conductivity, thermal diffusivity, phase transition, methods of determination, steady state, transient heat flow. Electrical properties; Dielectric loss factor, loss tangent, temperature dependent electrical conductivity and dielectric constant, method of determination, energy absorption from high-frequency electric field.

Unit II

Magnetic properties: paramagnetism, ferromagnetism, diamagnetism, magnetization, applications for magnetic field forces, magnetic resonance; Electromagnetic properties: electric polarization, temperature dependency, frequency dependency, microwave, conversion of microwaves into heat, penetration depth of microwaves, applications; Optical properties: refraction, colorimetry, near infrared, ultraviolet, applications; Acoustical properties: sound, ultrasonic sound and applications; Radioactivity: types of radiation, radioactive decay, measurement of ionizing radiation, natural radioactivity, applications.

Unit III

Contact stresses between bodies, hertz problems, firmness and hardness, mechanical damage, dead load and impact damage, vibration damage, friction, effect of load, sliding velocity and surface roughness. Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose, flow of bulk granular materials, aero dynamics of agricultural products, drag coefficients, terminal velocity.

Unit IV

Rheological properties and classification of fluid foods: measurement methods and techniques; Mechanisms and relevant models; Effect of temperature; Compositional factors affecting flow behavior; Viscosity of food dispersions – dilute and semi-dilute systems, concentration effects.

Unit V

Rheology of semi-solid and solid food; Rheological characterization of foods in terms of stress-strain relationship; Viscoelasticity; Transient tests - Creep Compliance and Stress Relaxation; Mechanical models for viscoelastic foods: Maxwell, Kelvin, Burgers and generalized models and their application; Dynamic measurement of viscoelasticity.

Unit VI

Large deformations and failure in foods: fracture, rupture and other related phenomena; Relationship between instrumental and sensory data; Texture Profile Analysis; Instrumental measurements – Empirical and Fundamental methods; Rheometers and Texture Analyzers; Measurement of Extensional viscosity; Acoustic measurements on crunchy foods.

Unit VII

Food structuring: traditional food structuring and texture improvement, approaches to food structuring, extrusion and spinning, structuring fat products, structure and stability, gels, gelation mechanisms, mixed gels, the microstructure of gels, structure-property relations angels.

Unit VIII

Examining food microstructures: light microscopy transmission electron microscopy, scanning electron microscopy, other instrumentation and techniques, image analysis: image acquisition, image processing and analysis.

V. Practical

- Viscosity measurements of fruit juices and semisolid food products
- Comparative analysis of Newtonian and non-Newtonian fluids
- Development of stress and strain curve and to study viscosity of Newtonian and non-newtonian fluids
- Temperature dependent and shear dependent rheology
- Pasting analysis of food; Determination of thermal conductivity, specific heat and glass transition temperature using differential scanning colorimetry (DSC)
- Texture analysis of fruits and vegetable-based products
- Texture analysis of baked foods products (bread/ biscuit)
- Starch characterization using starch master; Dough rheology using doughlab or farinograph
- Determination of microstructures in selected foods using light microscopy
- TEM and SEM, image analysis and image processing techniques; Evaluation of phase transition in colloidal systems, evaluation of structure texture function relations
- Case studies on food properties and applications.

VI. Suggested Reading

- Rao MA, Rizvi SS, Datta AK and Ahmed J. 2014. *Engineering Properties of Foods*. CRC press.

- Figura OL. and Teixeira AA. 2007. *Food Physics: Physical Properties - Measurement and Applications*. Springer Science & Business Media.
- Sahin S and Sumnu SG. 2006. *Physical Properties of Foods*. Springer Science and Business Media.
- Mohsenin NN. 1980. *Thermal properties of foods and agricultural materials*. New York. USA.
- Mohsenin NN. 1986. *Physical properties of plant and animal materials*. Gordon and Breach Science Publishers.
- Peleg M and Bagley EB. 1983. *Physical Properties of Foods*. In *IFT basic symposium series* (*USA*). AVI Pub. Co.
- Ronal J, Felix E, Bengt H, Hans F, Meffert Th., Walter EC and Gilbert V. 1983. *Physical Properties of Foods*. Applied Science Publishers.
- Bourne M. 2002. *Food texture and viscosity: concept and measurement*. Elsevier.
- Norton IT, Spyropoulos F and Cox P. 2010. *Practical food rheology: an interpretive approach*. John Wiley & Sons.

I. Course Title : Transport Phenomenon

II. Course Code : FPE 503

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction to transport phenomena – Molecular transport mechanism, transport properties and their proportionality constants in momentum, energy and mass transfer.

Unit II

Principles of Steady and unsteady state heat transfer and governing equations; transient heat transfer; Lumped system analysis; Estimation of Conductivity and other thermal properties of foods; overall heat transfer coefficient.

Unit III

Steady-state equations - Momentum transport equations for Newtonian and non-Newtonian fluids, continuity equation in different co-ordinates.

Unit IV

Equations of motion - Navier–Stokes equations and their application in viscous fluid flow between parallel plates and through pipes.

Unit V

Turbulent transport mechanism - Mathematical analysis; eddy viscosity and eddy diffusivity; velocity, temperature and concentration distribution; time smoothing equations. Inter-phase transport in isothermal system - friction factors for various geometries.

Unit VI

Mass transfer - Fick's law of diffusion, diffusion of gases and liquids through solids, equimodal diffusion, isothermal evaporation of water into air, mass transfer coefficients.

Unit VII

Dimensional analysis – Buckingham Pi-theorem and matrix method, application to transport phenomena, analysis among mass, heat and momentum transfer, Reynolds' analogy.

Unit VIII

Boundary layer concept - Theoretical and exact solutions for heat, mass and momentum transfer.

V. Practical

- Effects of water concentration and water vapor pressure on the water vapor permeability and diffusion of chitosan films
- Mass transfer description of the osmo dehydration
- Pretreatment efficiency in osmotic dehydration
- Structural effects of blanching and osmotic dehydration pretreatments on air drying kinetics of fruit tissues
- Thermal processing of particulate foods by steam injection (1. Heating rate index for diced vegetables 2. Convective surface heat transfer coefficient for steam)
- Relating food frying to daily oil abuse (1. Determination of surface heat transfer coefficients with metal balls 2. A practical approach for evaluating product moisture loss, oil uptake, and heat transfer)
- Heat and mass transfer during the frying process; Influence of liquid water transport on heat and mass transfer during deep-fat frying
- Numerical simulation of transient two-dimensional profiles of temperature, concentration, and flow of liquid food in a can during sterilization
- Case studies on transport phenomenon and its applications.

VI. Suggested Reading

- Bird RB, Stewart WE and Lightfoot EN. 2007. *Transport phenomena*. John Wiley & Sons.
- Treybal RE. 1980. *Mass transfer operations*. New York.
- Yuan SW. 1969. *Foundations of Fluid Mechanics*. Prentice Hall of India.
- Welti-Chanes J and Velez-Ruiz, JF. (Eds.). 2016. *Transport phenomena in food processing*. CRC press.
- Geankoplis CJ. 2003. *Transport processes and separation process principles:*(*includes unit operations*). Prentice Hall Professional Technical Reference.

I. Course Title : Bioprocessing and Down Stream Engineering

II. Course Code : FPE 504

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction: Interaction of biochemical engineering, biochemistry and microbiology, Reaction kinetics, kinetics of batch and continuous cultures, process variables, biocatalyst and enzyme kinetics, scope and present status in India in relation to food industry.

Unit II

Fermenter and bioreactors: Transport phenomenon in microbial systems, types of reactor, working principles, aeration and agitation, sterilization and sanitation, advances in continuous fermentation, developments in solid-state fermentation for food applications.

Unit III

Alcoholic beverages: Production of alcoholic beverages: raw materials, culture, fermentation technology of non-distilled beverages (beer and wine) and distilled alcoholic beverages (brandy, whiskey, vodka, rum, gin).

Unit IV

Single Cell Proteins: Single cell proteins production, substrates, factors effecting SCP production, composition, uses, economic parameters and constrains including safety aspects.

Unit V

Organic acids/acidulants: Raw materials, Starters and fermentation conditions, recovery and applications, Case studies production of acetic acid (vinegar), citric acid, lactic acid and gluconic acid.

Unit VI

Biocatalysts in food processing: Sources of enzymes, advantages of microbial enzymes, mechanism of enzyme function, Production and purification of enzymes, immobilization and applications of biocatalysts in food processing, enzyme biosensors.

Unit VII

Down-stream processing: Handling of materials in microbial systems, filtration, centrifugation, sedimentation, chromatography, membrane separation (UF and NF) and electrophoresis, separation and disintegration of cells for product recovery operations. Biological waste treatment and in-plant sanitation.

Unit VIII

Modeling, simulation and scale-up: Bioprocess modeling and simulation and its application in industrial fermentation, scale-up of fermentation processes, design and analysis of biological fermenter and bioreactors.

V. Practical

- Studying biochemical changes during handling of important food items
- Study of fermenter and fermentation process
- Study of bioprocess instrumentation and control system
- Study of bacterial growth in batch culture
- Production and maintenance of starter culture
- Production of enzyme, extraction and purification
- Production of SCP; Production of microbial pigments
- Production of amino acids
- Production of alcohol and alcoholic beverages
- Visit to brewery
- Visit to effluent treatment plant
- Bioprocess modeling and simulation
- Case Studies & Reports.

VI. Suggested Reading

- Schügerl K and Zeng AP. 2010. *Advances in Biochemical Engineering Biotechnology: Tools and Applications of Biochemical Engineering Science*. Springer
- Scheper Th.(Ed). *Advances in Biochemical Engineering and Biotechnology* Series. Springer
- Ghose TK and Fiechter A. 1971. *Advances in Biochemical Engineering-I. Indian Journal of Physics*, 47, 189-192.
- James EB and David FO. 1986. *Biochemical Engineering Fundamentals*. McGraw-Hill Book Co. Inc., New York
- Scheper T, Bajpai P, Bajpai PK, Dochain D, Dutta NN, Ghosh AC, Mathur RK,

Mukhopadhyay A, Perrier M, Rogers PL, Shin HS, Wang B. 1996. *Biotreatment, downstream processing and modelling*. Springer
- Doran PM. 1995. *Bioprocess engineering principles*. Elsevier
- Perry JH. 2007. *Chemical engineers' handbook*, 8e. McGraw-Hill Professional
- Stumbo CR. 2013. *Thermobacteriology in food processing*. Elsevier
- Stanbury PF, Whitaker A and Hall SJ. 2013. *Principles of fermentation technology*. Elsevier
- Hitzmann B 2017. *Measurement, modeling and automation in advanced food processing*. Springer

I. Course Title : Energy Management and Auditing in Food Industry

II. Course Code : FPE 505

III. Credit Hours : 2+1

IV. Theory

Unit I

General Aspects of Energy Management & Energy Audit: Energy scenario, basics of energy and its various forma, material and energy balance, monitoring and targeting and financial management.

Unit II

Energy Auditing Basics: ASHRAE definitions of energy audits, the audit process, pre-site and post-site work, audit report.

Unit III

Energy Accounting and Analysis: Energy Accounting and Analysis, The energy use index, Conditioned area, electricity costs, Thermal energy costs, Energy-using systems, Commercial energy use profiles, Identifying potential measures, Industrial audit Opportunities, Industrial Energy Use Profiles.

Unit IV

Energy economics: Simple payback, time value of money, job simulation experience, making decisions for alternate investments, depreciation, taxes and the tax credit, impact of fuel inflation on life cycle costing.

Unit V

Measurements, Survey instrumentation, and data Collection: General audit instrumentation; co2, temperature, pressure, fluid and fuel flow, combustion gas composition, electrical and light measurement, measuring building losses, application of IR thermograph, infrared radiation and its measurement, measuring electrical system performance.

Unit VI

Energy and Water Conservation Technologies Applied to Food Processing Facilities: Conservation in steam generation and consumption system, energy conservation in heat exchangers, conservation in compressed air system, conservation in power and electrical systems, waste-heat recovery and thermal energy storage in food processing facilities, building envelop audit, energy consumption and saving opportunities.

V. Practical

- Study and practice with energy assessment and auditing instruments

- Performance assessment of motors and variable speed drives
- Performance assessment of pump, fans and blowers
- Performance assessment of refrigeration system
- Performance assessment of heat exchangers
- Performance assessment of furnace
- Performance assessment of boilers
- Conservation possibilities in dairy processing facilities
- Conservation possibilities in grains and oilseeds milling plants
- Conservation possibilities in sugar and confectionary processing facilities
- Conservation possibilities in fruit and vegetable processing facilities
- Conservation possibilities in bakery processing facilities
- Conservation possibilities in meat processing facilities
- Case studies & field reports.

VI. Suggested Reading

- Wang L. 2009. *Energy Efficiency and Management in Food Processing Facilities*. CRC Press
- Thumann A, Niehus T and Younger WJ. 2013. *Handbook of Energy Audits* 9e. Fairmont Press
- Klemes J, Smith R and Kim JK. 2008. *Handbook of water and energy management in food processing*. Elsevier.
- Christopher CS. 2007. *Electric Water: The Emerging Revolution in Water and Energy*. New Society Publishers
- BEE-NPC Cases studies

I. Course Title : Numerical Techniques and Simulation

II. Course Code : FPE 506

III. Credit Hours : 1+1

IV. Theory

Unit I

Modelling and Simulation: Fundamentals of modeling and simulation; Different steps for modeling and simulation, Types of models; Advantages of modeling and simulation, Application areas of simulation.

Unit II

Solution of partial differential equations models: Differential laplace, Poisson, parabolic and hyperbolic equations, Bender – Schmidt method, finite difference method, finite volume method.

Unit III

Optimization: Optimization theory and methods, Graphical and numerical methods of optimization; experimental optimization; linear and nonlinear un-constrain and constrain optimization, multivariate optimization, genetic algorithm, goal driven optimization.

Unit VI

Modelling and simulation applications of some food engineering operations: Thermal processing, convection & osmotic dehydration, spray & freeze drying, deep fat frying; extrusion process; filtration processes; distillation and Extraction processes.

Unit V

Computational fluid dynamics (CFD) applications in food processing.

V. Practical

- Introduction to various features in different spreadsheet softwares
- Solving problems using functions and/or add-Ins and/or Analysis Tool pack in spreadsheets
- Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data
- Testing linearity and normality assumption, Testing the goodness of fit of different models
- Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, Analysis of variance
- Practice on modelling and simulation softwares i.e. MATLAB, FLUENT, GAMBIT, EDEM, Solid works, ANSYS
- Practice on process optimization softwares i.e. SAS, SPSS, Origin Pro, Design Expert(DX), Minitab, Matlab
- Practice on design optimization softwares i.e. Solid works, ANSYS.

VI. Suggested Reading

- Das H. 2005. Food *Processing Operations Analysis*. Asian Books Private Limited
- Denn MM. 1986. *Process Modeling*. Longman
- Holland CD. 1975. *Fundamentals and Modeling of Separation Processes*. Prentice Hall.
- Luyben WL. 1990. *Process Modeling Simulation and Control for Chemical Engineers* 2ed. McGraw Hill.
- Najim K. 1990. *Process Modeling and Control in Chemical Engineering*. CRC
- Aris R. 1999. *Mathematical Modeling, Vol. 1: A Chemical Engineering Perspective* (*Process System Engineering*). Academic Press.
- Kreyszig E. 2005. *Advanced Engineering Mathematics*. John Wiley & Sons publication
- Granato D and Ares G. 2014. *Mathematical and statistical methods in food science and technology*. IFT Press, Wiley Blackwell
- Standard software for modelling, analysis and simulations

I. Course Title : Computer Aided Design of Food Plant Machinery and Equipment

II. Course Code : FPE 507

III. Credit Hours : 1+2

IV. Theory

Unit I

Introduction - Definition of CAD/CAM, product cycle.

Unit II

Automation, CPU, types of memory, input/output devices, data presentation, data and file structures, data base design, design work station.

Unit III

Graphics terminal, operating devices, plotters and other output devices, CPU secondary storage, Turnkey CAD system, selection criteria, evaluation of alternative systems.

Unit IV

Geometric Modeling Techniques - wireframe, surface and solid modeling, Geometric transformations, Graphics standards.

Unit V

CAM - Introduction to Numerical Control (NC) technology, current status of NC, Influence of NC in design & manufacturing.

Unit VI

Computer aided NC programming in APT language, elements of APT language, APT vocabulary, symbols, numbers and scalars, punctuation, definition, statement labels, notations for APT statement format, statements defining point, line, circle, vector, planes and curves, point to point motion.

V. Practical

- Preparation of manual drawings with dimensions from Models and Isometric drawings of objects and machine components
- Preparation of sectional drawings of selected machine parts
- Drawing of riveted joints and thread fasteners
- Demonstration and practice on computer graphics and computer aided drafting using standard softwares such as AutoCAD and/or Inventor and/or Solidworks and/or Creo and/or Catia
- Computer graphics for food engineering applications
- Practice and use of basic and drawing commands on AutoCAD and Solid works
- Generating simple 2-D drawings with dimensioning using AutoCAD and Solidworks
- Small projects using CAD/CAM
- Practice on assembly using Solidwork assembly tool
- Analysis of machine/equipment component for structural parameters using FEM
- Design optimisation of food machine/equipment using goal driven optimization technique
- Kinematic and dynamic analysis of mechanism and machines using Solidworks motion study tool
- Small projects using CAD/CAM
- To study design standards of general food processing equipment and systems

VI. Suggested Reading

- Farin G, Hoschek J and Kim MS. 2002. *Handbook of computer added geometric design*. Elsevier Science
- Goetsch DL. 1988. *MicroCADD: Computer aided design and drafting on microcomputers*. Prentice Hall
- Holah JT and Lelieveld HLM. 2011. *Hygienic design of food factories*. Woodhead publishing house.
- Higgins L and Morrow LC. 1977. *Maintenance Engineering Hand-Book*. McGraw Hill.
- Keating FH. 1959. *Chromium-Nickel Austentic Steel*. Butterworths Scientific Publ.
- Newcomer JL. 1981. *Preventive Maintenance Manual for Dairy Industry*. Venus Trading Co., Anand.
- Stanier W. 1959. *Plant Engineering Hand-Book*. McGraw Hill.

I. Course Title : Food Safety and Storage Engineering

II. Course Code : FPE 508

III. Credit Hours : 2+1

IV. Theory

Unit I

Overview of food microbiology: Foodborne illness, food spoilage, food fermentation, microbiological physiology and food preservation, microbiological analysis, safety management systems. Overview of foodborne pathogens: Bacterial pathogens, food borne viruses and parasites.

Unit II

Chemical safety of foods: nature of chemical hazards in foods, food safety engineering and control of chemical hazards, food allergen control. Intrinsic and extrinsic parameters for microbial growth and heat inactivation: Intrinsic and extrinsic factors affecting microbial growth, factors affecting heat resistance, combining traditional peroration techniques.

Unit III

Kinetics of microbial inactivation: Microbial inactivation kinetics based on food processing methods: thermal, pressure, pulsed electric field, microwave and radio frequency, ohmic and inductive heating etc. Kinetic parameter for the inactivation of pathogens: *Salmonella, Listeria monocytogenes, Staphylococcus aureus, Escherichia coli, Bacillus cereus, Clostridium, Vibrio*, other pathogens.

Unit IV

Predictive microbial modelling: classification of models: Kinetic & probability, Empirical & mechanistic models, Primary, secondary & tertiary models, Deterministic & stochastic models; Description of main models, Modelling growth curves, Modelling inactivation/survival curves, Secondary models, Probability models; Applications of predictive microbial modelling: Hazard analysis critical control point (HACCP) & quantitative risk assessment (QRA), Microbial shelf-life studies, Temperature function integration and temperature monitors, Product research and development, Design of experiments; Predictive microbial modelling and quantitative risk assessment.

Unit V

Process-dependent microbial modeling: Predictive microbial kinetic models, Temperature-dependent microbial growth kinetic models, Irradiation-dependent microbial growth model, Pulsed electric field-dependent microbial growth model, High-pressure-dependent microbial growth model; Process modeling; Integration of process and microbial growth kinetic models.

Unit VI

Storage and handling systems for grains, horticultural and animal based produces; post-harvest physiology of fruits and vegetables; biochemical changes during storage, production, distribution; storage capacity estimate models, ecology, storage factors affecting losses, storage requirements.

V. Practical

- Rapid methods and automation in microbiology: trends and predictions

- Study on phage-based detection of foodborne pathogens
- Study on real-time PCR
- Study on DNA Array
- Study on immunoassay
- Offline and online assessments for food safety for industry
- Storage pest, insects and rodent control
- Study on storage systems and structures, Shelf life evaluation of packaged food products
- Recent advancements in storage and handling systems
- Hygienic design standards and codes for food processing equipment/ system
- Case studies on food safety engineering, guidelines, regulations.

VI. Suggested Reading

- Sun DW. 2015. *Handbook of food safety engineering*. Wiley Black Well Academic Press, Elsevier Ltd
- International Organization for Standardization. 2018. *Food Safety Management Systems: Requirements for Any Organization in the Food Chain*. ISO.
- Shejbal J. 1980. Controlled Atmosphere Storage of Grains. Elsevier.
- Vijayaraghavan S. 1993. Grain Storage Engineering and Technology. Batra Book Service
- Chakraverty A and Singh RP. 2014. Postharvest technology and food process engineering. CRC Press
- Chakraverty A, Mujumdar AS and Ramaswamy HS. 2002. *Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices*. CRC Press
- ISO. 22000 Food safety management systems - Requirements for any organization in the food chain. Technical Committee ISO/TC 34, Food products and updates
- Case Studies and Field Reports - Food Safety Engineering

I. Course Title : Equipment, Machine and System Design for Indigenous Food Products

II. Course Code : FPE 509

III. Credit Hours : 0+2

IV. Aim of the course

To develop understanding for mechanization of selected indigenous food products, associated materials of construction, codes and standards, mass balance, specific energy consumption, design, instrumentation, scale of automation, ergonomics, schematics and designing systems/line as a whole.

Students (in group or individual) should be able to evaluate existing production process and categorize whole process in different unit operations such as raw material handling, storage, thermal processing, packaging etc. Computer added design, drafting and simulation of existing system for production and packaging of indigenous food products.

V. Practical

- Visits to indigenous food manufacturing sites and study of existing indigenous food production system
- Study of relevant codes, guidelines and standards for the existing indigenous food production system (product, process, area and personal hygiene)
- Evaluation of available concepts of indigenous food product manufacturing and amelioration
- Computer aided design, drafting and simulation of the selected systems

- Case studies on equipment, machine and system available for the indigenous food products

VI. Suggested Reading

- Holah J and Lelieveld H. (Eds.). 2011. *Hygienic Design of Food Factories*. Elsevier.
- Steinkraus K. 2004. *Industrialization of Indigenous Fermented Foods, Revised and Expanded*. CRC Press.
- Steinkraus KH. 1995. *Handbook of Indigenous Fermented Foods*. CRC press
- Couper JR, Penney WR, Fair JR and Walas SM. 2012. *Chemical Process Equipment - Selection and Design*, 3e. Elsevier
- Saravacos GD and Kostaropoulos AE. 2002. *Handbook of food processing equipment*. Kluwer Academic/Plenum.
- George SG, Kostaropoulos AE. 2015. *Handbook of Food Processing Equipment*, 2e. Springer
- Cramer MM. 2013. *Food plant sanitation: design, maintenance, and good manufacturing practices*, 2e. CRC Press.
- Willey RR. 2006. *Practical Design, Construction and Operation of Food Facilities*. Academic Press
- Baker CG and Christopher GJB (Ed.). 2013. *Handbook of food factory design*. New York, NY: Springer.
- Joshi MV and Mahajani VV. 2000. *Process Equipment Design*, 3e. Macmillan India.
- Brownell LE, Young EH. 1968. *Process equipment design*, 2e. Wiley Eastern Edn. New York
- Ahmad T. 2009. *Dairy Plant Engineering and Management*, 8e. Kitab Mahal
- Hygienic design and sanitary guidelines and related documents/ publications

I. Course Title : Operation Research

II. Course Code : FPE 510

III. Credit Hours : 2+1

IV. Theory

Unit I

Introduction to operations research: Elementary concepts and objectives of Operations Research, Applications of operations research in decision making.

Unit II

Linear programming problem: Mathematical formulation of the linear programming problem and its graphical solution, Simplex method.

Unit III

Transportation problem: Definition and mathematical formulation, Initial basic feasible solution, Optimal solution. Assignment problem: Introduction and mathematical formulation, Solution of assignment problem.

Unit IV

Inventory control: Introduction and general notations, Economic lot size models with known demand. Replacement theory: Introduction and elementary concepts, Replacement of items deteriorating with time.

Unit V

Sequencing problem: Introduction and general notations, Solution of a sequencing problem.

Unit VI

Queuing theory: Introduction and classification of queues, Solution of queuing models.

Unit VII

Project planning and network analysis: Introduction and basic definitions in Network Analysis, Rules for drawing network analysis, Critical path method (CPM), Project evaluation and review technique (PERT).

V. Practical

- Studies on application of Linear Programming on food product standardization
- Studies on use of Transportation and Assignment Problems in food plant operations
- Studies on Economic Order Quantity and Replacement Model
- Studies on Sequencing of food plant operations; Studies on Queuing Model
- Network Analysis using CPM and PERT.

VI. Suggested Reading

- Ackoff RK and Sassioni MW. 1978. *Fundamentals of Operations Research*. Wiley Eastern, New Delhi
- Wagner HM. 1978. *Principles of Operations Research, with Applications to Management Decisions*. Prentice Hall of India, New Delhi
- Taha HA. 2007. *Operations Research: An Introduction*. Pearson Prentice Hall, New Jersey
- Goel BS and Mittal SK. 1985. *Operations Research*. Pragati Prakashan, Meerut
- Panneerselvam R. 2012. *Operations Research*. PHI Learning Pvt. Ltd.
- Prasanna C. 2009. *Projects*. Tata McGraw-Hill Publication, New Delhi.
- Nicolas JM. 2003. *Project Management for Business and Technology – Principles and Practices*. Pearson Prentice Hall
- Kerzner H and Kerzner HR. 2017. *Project Management: a Systems Approach to Planning, Scheduling, and Controlling*. John Wiley & Sons.
- Gopalakrishnan P and Ramamoorthy VE. 2005. *Textbook of Project Management*. Macmillan.

I. Course Title : Process Control in Food Industries

II. Course Code : FPE 511

III. Credit Hours : 2+1

IV. Theory

Unit I

Process Control: Dynamic behavior of first/second order systems, Response of first order systems/first order system in series. Block diagrams and transfer functions, Feedback control, P, PI, PID controllers.

Unit II

Measurement of Electrical and Non Electrical Quantities. Motion and displacement measurement: Strain gages, Hall effect devices and Proximity sensors, Large displacement measurement using synchros and resolvers, Shaft encoders. Pressure Measurement: Mechanical devices like Diaphragm, Bellows, and Bourdon tube, Variable inductance and capacitance transducers, Piezo electric transducers, Low pressure and vacuum pressure measurement using Pirani gauge, McLeod gauge, Ionization gauge. Force and Torque Measurement: Load cells and their applications, various methods for torque measurement. Flow measurement differential pressure meter like, Rotameter, Turbine flow meter, Electromagnetic flow meter, hot wire anemometer, Ultrasonic flow meter. Temperature Measurement: Resistance type temperature sensors – RTD & Thermistor Thermocouples & thermopiles, Different types of pyrometers. Humidity measurement and Moisture measurement techniques. Liquid level measurement: Resistive, inductive and capacitive techniques for level measurement, Ultrasonic and radiation methods, Air purge system (Bubbler method).

Unit III

Digital Data Acquisition Systems & Control: Use of signal conditioners, scanners, signal converters, recorders, display devices, A/D & D/A circuits in digital data acquisition. Instrumentation systems. Types of Instrumentation systems. Data–acquisition system. Multiplexing systems. Modern digital data acquisition system.

Unit IV

Industrial Automation. PLC, DCS and SCADA System: Introduction, Basic parts of a PLC, Operation of a PLC, Basic symbols used in PLC realization, Difference between PLC and Hardwired systems, Difference between PLC and computer, Relay logic to ladder logic, Ladder commands, Examples of PLC ladder diagram realization, PLC timers, PLC counters and examples, Classification of PLCs, History of DCS,DCS concepts, DCS hardware & software, DCS structure, Advantages and disadvantages of DCS, Representative DCS, SCADA, SCADA hardware & software.

Unit V

Image Processing Applications: Methodology, Shape analysis, Feature detection and object Location, Three-dimensional processing. Application to food industry: Inspection and inspection Procedures, X-Rayi, Computer vision systems, Electronic nose and Electronic tongue.

Unit VI

Virtual Instrumentation: Introduction to LABVIEW: Virtual instruments, Parts of VI, Project explorer, Front panel and block diagram window, Creating simple VI.

V. Practical

- Study of various for measurement of pressure, temperature, flow, level
- Study of PLC and to program a PLC using Ladder programming & PLC based control of Multi process system
- To make ladder logic diagrams and flow sheet diagrams for control logic
- Study of data loggers- computerized data acquisition and data processing
- Programming and making GUI in LABVIEW and softwares
- Study of SCADA Application Software/ Computerized Control of PC-PLC Based Multi-Process Control System.

VI. Suggested Reading

- McFarlane I. 1995. *Automatic Control of Food Manufacturing Processes, 2e*. Springer Science and Business Media
- Bhanot S. 2008. *Process Control: Principles and Application*. Oxford University Press.
- Singh SK. 2005. *Industrial Instrumentation & Control, 2e*. Tata McGraw-Hill Education.
- Krishnaswamy K. 2003. *Industrial Instrumentation* (Vol. 1). New Age International.
- Liptak BG. 2018. *Instrument Engineers' Handbook, Volume Two: Process Control and Optimization*. CRC press.
- Jain RK. 1988. *Mechanical and Industrial Measurements*. Khanna Publishers.
- Rangan CS, Sarma GR and Mani VSV. 1983. *Instrumentation: Devices and Systems*. Tata McGraw-Hill.
- Patranabis D. 1976. *Principles of Industrial Instrumentation*. Tata McGraw-Hill Publishing.

I. Course Title : Project Engineering and Management

II. Course Code : FPE 512

III. Credit Hours : 2+1

IV. Theory

Unit I

Overview of project management: Functions and viewpoints of management, evolution of project management, forms and environment of project management.

Unit II

Project life cycle; Project selection: Project identification and screening, project appraisal, project charter, project proposal, project scope, statement of work; Feasibility studies

Unit III

Project planning and scheduling: Work breakdown structure, planning and scheduling of activity networks, network scheduling, precedence diagrams, critical path method, program evaluation and review technique, assumptions in PERT modelling, decision CPM, GERT

Unit IV

Project cost estimating: Technical Analysis and introduction to various component of project installation and commissioning cost and their estimation; Types of estimates and estimating methods, dynamic project planning and scheduling, time-cost trade-offs, resource considerations in projects, resource profiles and levelling, limited resource allocation

Unit V

Project implementation, monitoring and control:, project management process and role of project manager, team building and leadership in projects, organizational and behavioral issues in project management, project monitoring and control, PERT/ cost method, earned value analysis

Unit VI

Elements of Cost of Production; Financing of projects: Debt-Equity ratio etc. Introduction to concepts of inflation, location index and their use in estimating plant and machinery cost. Depreciation concept, Indian norms and their utility in estimation, Capital cost estimation, Working capital estimation, Project Evaluation, break-even analysis, ROI, IRR., Discounted cash flow analysis

Unit VII

Project completion and future directions: Project completion and review; Project management: Recent trends and future directions; Computers in project management

V. Practical

- Studies on Market Survey based on enterprise
- Preparation of Project Report
- Project selection, identification, appraisal and scope
- Methods of monitoring and feasibility of projects
- Studies on investment and repayment plants
- Project monitoring and Control – PERT Modeling

VI. Suggested Reading

- Patel JB and Allampalli, D. G. 1991. *A Manual on How to Prepare a Project Report.*
- Patel JB and Modi SS. 1995. *A Manual on Business Opportunity Identification and Selection.*
- *Manual for Entrepreneurs* by EDI Ahmedabad (2005). Tata McGraw Hill Education.
- Chandra P. Projects: Planning, Analysis, Selection,Financing, Implementation, and Review
- Peters MS and Timmerhaus KD. Plant Design and Economics for Chemical Engineers
- Rase HF. *Project Engineering of Process Plants*
- Panneerselvam R. 2012. *Operations Research.* PHI Learning Pvt. Ltd.
- Prasanna C. 2009. *Projects.* Tata McGraw-Hill Publication, New Delhi.
- Nicolas JM. *Project Management for Business and Technology – Principles and Practices.* Pearson Prentice Hall
- Kerzner H and Kerzner HR. 2017. *Project management: a systems approach to planning, scheduling, and controlling.* John Wiley & Sons.
- Gopalakrishnan P and Ramamoorthy VE. 2005. *Textbook of Project Management.* Macmillan.

I. Course Title : Food Process Automation and Robotics

II. Course Code : FPE 513

III. Credit Hours : 2+0

IV. Theory

Unit I

Automated evaluation of food quality, food quality quantization and process control, typical problems in food quality evaluation.

Unit II

Data acquisition: Sampling elaboration with examples, concepts and systems for data acquisition such as: ultrasonic signal acquisition, electronic nose data acquisition, frying data acquisition for quality process control, Image acquisition.

Unit III

Data analysis: Data preprocessing, Static data analysis, Dynamic data analysis, Image processing: Image segmentation, Image feature extraction.

Unit IV

Modeling & prediction: Modeling strategies: Theoretical and empirical modeling, Static and dynamic modeling, Linear statistical modeling, ANN modeling. Prediction and classification, Sample classification based on linear statistical and ANN models, Electronic nose data; One-step-ahead prediction.

Unit V

Control: Process control, Internal model control, Predictive control, Neuro-fuzzy PDC for snack food frying process, Systems integration: Food quality quantization and process control systems integration.

Unit VI

Automation in sorting, thermal processing, fresh produce; Automation in food chilling and freezing; In storage, transport, retail systems; fruit vegetable processing; cleaning, grading, canning etc.

Unit VII

Automation in meat processing, carcass production, separation; before and after chilling; Automation in poultry industry; hanging, conveying, processing, packing;

Automation in sea food processing, in unit operations associated.

Unit VIII

Automatic process control in food industry. Process control methods in food industry, current, future trends. Robotics in food industry, specification of food sector robot, control law algorithm.

V. Practical

- To study different types of sensors for measurement of temperature, pressure, flow and level
- To study interfacing systems for analogue to digital signals
- To study sensors for automated food process control
- To study different logic controlling systems
- To study computer vision systems used in industries
- To study machine vision systems used in industries
- To study optical sensors and online spectroscopy for automated quality and safety inspection of food products
- To study supervisory Control and Data Acquisition (SCADA) and related systems for automated process control in the food industry
- To study different configurations of industrial robots
- To study gripper technologies for food industry robots
- To study wireless sensor networks (WSNs) components in the agricultural and food industries
- To study intelligent quality control systems in food processing based on fuzzy logic
- Application of automation and robotics for bulk sorting, chilling and freezing, meat processing, poultry industry, seafood processing, packaging in confectionery etc in food processing industries
- Case studies and field reports on Food Process Automation and Robotics.

VI. Suggested Reading

- Caldwell DG. (Ed.). 2012. *Robotics and automation in the food industry: Current and future technologies*. Elsevier.
- Dwivedi SN, Verma AK and Sneckenberger JE. 1991. *CAD/CAM robotics and factories of the future*. Springer
- Doeblin EO and Manik DN. 2003. *Measurement systems: applications and design, 5e*. Tata McGraw Hill.
- Kuo BC and Golnaraghi F. 1995. *Automatic control systems*, 9e. Prentice-Hall.
- Rajput RK. 2008. *Robotics and Industrial Automation*, 2e. S. Chand Publishing
- Groover MP, Weiss M, Nagel RN and Odrey NG. 1986. *Industrial Robotics: Technology, Programming, and Applications*. McGraw-Hill.
- Huang Y, Whittaker AD and Lacey RE. 2001. *Automation for Food Engineering: Food Quality Quantization and Process Control*. CRC Press.
- Bhuyan M. 2006. *Measurement and Control in Food Processing*. CRC Press.
- Zude M. 2008. *Optical Monitoring of Fresh and Processed Agricultural Crops*. CRC press.
- Dochain D. 2001. *Automatic Control of Bioprocesses. Control Systems, Robotics and Manufacturing Series*. Wiley-ISTE
- Sun DW. (Ed.). 2012. *Computer Vision Technology in the Food and Beverage Industries*. Elsevier.
- Kress-Rogers E and Brimelow CJ. (Eds.). 2001. *Instrumentation and Sensors for the Food Industry*. Woodhead Publishing.

I. Course Title : Water and Waste Management
II. Course Code : FPE 514
III. Credit Hours : 2+1

IV. Theory

Unit I

Basic considerations: Characterization of different industry effluents and utilization of by-products; Standards for emission or discharge of environmental pollutants from industries. Elements of importance in the efficient management of wastes.

Unit II

Physical and chemical parameters for waste; oxygen demands; BOD, COD and their interrelationships; residues (solids), fats, oils and grease, forms of nitrogen, sulphur and phosphorus, anions and cations, surfactants, colour, odour, taste, toxicity. Unit concept of treatment of food industry effluent, screening, sedimentation floatation as pre- and primary reactants.

Unit III

Primary treatment, secondary and tertiary waste treatments by physical, chemical and biological methods. Effluent and solid waste utilization by Biological oxidations: Objects, organisms, reactions, oxygen requirements, aeration devices systems: lagoons, activated sludge process, oxidation ditches, rotating biological contractors and their variations and advanced modifications.

Unit IV

Wastewater treatment systems. Physical separations, coagulation and flocculation; micro-strainers, filters, ultra-filtration and reverse osmosis; water softening. Physico-chemical separations: activated carbon adsorption, ion-exchange electro-dialysis and magnetic separation. Chemical oxidations and treatment coagulation and flocculation. Disinfection. Handling disposal of sludge.

Unit V

Waste management strategies and value added products from of agri-food processing industry; Recovery of biologicals from fruit, vegetables, dairy, meat, fish and poultry processing industry.

V. Practical

- Determination of Alkalinity, Acidity and pH of a given waste water sample
- Determination of electric conductivity of a given sample
- Determination of hardness (Chlorides and Sulphates) of a given waste water sample
- Determination of Solids in wastewater, Total Solids, Suspended Solids, Dissolved Solids, Volatile Solids, Fixed Solids, Settleable Solids
- Estimation of dissolved oxygen and BOD exerted by the given waste water sample
- Estimation of COD exerted by the given waste water sample
- Determination of Nitrates in waste water
- Determination of Fats, oils and greases in waste water
- Determination of fecal contamination of water- qualitative and quantitative Estimation
- Determination of SPC of different wastes
- Visit of an effluent treatment plant in a food processing industry.

VI. Suggested Reading

- Arvanitoyannis IS. 2010. *Waste management for the food industries*. Academic Press.
- Zall RR. 2008. *Managing food industry waste: Common sense methods for food processors*. John Wiley and Sons.
- Shuler ML, Kargi F, DeLisa M. 2017. *Bioprocess engineering: basic concepts*. Prentice-Hall.
- Waldron KW. (Ed.). 2009. *Handbook of waste management and co-product recovery in food processing*. Elsevier.
- Mattsson B and Sonesson U. (Eds.). 2003. *Environmentally-friendly food processing*. Woodhead publishing.
- Environment (Protection) Act 1986, Govt of India and relevant publications

Course Title with Credit Load
Ph.D. in Process Engineering

Course Code	Course Title	Credit Hours
Major Courses		
FPE 601	Food Machinery and Utility Design	3+0
FPE 602	Concentration and Drying Engineering	3+0
FPE 603	Automation and Robotics	2+0
FPE 604	System Analysis and Optimization	3+0
FPE 605	Food Analytical Techniques	1+2
FPE 606	Food Handling and Storage Engineering	3+0
FPE 607	Separation Engineering	3+0
FPE 608	Novel Food Process Engineering	2+0
FPE 609	Design of Packaging System	2+0
FPE 610	Special problem	0+2
Minor Courses		
FPT 601	Novel Technologies for Food Processing and Shelf Life Extension	3+0
FPT 605	Food Process Modeling and Scale up	3+0
FSQ 603	Quality Assurance in Food Supply Chain	3+0
FSQ 604	Formulation of Standards of Food Products, Packaging and Labeling	2+0
Supportive Courses		
FPE 605	Food Analytical Techniques	1+2
FSQ 607	Sensory Evaluation of Foods	2+0
Seminar		
FPE 631	Seminar I	0+1
FPE 641	Seminar II	0+1

Course Contents
Ph.D. in Process Engineering

I. Course Title : Food Machinery and Utility Design
II. Course Code : FPE 601
III. Credit Hours : 3+0

IV. Theory

Current trends in use of machinery and utilities, utilities for production of indigenous food products, systems used in mass food production, codes and standards applicable, performance assessment, safety and hygiene requirement with respect to machine, products and operator, suitability and scale of automation, innovativeness, environmentally friendly, ergonomics, resource utilization and assessment.

V. Suggested Reading

- Myer K. 2013. *Handbook of Farm, Dairy, and Food Machinery*, 2e. Academic Press
- Hitzmann B. 2017. *Measurement, Modeling and Automation in Advanced Food Processing*. Springer
- Norton RL. 2003. *Design of Machinery*. McGraw-Hill
- Traitler H, Coleman B, Hofmann K. 2014. *Food Industry Design, Technology and Innovation*. Wiley-Blackwell.
- Piramuthu S and Zhou W. 2015. *RFID and Sensor Network Automation in the Food Industry*. Wiley-Blackwell.
- Holah J and Lelieveld H. 2011. *Hygienic Design of Food Factories*. Woodhead Publishing

I. Course Title : Concentration and Drying Engineering
II. Course Code : FPE 602
III. Credit Hours : 3+0

IV. Theory

Recent development in concentration and drying processes, technologies and engineering, problem solving and case studies.

V. Suggested Reading

- Anandharamakrishnan C and Padma IS. 2015. *Spray Drying Techniques for Food Ingredient Encapsulation*. Wiley-Blackwell
- Oetjen GW, Haseley P. 2018. *Freeze-Drying*, 3e. Wiley-VCH
- Krokida M. 2018. *Thermal and Nonthermal Encapsulation Methods*. CRC Press
- Anandharamakrishnan C. 2017. *Handbook of Drying for Dairy Products*. Wiley-Blackwell
- Zhang M, Bhandari B, Fang Z. 2017. *Handbook of Drying of Vegetables and Vegetable Products*. CRC Press
- Prakash O, Kumar A. 2017. *Solar Drying Technology: Concept, Design, Testing, Modeling, Economics and Environment*. Springer Singapore
- Karim A, Law CL. 2017. *Intermittent and Nonstationary Drying Technologies: Principles and Applications*. CRC Press
- Vasile M. 2016. *Advances in Heat Pump-Assisted Drying Technology*. CRC Press
- MengWai W. 2016. *Computational Fluid Dynamics Simulation of Spray Dryers: An Engineer's Guide*. CRC Press

- Reis FR. 2014. *Vacuum Drying for Extending Food Shelf-Life*. Springer International Publishing
- Rodrigues S. 2008. *Advances in Fruit Processing Technologies*. CRC Press
- Angela M and Meireles A. 2008. *Extracting Bioactive Compounds for Food Products Theory and Applications*. CRC Press
- Rivas EO. 2009. *Processing Effects on Safety and Quality of Foods*. CRC Press
- Lebovka NI, Vorobiev E, Cheìmat F. 2012. *Enhancing Extraction Processes in the Food Industry*. CRC Press

I. Course Title : Automation and Robotics
II. Course Code : FPE 603
III. Credit Hours : 2+0

IV. Theory

Rigid-body kinematics, inverse kinematics, newton-euler dynamics of robots, lagrangian dynamics, kane's method in robotics, systems of interacting rigid bodies, trajectory planning for flexible robots, robotic end effectors, sensors, precision positioning of rotary and linear systems, modeling and identification for robot motion control, step motion control by linear feedback methods, force/impedance control for robotic manipulators, robust and adaptive motion control of manipulators, sliding mode control of robotic manipulators, impedance, coordinated motion control of multiple manipulators, robot simulation, geometric vision, interface to virtual environments, flexible robot arms, manufacturing automation, problem solving and case studies.

V. Suggested Reading

- Caldwell DG. 2013. *Robotics and Automation in the Food Industry: Current and Future Technologies*. Woodhead Publishing
- Huang Y, Whittaker AD, Lacey RE. 2001. *Automation for Food Engineering: Food Quality Quantization and Process Control*. CRC Press
- Greeves T and Moore CA. 1995. *Automation in the Food Industry*. Springer
- Sandeep KP. 2011. *Thermal Processing of Foods: Control and Automation*. Wiley-Blackwell
- Derby SJ. 2005. *Design of Automatic Machinery*. Marcel Dekker
- Piramuthu S and Zhou W. 2015. *RFID and Sensor Network Automation in the Food Industry*. Wiley-Blackwell

I. Course Title : System Analysis and Optimization
II. Course Code : FPE 604
III. Credit Hours : 3+0

IV. Theory

Analyzing and creating data flow diagram, system development, requirement elicitation techniques, analysis strategies, creating and validating entity relation diagram, system acquisition, analysis of architectural design, hardware and software specification, moving logical models, and optimizing techniques for food plant systems, implementation, local and total optimization, optimization with and without restrictions; Total optimization techniques, Global search algorithms, Genetic Algorithms, Firefly Algorithm, Particle Swarm Optimization, advanced applications of Matlab and other softwares, problem solving and case studies.

V. Suggested Reading

- Lisnianski A, Frenkel I, Ding Y. 2010. *Multi-state system reliability analysis and optimization for engineers and industrial managers*.
- Huang Y, Whittaker AD, Lacey RE. 2001. *Automation for Food Engineering: Food Quality Quantization and Process Control*. CRC Press
- Haug EJ. 1984. *Computer aided Analysis and Optimization of Mechanical System Dynamics*. Springer
- Zin TT, Lin JCW. 2019. *Big Data Analysis and Deep Learning Applications*. Springer
- Ratner B. 2011. *Statistical and Machine-Learning Data Mining: Techniques for Better Predictive Modeling and Analysis of Big Data*, 2e. CRC Press
- Erdogdu F. 2008. *Optimization in Food Engineering*. CRC Press

I. Course Title : Food Analytical Techniques

II. Course Code : FPE 605

III. Credit Hours : 1+2

IV. Theory

Hands on experience on advance methods, equipment and instruments used for analysis of raw material, food products and confirmation of standards. Offline and online assessment of food properties.

V. Practical

Practice on UV-Visible, IR, Raman, & Mass spectroscopy.
Practice on Fluorescence, Turbidimetric and related techniques.
Practice on NMR/ESR spectroscopy.
Practice on general and advanced chromatographic (HPLC, GC, Paper, TLC/HPTLC, Ion, Flash etc.) techniques.
Practice on biological techniques such as Electrophoresis, PCR/RTPCR, Immunoassays etc
Practice on Immuno based analytical techniques such as ELISA & Lateral flow assay.
Determination of common adherents, colour, flavours and composition using specified methods.
Separation of selected biomolecules (protein, colour, amino acids, fat, colour, flavours, peptides, anti/ nutritional factors, casein etc) using different techniques.
Gel-filtration of biomolecules.
SDS gel electrophoresis and molecular weight determination.
Measurement of size and zeta potential of colloidal solution or emulsion using dynamic light scattering/ particle size analyser.
Practice on purification of selected biomolecules.
Estimation of minerals using AAS.
Determination of specific and non-specific antimicrobial factors of selected biomolecules.
Determination of health benefits of selected biomolecules/ products.
Correlation of offline with online assessment of selected parameters.
Correlation among industrial, national and international methods of selected concerned parameters.

VI. Suggested Reading

- Boziaris IS. 2014. *Novel Food Preservation and Microbial Assessment Techniques*. CRC Press

- Renfu L. 2016. *Light scattering technology for food property, quality and safety assessment*. CRC Press

I. Course Title : Food Handling and Storage Engineering

II. Course Code : FPE 606

III. Credit Hours : 3+0

IV. Theory

Recent development in handling and storage. Bulk storage structure, silos, cold storages, CA storages, Modified atmosphere storage, transportation and cold chain systems, handling and storage low and ambient temperatures, during supply chain, codes and standards, problem solving and case studies.

V. Suggested Reading

- Guineì RPF, Correia PMR. 2013. *Engineering Aspects of Cereal and Cereal-based Products*. Taylor & Francis
- Mascheroni RH. 2012. *Operations in Food Refrigeration*. CRC Press
- Farid MM. 2010. *Mathematical Modeling of Food Processing*. CRC Press
- Teixeira JA and Vicente AK. 2014. *Engineering Aspects of Food Biotechnology*. CRC Press
- Varzakas T, Tzia C. 2014. *Food Engineering Handbook*. CRC Press
- Saravacos GD, Maroulis ZB. 2011. *Food Process Engineering Operations*. CRC Press
- Ron BH Wills, Golding JB. 2015. *Advances in Postharvest Fruit and Vegetable Technology*. CRC Press
- Petr D, Marilyn R. 2015. *Engineering Aspects of Food Emulsification and Homogenization*. CRC Press
- Constantina T, Theodoros V. 2016. *Handbook of Food Processing: Food Safety, Quality, and Manufacturing Processes*. CRC Press

I. Course Title : Separation Engineering

II. Course Code : FPE 607

III. Credit Hours : 3+0

IV. Theory

Recent development in separation processes (absorption, adsorption, extraction, distillation, chromatography, crystallization, flocculation, coagulation and membranes etc), associated material and mass balance, material for construction and interaction with products, resource requirements, design configurations, codes and standards applicable, problem solving and case studies.

V. Suggested Reading

- Field RW, Molnar EB, Lipnizki F, Vatai G. 2017. *Engineering Aspects of Membrane Separation and Application in Food Processing*. CRC Press
- Holland CD. 1983. *Computer Methods for Solving Dynamic Separation Problems*. Mcgraw Hill
- Wankat PC. 2012. *Separation Process Engineering*, 3ed. Prentice Hall
- Sridhar S. 2019. *Membrane Technology*. CRC Press
- Rushton A, Ward AS, Holdich RG. 1996. *Solid-Liquid Filtration and Separation Technology*. Wiley-VCH
- Tewari PK. 2016. *Nanocomposite Membrane Technology*. CRC Press
- Basile A, Figoli A, Khayet M. 2015. *Pervaporation, vapour permeation and membrane distillation: principles and applications*. Woodhead Publishing

- Dickson J, Hu K. 2015. *Membrane Processes for Dairy Ingredient Separation*. John Wiley & Sons
- Hoek EMV, Tarabara VV. 2013. *Encyclopaedia of Membrane Science and Technology*. Wiley
- Levy RV, Jornitz MW, Jornitz MW. 2006. *Sterile Filtration*. Springer-Verlag Berlin Heidelberg
- Chemat S. 2017. *Edible oils: Extraction, Processing, and Applications*. CRC Press

I. Course Title : Novel Food Process Engineering

II. Course Code : FPE 608

III. Credit Hours : 2+0

IV. Theory

Developments in thermal and non-thermal processes such as HPP, SCFE, cryoprocessing, PSE, cold plasma, ultrasonication, radiofrequency, pulse light, microencapsulation, micro fluidization, spray freeze drying, minimal processing, radiation processing, fermentation, novel sensors etc problem solving and case studies.

V. Suggested Reading

- Houška M, Vinagre Silva FVM. 2017. *High Pressure Processing of Fruit and Vegetable Products*. CRC Press
- Lebovka NI, Vorobiev E; Cheìmat F. 2012. *Enhancing Extraction Processes in the Food Industry*. CRC Press
- Passos, and Ribeiro P. 2016. *Innovation in Food Engineering: New Techniques and Products*. CRC Press
- Tokusoglu O, Swanson BG. 2014. *Improving Food Quality with Novel Food Processing Technologies*. CRC, Taylor and Francis
- Koutchma T. 2014. *Adapting High Hydrostatic Pressure (HPP) for Food Processing Operations*. Academic Press
- Ojha KS, Tiwari BK. 2016. *Novel Food Fermentation Technologies*. Springer International Publishing
- Rahman MA, Mukhopadhyay SC, Yu PL. 2014. *Novel Sensors for Food Inspection: Modelling, Fabrication and Experimentation*. Springer International Publishing
- Boziaris IS. 2014. *Novel Food Preservation and Microbial Assessment Techniques*. CRC Press
- Angela A and Meireles A. 2008. *Extracting Bioactive Compounds for Food Products Theory and Applications*. CRC Press
- Rivas EO. 2009. *Processing Effects on Safety and Quality of Foods*. CRC Press

I. Course Title : Design of Packaging System

II. Course Code : FPE 609

III. Credit Hours : 2+0

IV. Theory

Compatibility of packaging material with products, designing of unit and bulk package, developments in smart, intelligent and active packaging, continuous packaging systems for liquid and food, recent development in testing of packaging material and interaction, migrations study, edible packaging, process friendly packaging, shelf life assessment, codes and standards, problem solving and case studies.

V. Suggested Reading

- Ahvenainen R. 2003. *Novel Food Packaging Techniques*. CRC Press
- Piringer OG, Baner AL. 2008. *Plastic Packaging: Interactions with Food and Pharmaceuticals*, 2e. Wiley-VCH
- Piringer OG and Baner AL. 2000. *Plastic Food Packaging Materials: Barrier Function, Mass Transport, Quality Assurance, Legislation*. Wiley-VCH
- Brody AL. 2001. *Active Packaging for Food Applications*. CRC Press
- Sun DW. 2000. *Handbook of Frozen Food Processing and Packaging*. CRC Press
- Angelo CM. 2015. *Edible Food Packaging: Materials and Processing Technologies*. CRC Press
- Robertson GL. 2009. *Food Packaging and Shelf Life A Practical Guide*. CRC Press
- Moskowitz HR, Reisner M, Lawlor JB, Deliza R. 2009. *Packaging Research in Food Product Design and Development*. Wiley-Blackwell
- RinusRijk and Veraart R. 2010. *Global Legislation for Food Packaging Materials*. Wiley-VCH
- Contemporary Food Engineering Series of CRC Press

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 4

Food Technology
– Safety and Quality

Preamble
(Safety and Quality)

Effective food safety and quality management systems are key not only to safeguarding the health and well-being of people but also to fostering economic development and improving livelihoods by promoting access to domestic, regional and international markets. Ensuring food safety is a public health priority. It incurs loss to global trade leading to further food waste, which can no longer be tolerated in a world where many still suffer from hunger. Effective food safety and quality management systems are key not only to safeguarding the health and well-being of people but also to fostering economic development and improving livelihoods by promoting access to domestic, regional and international markets.

Over the years Food Safety and Quality studies immersed as a scientific discipline describing handling, preparation, and storage of food in ways that prevent food-borne illness. This was well realized by the 5th Deans' Committee while they chose to have 'Food Safety and Quality Assurance' as one of the departments at College of Food Technology under Agricultural University setup in the country. Food Safety and Quality has been an area of priority for consumers, retailers, manufacturers and regulators. In the country FSSAI is now taking proactive steps in interest of consumers and to implement science based regulations related to food. This motivated the BSMA Committee for Food Science and Technology to come up with a new stream of M.Tech. and Ph.D. programme in the area Food Safety and Quality.

Food Safety and Quality Management is rapidly gaining importance both at national as well as international levels due to various reasons, viz. implementation of FSS Act 2006, globalization of food trade, harmonization of national standards with CODEX, legal changes at national and international levels etc. To implement the Act in the country, there is a need for human resources at various levels involving different stakeholders in the food chain from farm to fork which includes Auditors, Designated Officers, Adjudicating Officers and Food Safety Officers, Food Auditors, Food Analysts, Food Handlers etc. Development of trained human resource in food safety sector is essential for the future growth of food processing and national – international trade from it.

Present M. Tech. Food Technology (Safety and Quality) course frame work has its parity with national frame work with credit distribution among the different course types core and optional subject with due credits to seminar and research. Present curriculum at UG level offers adequate introduction on the safety and quality basics through that courses related to microbiology, chemistry, nutrition, basic analytical techniques, including the aspects of plant sanitation and HACCP. For advancement of knowledge and core competence courses on food quality, analysis, handling of food pathogens, chain traceability etc are kept as compulsory. The course content also offer opportunity to learn statistical and engineering aspect of quality including robust knowledge on risk assessment.

Here besides theory teaching practical hands on exposure is also a focus. Other core courses may be selected as per the resources and need analysis which are related to global regulatory and certification requirements, toxicology, food informatics etc. Future researchers as per their interest may find and opportunity to opt for a formal learning on research methodology and advanced food chemistry. Course structure also provides scope for learning across the PG departments. Master students of safety-quality will also have option to study Emerging Techniques in Food Packaging, Bio-processing, Down Stream Engineering, Industrial Manufacturing, Numerical Technique and Stimulation, Storage Engineering, Energy Management and Auditing in Food Industry etc.

Ph.D. programme in Safety and Quality is first of its kind in the country which intends to offer Ph.D. on this specialization as a formal degree. So far limited work in this area is taking place in the country and that to under general food technology programmes. The major highlights of Ph.D. programme are a formal course structure focused on the discipline of safety and quality with an opportunity to sharpen the instrumentation skill in a lab course. The researchers will be exposed to advances in food quality and safety assessment, health claim validation, toxicology and risk assessment, etc. along with food law making process nationally and at international front.

Thus the M.Tech. programme is intended to offer the industry ready professionals for food processing sector on one hand while they would be given training so that they can ponder upon the industry problems to offer solution either through deep scientific research or problem solving approach for quick industry solution and immediate response. The programme will also be good for who enjoy quality control job or interested in strengthening their proficiency in design and implementations of quality management systems. The programme shall also open new vista for entrepreneurs who intend to diversify in Food Safety and Quality Aspects. While Ph.D. programme is envisaged to begin a new era of food safety and quality research. While proposing this programme it is believed that this programme will also cover research gap in the area and will provide primary data from the country to be used in international platforms like Codex which has been lacking in the past. The committee also has taken care that course in safety quality should offer knowledge opportunity matching to contemporary global scenario in the field. The committee hopes that the course will meet the expectations of different stakeholders of the sector and learners.

Course Title with Credit Load
M.Tech. in Safety and Quality

Major Courses

Course Code.	Course Title	Credit Hours
FSQ 501	Techniques in Food Quality Analysis*	2+2
FSQ 502	Microbiology of Food Spoilage and Pathogens*	2+1
FSQ 503	Advanced Food Chemistry	2+1
FSQ 504	Global Food Laws and Regulations	2+0
FSQ 505	Food Safety Management Systems and Certification	2+1
FSQ 506	Process and Products Monitoring for Quality Assurance	2+0
FSQ 507	Quality Concepts and Chain Traceability*	2+0
FSQ 508	Management of Food By-products and Waste	2+0
FSQ 509	Special Problem/ Summer Internship	0+2
FSQ 510	Toxicology of Food Ingredients and Products	2+1
FSQ 511	Food Plant Utilities and Sanitation	2+0

*CompulsoryRest of the courses will be decided by the students advisory committee keeping the minimum limits set for award of degree.

Minor Courses

Course Code.	Course Title	Credit Hours
FPT 502	Emerging Technologies in Food Packaging	2+0
FPT 503	Industrial Manufacturing of Food and Beverages	2+1
FPT 504	Food Material and Product Properties	2+1
FPT 514	Food Ingredients and Additives	2+1
FPT 510	Aseptic Processing and Packaging	2+1
FPE 502	Engineering Properties of Food Materials	2+1
FPE 504	Bioprocessing and Down Stream Engineering	2+1
FPE 506	Numerical Technique and Stimulation	1+1
FPE 508	Food Safety and Storage Engineering	2+1

Supporting Courses

Course Code.	Course Title	Credit Hours
BSH 501	Research Methodology	2+0
BSH 502	Food Informatics	1+1
FBM 501	Post-Harvest Management	2+1

Course Code.	Course Title	Credit Hours
FBM 502	Food Business Management	2+0
FBM 503	Food Processing Entrepreneurship and Start up	0+1
FPE 515	Energy Management and Auditing in Food Industry	2+1
FPE 510	Operation Research	2+1

Common Courses

S. No.	Course Title	Credits
1.	Library and Information Services	1
2.	Technical Writing and Communications Skills	1
3.	Intellectual Property and its Management in Agriculture	1
4.	Basic Concepts in Laboratory Techniques	1
5.	Agricultural Research, Research Ethics and Rural Development Programmes	1

These courses are available in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

Seminar

Course Code	Course Title	Credit Hours
FSQ 599	Seminar	0+1

Course Contents
M.Tech. in Safety and Quality

I. Course Title : Techniques in Food Quality Analysis
II. Course Code : FSQ 501
III. Credit Hours : 2+2

IV. Theory

Unit I

Sampling Procedures, Calibration and Standardization: Sub- sampling and its procedures, LOD, LOQ, Internal standards, Reference standards and certified reference materials. Spectroscopy techniques: Operation, calibration and standardization procedures as applicable to particular technique. Principles and applications of pH Meter, Digital analyzer, Auto-analyzer, Ultraviolet-visible spectroscopy (UV-VIS), Infra-Red, Fourier-Transform Infrared Spectroscopy (FTIR), Near Infra Red (NIR), Atomic Absorption spectroscopy (AAS).

Unit II

Chromatography Techniques: Principles, Components and applications of (i) Paper Chromatography-Ascending and Descending-One dimensional & Two dimensional (ii) Thin layer chromatography (iii) Ion Exchange (iv) GC (v) GLC (vi) HPLC (vii) HPTLC (viii) GCMS (ix) LCMS (x) Amino acid Analyzer.

Unit III

Separation Techniques: Dialysis, Gel filtration, Electrophoresis: Principles, components and applications of (i) Paper (ii) Starch (iii) Gel (iv) Agar-gel (v) Polyacrylamide gel (vi) Moving boundary (vii) Immuno electrophoresis. Centrifugation: Types of centrifuge – Ordinary and Ultracentrifuge- Principle and applications.

Unit IV

Principle, Components and Applications of (i) Differential scanning calorimetry (DSC) (ii) Thermogravimetric analysis (TGA) (iii) Isothermal microcalorimetry (IMC) (iv) Thermomechanical analysis (TMA) (v) Isothermal titration caloritmetry (ITC) (vi) Dynamic elemental thermal analysis (DETA) (vii) Nuclear magnetic resonance (NMR) (viii) Scanning electron microscopy (SEM) (ix) Transmission electron microscopy (TEM) (x) X-ray diffraction technique (XRD) (xi) Rapid visco-analyzer (xii) Texture analyzer and (xiii) Micro-dough lab.

V. Practical

- Analysis and characterization of pigment in fruits by UV-VIS.
- Characterization of starches by FTIR spectroscopy.
- Assessment of microstructure of food components by SEM/Reviewing a micrograph obtained through SEM
- Study of thermal denaturation of proteins and food enzymes by DSC.
- Quantization of allergenic proteins by LCMS.

- Separate and identification of pesticides in food samples by HPLC.
- Identification and molecular characterization of proteins by SDS-PAGE.
- Quantization of lipids and fatty acids using TLC.
- Assessment of pasting properties of starches and flours/flour-blends using RVA.
- Analysis of textural properties of food products with texture analyzer.
- Comparative rheological study of wheat flour samples of different varieties.
- Differential thermal analysis (DTA) and Thermogravimatric Analysis of a food samples
- A rapid, visual demonstration of protein separation by gel filtration chromatography.
- Amino acid profiling of food samples

VI. Suggested Reading

- Ongkowijoyo P, Luna-Vital DA, de Mejia EG. 2018. *Extraction Techniques and Analysis of Anthocyanins from Food Sources by Mass Spectrometry: An Update Food chemistry*.
- Trimigno A, Marincola FC, Dellarosa N, Picone G and Laghi L. 2015. *Definition of Food Quality by NMR-based Foodomics, Current Opinion in Food Science* 4:99-104.
- Pare JRJ and Bélanger JMR. 2015. *Instrumental Methods of Food Analysis*: Elsevier.
- Cifuentes A. 2012. *Food Analysis: Present, Future, and Foodomics,* ISRN Analytical Chemistry.
- Skoog DA, Holler FJ and Nieman TA. 1998. *Principles of Instrumental Analysis* (5 Ed.): Harcourt, Singapore.

I. Course Title : Microbiology of Food Spoilage and Pathogens

II. Course Code : FSQ 502

III. Credit Hours : 2+1

IV. Theory

Unit I

Food Borne Pathogens, Host Invasion, Pathogenesis, Significance to public health Food hazards and risk factors, Pathogenic foodborne microorganisms – *Salmonella, Pathogenic Escherichia coli* and other *enterobacteriaceae, Staphylococcus aureus, Listeria monocytogenes, Clostridium botulinum, Clostridium perfringens and Bacillus cereus* Other Gram-positive pathogens, *Campylobacter, Brucella, Aeromonas, Vibrio cholerae, Mycobacterium, Shigella.*

Unit II

Fungal and viral food-borne disorders, Food-borne important animal parasites, Mycotoxins, Incidence and behavior of microorganisms in meat, poultry, milk and milk products, fresh agro produce, sea foods.

Unit III

Controlling pathogens and microbial toxin via food processing, Microbial growth and shelf life, Modeling of microbial growth, Safety concerns of food processed through non thermal processing, management of microbial risk and toxin in foods through HACCP, Risk in antimicrobial nano materials, Risk assessment and predictive modeling

Unit IV

Molecular approaches for detection and identification of food borne pathogens, Enzyme Immunoassay (EIA), Enzyme-linked immunosorbent assay (ELISA), Radioimmunoassay (RIA) - instrumentation and applications of each immunoassay technique. DNA: DNA purification, DNA Fingerprinting. PCR/RTPCR (Real time) based analysis and sequencing, Biosensors, Recombinant DNA technology; Microchip based techniques, cDNA and genomic libraries, immunochemical techniques.

V. Practical

- Preparation of common laboratory media and special media for cultivation of bacteria, yeast & molds.
- Isolation and identification of pathogens.
- Coliforms analysis of milk and water samples.
- Identification tests for bacteria in foods: IMVIC urease, catalase, coagulase, gelatin and fermentation (acid/gas).
- Determination of thermal death characteristics of bacteria.
- Determination of DNA and RNA of spoilage microorganism using PCR.
- Detection of DNA of trace components allergens, like nuts using ELISA.
- DNA/RNA based microarray experiment.
- Demonstration of DNA fingerprinting.
- Determination of growth and activity of microorganisms in incubator.
- Determination of preservatives and food colours using Biosensor.
- Process time calculation for an indicator organism
- Microbes responsible recall – case studies.

VI. Suggested Reading

- Ray B and Bhunia A. 2007. *Fundamental Food Microbiology*, 4th Ed. CRC Press, Boca Ratan, FL.
- Food and Drug Administration. *Food-Borne Pathogenic Microorganisms and Natural Toxins Handbook: The Bad Bug Book*.
- Fratamico PM, Bhunia AK and Smith JL. 2005. *Food-Borne Pathogens: Microbiology and Molecular Biology*. Caister Academic Press.
- Juneja VK, Dwivedi HR and ofos JN. (Eds) 2017, *Microbial Control and Food Preservation - Theory and Practice*, Springer
- Schmidt RH and Rodrick GE. 2013 *Food Safety Handbook* Wiley

I. Course Title : Advanced Food Chemistry

II. Course Code : FSQ 503

III. Credit Hours : 2+1

IV. Theory

Unit I

Composition, nutritional and functional value of food: Water activity and sorption phenomenon, Engineered foods and influencing water activity and shelf-life; Chemical reactions of carbohydrates–oxidation, reduction, with acid & alkali; Maillard reaction, Caramelization, Ascorbic acid oxidation, Resistant Starch, Soluble and Insoluble fibre, Pigments and approaches to minimize the impact of food processing, Molecular Mobility.

Unit II

Structure and Properties of proteins; electrophoresis, sedimentation, amphoterism, denaturation, viscosity, gelation, texturization, emulsification, foaming, protein-protein and other interactions in food matrix; Lipids: melting point, softening point, smoke, flash and fire point, turbidity point, polymorphism and polytypism; polymerization and polymorphism, flavor reversion, auto-oxidation and its prevention, fat in food matrix like fat globule in milk, PUFA, MUFA, CLA, ω - fatty acids, trans fatty acids, phytosterol, etc.

Unit III

Description of food flavours; Flavour enhancers, Food acids their tastes and flavours, Principles and techniques of flavour encapsulation, types of encapsulation; Factors affecting stabilization of encapsulated flavour and their applications in food industry.

Unit IV

Processing and packaging induced chemicals and their control – acrylamide, nitrosamines, carcinogenic and genotoxicchlorpropanols such as 3-monochloropropane-1, 2-diol (3-MCPD), PAHs (in grilled and smoked products), dioxine, histamine, ethyl carbamate, furan, bisphenol A or phthalates from plastic materials, microplastics, 4-methylbenzophenone and 2-isopropylthioxanthone from inks, mineral oil from recycled fibres or semicarbazide from a foaming agent in the plastic gasket.

V. Practical

- Estimation of protein content in food samples using spectroscopic methods
- Study of effect of heat on protein denaturation using enzymes
- Study of effect of various salt solutions on solubility of proteins
- Separation of milk proteins by salting out method
- Separation of proteins using chromatographic methods
- Fractionation of proteins
- Extraction and purification of essential oil/ flavouring compound of a natural source
- Study the process of starch retrogradation, gelatinization and modification
- Estimation of crude and dietary fibres in given food sample
- Analysis of resistant starches
- Estimation of various antioxidants, polar compounds and free fatty acids in frying oils
- Extraction and purification of natural plant pigment
- Functional properties and isoelectric point of proteins
- Qualitative and quantitative evaluation of processing and packaging induced chemicals
- Qualitative identification of different flavouring compounds

VI. Suggested Reading

- Fennema OR, Ed., 2008. *Food Chemistry*, Marcel and Dekker, Inc., New York, NY.
- Belitz HD, Grosch W and Schieberle P. 2009. *Food Chemistry*. Springer.
- Varelis P, Melton L and Shahidi F. 2019. *Encyclopedia of Food Chemistry*. Elsevier.
- Cheung P, Mehta CK and Bhavbhuti M. 2015. *Handbook of Food Chemistry*. Springer

I. Course Title : Global Food Laws and Regulations

II. Course Code : FSQ 504

III. Credit Hours : 2+0

IV. Theory

Unit I

International Plant Protection Convention, world organization for animal health (OIE), sanitary and phytosanitary measures (SPS), Codex Alimentarius, FAOLEX, OECD Agriculture and Fisheries, International Trade Centre's Standards Map, FAO Food safety and quality emergency Prevention, JFSCA, Fundamental Principles of food safety governance, Risk Analysis as a Method to Determine the Regulatory Outcome, Increasing Responsibility of Businesses (Private) Risk Assessors, Concept of harmonization of global food laws,

Unit II

EU Food Safety Standards - Regulation 178 of 2002, The European food safety authority (EFSA), A critical overview of the EU food safety policy and standards, COMESA Food Safety Standards - An overview, Case Studies in Food Safety Standards in EU-COMESA Trade, Private voluntary standards (PVS) and EU food safety standards, FDA Food safety modernization Act (FSMA), FSPCA Preventive Controls for Human Food, Foreign Supplier Verification Programs (FSVP), Food Facility Registration, FDA - Current Good Manufacturing Practices (CGMPs)

Unit III

Hazard Analysis & Critical Control Points (HACCP) guidelines, Foreign Food Facility Inspection Program, International and Interagency Coordination, Registration of Food Facilities, Seafood Imports and Exports, Regulation on GM Foods, Regulations on Irradiated foods, Global Regulations on Health Foods, International Law on Adequacy of thermal processing, Grain Fumigation for Export, Law of trading horticultural Products, Safety Frame Applied to Food Applications of Nanotechnology.

Unit IV

Review of Indian Regulatory Scenario in Food and Food Products - Food Safety and Standards (FSS) Act, 2006, FSS Rules and Regulations, Agricultural Produce Act, 1937 (Grading and Marketing), Export (Quality Control & Inspection), Act, 1963 and Rules, Bureau of Indian Standards relevant to food safety, Legal Metrology Act, International Food Control Systems/ Laws

V. Suggested Reading

- Osiemo O. 2018. *Food Safety Standards in International Trade: The Case of the EU and the COMESA*, CRC
- Villarreal AM. 2018. *International Standardization and the Agreement on Technical Barriers to Trade*, Cambridge University Press
- Meulen B, Bremmers H, Purnhagen K, Gupta N, Bouwmeester HL and Geyer L. 2014. *Governing Nano Foods: Principles-Based Responsive Regulation*
- Understanding the Codex Alimentarius, 3rd ed., 2006.
- Vapnek J and Spreij M. 2005. *Perspectives and Guidelines on Food Legislation, with a new model food law for the Development Law Service* FAO Legal Office
- US FDA Website
- European Food Safety Authority (EFSA) website

I. Course Title : Food Safety Management Systems and Certification

II. Course Code : FSQ 505

III. Credit Hours : 2+0

IV. Theory

Unit I

Food safety management systems and its requirements for any organization in the food chain, Block chain concept, Global food safety initiative (GFSI), PAS 220, Prerequisite programs on food safety for food manufacturing, Audits: Introduction, objectives, documentation, responsibilities.

Unit II

Food safety plan overview, Good manufacturing practices and other prerequisite programs, GAP and GMP, Preliminary Steps in Developing a food safety plan, Resources for food safety plans, HACCP, TACCP and VACCP.

Unit III

Biological/ Chemical/ Physical and Economically motivated food safety hazards, Process preventive controls, Food allergen preventive controls, Sanitation preventive controls, supply chain preventive controls, verification and validation Procedures, Record Keeping Procedures, Recall Plan

Unit IV

FSMS and FSSC 22000. ISO 22003, ISO 20005 and traceability in food chain, ISO 14000 series – certification and its importance, ISO 17025 - General requirements for the competence of testing and calibration laboratories, BRC Standard, BRC Storage and Distribution, SQF, Southern Rocklobster Seafood, Retailer programs like Woolworths, Coles, Costco and ALDI, Concept of Auditing.

V. Suggested Reading

- Salazar E. 2013. *Understanding Food Safety Management Systems: A Practical Approach to the Application of ISO-22000:2005*, Create Space Independent Publishing Platform.
- ISO 22000 *Standard Procedures for Food Safety Management Systems*, 2008, Bizmanualz, Inc.
- Dillon M and Griffith C (ed). 2001. *Auditing in the Food Industry - From Safety and Quality to Environmental and Other Audits*, CRC Press
- Inteaz A. 2003. *Food Quality Assurance: Principles and Practices*, CRC Press
- Respective certification documents

I. Course Title : Process and Products Monitoring for Quality Assurance

II. Course Code : FSQ 506

III. Credit Hours : 2+0

IV. Theory

Unit I

Variability of the Production Process - Control chart of the middle values and ranges, Medians and ranges, Middle values and standard deviations, Largest and smallest selected value and other individual values.

Unit II

Automation of the Control of Production Processes, Fluorescence cytometry for the rapid analysis of food microorganisms, Infrared spectroscopic methods,

Unit III

Machine vision for the food industry, Ultrasonic methods, Sampling procedures for on line quality

Unit IV

Evaluation the Capability of Production Process and Machine, Chemical sensors RFID, Analysis of the Current State of the Regulation of Manufacturing Processes

V. Suggested Reading

- Rodríguez MEP. 2018. *Process Monitoring and Improvement Handbook,* Second Edition 2018 by ISBN: 978-0-87389-974-1
- *Food Process Monitoring Systems* 1993, Springer

I. Course Title : Quality Concepts and Chain Traceability

II. Course Code : FSQ 507

III. Credit Hours : 2+0

IV. Theory

Unit I

Quality – Concepts, Quality as wining strategy, Total quality management TQM: Introduction, definitions and principles of operation, Tools and Techniques, such as, quality circles, 5 S Practice, Total quality control (TQC), Total employee involvement (TEI), Problem solving process, Quality function deployment (QFD), Failure mode and effect analysis (FMEA), Fault Tree Analysis (FTA), Kizen, Poka-Yoke, QC Tools, PDCA Cycle, Quality Improvement Tools, TQM implementation and limitations, JH – Autonomous maintenance

Unit II

Introduction, Content, Methods, Advantages and Limitation of: Just –in –Time and Quality Management KANBAN system, Total productive maintenance (TPM), QS 9000. Basic concept, Principle, methodology of contemporary trends: Lean manufacturing, Agile manufacturing, World class manufacturing, Concurrent engineering, Bench marking, Cost of quality (COQ) system.

Unit III

Reliability engineering fundamentals; Failure data analysis; Failure rate; mortality curve; Concept of burn in period; Useful life and wear out phase of a system; Mean time to failure (MTTF); Mean time between failure, (MTBF) and mean time to repair (MTTR); Reliability in terms of Hazard rate and failure density, Measurement systems analysis for accuracy, Probability for quality.

Unit IV

SQC -Statistical quality control– X/ R/ p and c chart, Shewhart and types of control charts, Process capability analysis, process capability index. Acceptance sampling by variables and attributes, design of sampling plans, single, double, sequential and continuous sampling plans, design of various sampling plans for food industry (Note:SQC tables can be used in the examination), Capability analysis. Statistical process control.

Unit V

Traceability in food safety management, Applications of traceability, Traceability challenges, Traceability requirements and standards: ISO 22005, Traceability implementation & application: Traceability data & process flow, Traceability process participants, Traceable item, Batch/Lot and Traceability links management, Food authenticity tools.

V. Suggested Reading

- Montgomery, Jennings andPfund. 2010. *Managing, Controlling and Improving Quality*, Wiley
- Arora KC. 2016 (4th Edition). *Total Quality Management*, S K Kataria& Sons Pub

- Grant EL and Leavenworth RS. 1996.,7th Ed 1996, Statistical Quality Control, McGraw-Hill

I. Course Title : Management of Food By-products and Waste

II. Course Code : FSQ 508

III. Credit Hours : 2+1

IV. Theory

Unit I

Management of Food Waste, Principles of sustainable systems and Green chemistry, Waste management purpose and strategies, Waste & its consequences in pollution and global warming, Food waste classification, Mitigation measures for food processing wastes, Food waste Handling and Management laws – National and international.

Unit II

Approaches to Solid Waste Management - Bio gas and electricity generation, Bioactive compounds extraction, Sourcing natural colour, Valorization, Biofueling, Biofertilizers, Bio-ethanol, Activated carbon, Biochar, other biological approaches, Use for biodegradable plastic, biofertilizers and environmental bioremediation.

Unit III

Approaches to Effluent Waste Management Basic unit operations in wastewater treatment, Anaerobic digestion of organic residues and wastes, Fundamentals and applications of anaerobic digestion for sustainable treatment of food industry wastewater, Effluent treatment strategies for dairy/ brewery/ winery, Common biological treatment processes and on-site treatment systems.

Unit IV

Case studies, commercially viable practices and success stories of value added products of waste and by-products from processing of different plant and animal food products, Food waste for pulp & paper, flavorings and aromas production

V. Practical

- Study of waste utilisation processes by site visit/ site plan studies
- Characterization of effluent for Dissolved solids (TDS), Suspended solids, BoD, CoD,
- Nitrogen (as N), Phosphorus (as P), Alkalinity (as $CaCO_3$), Sulphate (as SO_4), Total organic carbon (TOC)
- Characterization of food waste as feedstock for anaerobic digestion
- Various treatments in use for waste disposal: study on operational precautions;
- Extraction of banana fibre,
- Utilisation of ghee residue in caramel toffee;
- Extraction of volatile oils from organic waste;
- Use of fruit/vegetable residue for the production of cellulose;
- Use of mango kernels for manufacturing of starch;
- Production of pectin/citric acid from organic waste

VI. Suggested Reading

- Wastewater treatment and use in agriculture - FAO irrigation and drainage paper 47, http://www.fao.org/docrep/t0551e/t0551e00.htm#Contents
- Waste Biomass Valor (2017) 8:2209–2227 DOI: 10.1007/s12649-016-9720-0

- Guillermo et. al. A Methodology for Sustainable Management of Food Waste 2017, Waste and Biomass Valorization, Volume 8, Issue 6, pp 2209–2227
- Agricultural Waste Management Systems, Chapter 9, USDA Agricultural Waste Management Field Handbook https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31493.wba
- Oreopoulou, Vasso, Russ, Winfried (Eds.) Utilization of By-Products and Treatment of Waste in the Food Industry, 2007, Springer
- Anil Kumar Anal (Editor), 2017, Food Processing By-Products and their Utilization, Wiley-Blackbell

I. Course Title : Toxicology of Food Ingredients and Products

II. Course Code : FSQ 510

III. Credit Hours : 2+1

IV. Theory

Unit I

General Concepts in Food Toxicology: Definitions, General principles of food toxicology, Toxicology terminologies – Acute, Subacute, Subchronic and Chronic toxicity and other important terminologies; Classification of toxicants, Food Allergy, Food Toxicity, Food Idiosyncrasy, Common food adulterants, Risk assessment, Common techniques for identification/quantification of food toxins, LD50 and LC50 oral-dermal-inhaled, feeding trials and in vitro tests for toxicology.

Unit II

Toxicology of Food additives: Food additives toxicity, Safety Determination of direct and Indirect Food Additives, Acceptable daily intake (ADI), estimated daily intake (EDI), Interaction in food matrix, Evaluation of new and emerging ingredients, Toxicological Study Requirements as per FSSAI for the approval of non-specified foods/food ingredients,

Unit III

Toxicants and contaminants in food: algal toxins, plant toxins and anti-nutrients, dietary estrogens and antiestrogens, Inherent toxins & allergens, process induced toxicants, toxins from packaging, fumigants, safety challenges in of genetically engineered foods, pesticides, heavy metals, carcinogens, polycyclic aromatic hydrocarbons etc.,

Unit IV

Nutraceuticals and functional foods: toxicity and toxicological clearance from regulator, Interactions of prescription drugs, food, alcohol and nutraceuticals. National and international regulatory aspects of health foods and nutraceuticals.

V. Practicals

- Determination of trypsin inhibitors in legumes
- Estimation of phytates/oxalates in cereals/legumes
- Determination of Acrylamide and 5-hydroxymethylfurfural formation in reconstituted potato chips during frying
- Determination of Hydroxymethylfurfural in Baby Foods
- Metals and toxic Metals e.g. Cd, Hg etc.
- Pesticide residues e.g. Dioxin, Aldrin, Malathion etc.
- Mycotoxins, Argemone, Khesari dal, Ergot, Karnal bunt, Dhatura, etc.

- Allergens, Antibiotic & hormone residues, Veterinary drug residue,
- Other new contaminants and toxins (For example: Cyclopiazonic acid in Buckwheat flour)
- Determination of Naturally Occurring Toxic Substances (NOTS) and Deoxynivalenol (DON)
- Elisa for toxins and allergens

VI. Suggested Reading

- *Introduction to Food Toxicology*: By Takayuki Shibamoto and Leonard F. Bjeldanes. 2nd edition; Academic Press
- *Safety Evaluation of Certain Contaminants in Food*, WHO Food Additives Series: 63, FAO JECFA Monographs 8, http://www.fao.org/3/a-at881e.pdf
- Chapter 30: *Food Toxicology*. In Casarett and Doull's Toxicology: The Basic Science of Poisons by Curtis D. Klaassen. 8th edition; McGraw-Hill Medical Publishing Division
- *Food Toxicology: Current Advances and Future Challenges* by Ashish Sachan, Suzanne Hendrich, 2017, Apple Academic Press
- *Food Toxicology* by Debasis Bagchi, Anand Swaroop, 2016, CRC Press
- General Standard For Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995) Amended up to 2015,www.fao.org/input/download/standards/17/CXS_193e_2015.pdf

I. Course Title : Food Plant Utilities and Sanitation

II. Course Code : FSQ 511

III. Credit Hours : 2+0

IV. Theory

Unit I

General principles of food plant Design and layout, CIP system, sanitizers used in food industry. Personnel hygiene and assessment of surface sanitation by swab and rinse method

Unit II

Sanitation of coolers/chillers/freezers, Design of warehouses, conventional & modern storage structures for fruits, vegetables, meat and marine products, pest and rodent control

Unit III

Waste disposal for Food Plant Hygiene and Sanitation, ETP design and layout, Food hygiene and safety in transportation, with a focus on warehouse storage and refrigerated ships, Process water quality and treatments at plant level, Process plant sanitation - chemistry and water in CIP

Unit IV

Preparation of a sanitation schedule for food preparation area, testing of sanitizers and disinfectants, Steam generation and performance, Boiler operation, forced and induced draught. Flue gas composition and performance analysis, Process air generation, air requirement & supply system. Air Moving and vacuum equipment, Power supply system for food process plants and plant earthing.

V. Suggested Reading

- Marriott NG and Gravani RB. 2006. *Principles of Food Sanitation*, 5th edition
- Rao DG. 2010. *Fundamentals of Food Engineering*, PHI learning Private Ltd.
- James A. 2013. *The Supply Chain Handbook, Distribution Group*.
- FAO, US. 1984. *Design and Operations of Cold Store in Developing*.

Course Title with Credit Load
Ph.D. in Safety and Quality

Course Code	Course Title	Credit Hours
Major Courses		
FSQ 601	Food Quality and Safety Assessment	1+2
FSQ 602	Food Toxicology and Risk Assessment	3+0
FSQ 603	Quality Assurance in Food Supply Chain	3+0
FSQ 604	Formulation of standards of Food Products, Packaging and Labeling	2+0
FSQ 605	Food and Nutraceutical Chemistry	3+0
FSQ 606	Food Microbiology and Safety	3+0
FSQ 607	Sensory Evaluation of Foods	2+0
FSQ 608	Special problem	0+2
Minor Courses		
FPT 601	Novel Technologies for Food Processing and Shelf Life Extension	3+0
FPT 605	Food Process Modeling and Scale up	3+0
FPE 602	Concentration and Drying Engineering	3+0
FPE 606	Food Handling and Storage Engineering	3+0
Supportive Courses		
FPE 715	Food Analytical Techniques	1+2
FSQ 724	Sensory Evaluation of Foods	2+0
	Seminar	
FSQ 698	Seminar I	0+1
FSQ 699	Seminar II	0+1

Course Contents
Ph.D. in Safety and Quality

I. Course Title : Food Quality and Safety Assessment
II. Course Code : FSQ 601
III. Credit Hours : 1+2
IV. Theory

Physical quality - Advances in Quantitative Evaluation of Physical Characteristics of Food as an indicator of quality, modern approaches for colour, texture and microstructure of food

Chemical Quality - Advances in instrumentation used for chemical analysis of foods and methods developed for rapid analytical methods, modern non-destructive testing methods, newer biomarkers for food authenticity, and approaches for using an analyte protectant in gas chromatographic analysis. Review of recent updates on the chemical safety threats such as contaminants from agrochemicals, process, packaging materials and environment.

Biological Quality - Updates in molecular biological approaches for rapid detection, Relevance of metabolomics, transcriptomics and proteomics in food analysis and quality evaluations and current food industry applications, Emerging microbial and other macro-biological threats for foods: mitigation and detection.

V. Practicals

- Lab exercises on food microstructures
- Food authentication, newer approaches in food analysis
- Complex culture isolation and identification
- Molecular methods to detect pathogens
- Individual exercise on design of experiments in food analysis and inter learner parity.
- Protein based detection of genetic modification ingredient
- Detection of 3-monochloropropane-1,2-diol (MCPD) esters, mineral oil saturated hydrocarbons (MOSH) or mineral oil aromatic hydrocarbons (MOAH), or polyfluorinated alkyl substances (PFAS)
- Species differentiation in meat - tryptic digestion of myosine by LC-MS/MS

VI. Suggested Reading

- Donna R and Unnevehr L, *International Trade and Food Safety* ed. Sy J. Buzby. Agricultural Economics Report 828. Washington: Economic Research Service. USDA. 2002.
- Josling T, Roberts D and Orden D, *Food Regulation and Trade: Towards a Safe and Open Global System*. Institute for International Economics. 2004

I. Course Title : Food and Nutraceutical Chemistry
II. Course Code : FSQ 605
III. Credit Hours : 3+0
IV. Theory

Recent advances in mechanism of action and chemical properties of potential and established nutraceutical compounds and their applications in functional foods - Updates in chemistry of Nutraceuticals with diseases modifying indications modifying potential for Allergy, Alzheimer's disease and nutraceuticals, Cardiovascular diseases, Cancer, Diabetes, Eye disorders, Immune system, Inflammation, Obesity, Parkinson's, Alzhaimar etc. Complications and toxicity potential of nutraceuticals, Modern approaches regulatory clearance and ban of nutraceutical.

Regulatory developments in health claims. Disease risk reduction claims and proprietary claims – recent protocols for phytosterols, digestible starch, slowly digestible starch, flavanols, grain/millet fibre, glucomannan, guar gum and hydroxypropyl methylcellulose and fructose etc.

V. Suggested Reading

- Robert EC. 2006. *Handbook of Nutraceuticals and Functional Foods*. 2nd Ed.Wildman.
- Ashwini C *et al*. 2013. *Role of Nutraceuticals in Various Diseases: A Comprehensive Review*. ISSN: 2231-2781.
- Schneeman B. 2015. *Science-Based Regulatory and Policy Considerations in Nutrition,* American Society for Nutrition. Adv. Nutr. 6: 361S–367S, 2015; doi:10.3945/an.114.007013.

I. Course Title : Food Microbiology and Safety

II. Course Code : FSQ 606

III. Credit Hours : 3+0

IV. Theory

Technological advances in starter cultures, Prospective application of food-grade microorganisms and fermenters for food preservation and food safety, Newer approaches on molecular techniques for detection of food borne pathogens, Safety evaluation of novel technologies of processing and food-surface disinfection, Latest software tools for predictive microbiology and microbial risk assessment in foods, Use of next generation sequencing for improving food safety, Role of nanotechnology in microbial food safety, New rapid detection methods including immune chromatographic or "dipstick" assays, commercial kits for indicator and pathogenic bacteria, Microbial bio-sensors and detector system in monitoring of food pathogens and antibiotic/pesticide residues.

V. Suggested Reading

- Fratamico, PM and Bayles DO in Food Borne.
- Verma DK. *Microbiology for Food and Health, Technological Developments and Advances*.
- Sofos J. *Advances in Microbial Food Safety*,1st Edition, Woodhead Publishing

I. Course Title : Sensory Evaluation of Foods

II. Course Code : FSQ 607

III. Credit Hours : 1+1

IV. Theory

Advances in rheological and texture measurement, Current sensory evaluation approaches, Applications and limitations of n e-nose, e-tongue, Data Analysis for Electronic sensory judgment and validation approaches. Computer-aided sensory evaluation of foods, statistical analysis of sensory data.

V. Suggested Reading

- Rao ES. 2013. *Food Quality Evaluation*, Variety Books.
- Meilgard. 1999. *Sensory Evaluation Techniques*, CRC Press
- Maslowitz H. 2000. *Applied Sensory Analysis of Foods*. Vols. I, II. CRC Press.

Syllabus of Supportive Courses

I. Course Title : Post-Harvest Management
II. Course Code : FBM 501
III. Credit Hours : 2+1
IV. Theory

Unit I

Post-harvest handling of F&V. Maturity indices, harvesting and post-harvest handling of fruits and vegetables. Respiration and ripening process. Factors affecting respiration and ripening. Pre and post-harvest factors affecting quality on post-harvest shelf life. Chemicals used for hastening and delaying ripening of fruits and vegetables. Methods of storage – precooling, prestorage treatments, low temperature storage, controlled atmospheric storage, hypobaric storage, irradiation and low cost storage structures, Cleaning & Washing machinery and methods for grading.

Unit II

Packing technology for export. Fabrication of types of containers, cushioning material, vacuum packing, poly shrink packing, specific packing for export of mango, banana, grapes kinnow, sweet orange, and mandarin etc. Principles of preservation by heat, low temperature, chemicals and fermentation. Cut fruits and vegetables.

Unit III

Post-harvest practices for safe storage of food grains. Preparation of threshing, threshers for different crops, parts, terminology, care and maintenance. Winnowing, manual and power operated winnowers. Groundnut decorticators- hand and power operated, principles of working. Maize shellers & castor shellers. Drying- grain drying method and equipment. Grain storage and practices.

Unit IV

Post-harvest technology for major spices (black pepper, cardamom, coriander, cinnamon, ginger, onion and garlic, paprika, saffron, turmeric), their post-harvest diseases and storage pests and their management; Packaging and storage of spices and spice powders.

V. Practical

- Macro quality analysis, grading, packaging.
- Harvesting indices of different vegetable crops;
- Grading and packing of vegetables;
- Practice in judging the maturity of various fruits and vegetables.
- Conservation of zero energy cool chambers for on farm storage.
- Determination of physiological loss in weight (PLW), total soluble solids (TSS), total sugars, acidity and ascorbic and content in fruits and vegetables. Packing methods and types of packing and importance of ventilation.

- Pre-cooling packing methods for export or international trade. Methods of prolonging storage life.
- Effect of ethylene on ripening of banana, sapota, mango, sapota.
- Identification of equipment and machinery used is preservation of fruits and vegetables.
- Preservation by drying and dehydration.
- Visit to local processing units.
- Visit to local market yards and cold storage units.
- Visit to local market and packing industries.

VI. Suggested Reading

- Pantastico B. *Post Harvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables*. The AVI Publishing Co. Inc, Westport
- Ryall, AL and Lipton WJ. *Handling, Storage and Transportation of Fruits & Vegetables.* Vol I. The AVI Pub. Company
- Ryall AL and Peltzer WT. *Handling, Storage and Transportation of Fruits and Vegetables* – Vol II. The AVI Pub. Co.
- Rydstm Heele S. *Post Harvest Physiology and Pathology of Vegetables.* Marcel Dekker

I. Course Title : Food Business Management

II. Course Code : FBM 502

III. Credit Hours : 2+0

IV. Theory

Unit I

Business management; introduction, theories and functions, food industry management; marketing management and human resource development, personal management. Sectors in food industry and scale of operations in India.

Human resource management, study the basics about HR and related policies and capacity mapping approaches for better management. Consumer Behavior towards food consumption, consumer surveys by various institutes and agencies, Various journals on consumer behaviour and market research, Internet based data search.

Unit II

Materials management – types of inventories, inventory costs, managing the inventories, economic order quantity (EOQ). Personnel management – recruitment, selection and training, job specialization. Marketing management – definitions, planning the marketing programmes, marketing mix and four P' s. Financial management – financial statements and rations, capital budgeting. Project management – project preparation evaluation measures.

Unit III

International trade; basics, classical theory, theory of absolute advantage. theory of comparative, modern theory, free trade- protection, methods of protection, quotas, bounties, exchange control, devaluation, commercial treaties, terms of trade, balance of payments, EXIM policy, foreign exchange, mechanics of foreign exchange, GATT, WTO, role of WTO,

International Trade in agriculture. World trade agreements related with food business, export trends and prospects of food products in India.

Unit IV

World consumption of food; patterns and types of food consumption across the globe. Ethnic food habits of different regions. Govt. institutions related to international ad trade; APEDA, Tea board, spice board, wine board, MOFPI etc. management of export import organization, registration, documentation, export import logistics, case studies. Export and import policies relevant to horticultural sector. Project: Consumer Survey on one identified product - both qualitative and quantitative analysis (say, Consumer behavior towards Pickles and Chutneys).

V. Suggested Reading

- David D and Erickson S. 1987. *Principles of Agri Business Management*. Mc Graw Hill Book Co., New Delhi.
- Acharya SS and Agarwal NL. 1987. *Agricultural Marketing in India*. Oxford & ISH Publishing Co., New Delhi.
- Cundiff Higler. 1993. *Marketing in the International Environment*, Prentice Hall of India, New Delhi.
- Batra GS and Kumar N. 1994. *GAD Implications of Denkel Proposals* - Azmol Publications Pvt., New Delhi.
- Phill Kottler. 1994. *Marketing Management* - Prentice Hall of India, New Delhi.

I. Course Title : Food Processing Entrepreneurship and Start-up
II. Course Code : FBM 503
III. Credit Hours : 1+1

IV. Theory

Unit I

Assessing overall business environment in the Indian economy. Overview of Indian social, political and economic systems and their implications for decision making by individual entrepreneurs. Globalisation and the emerging business/ entrepreneurial environment.

Unit II

Concept of entrepreneurship; entrepreneurial and managerial characteristics; managing an enterprise; motivation and entrepreneurship development; importance of planning, monitoring, evaluation and follow up; managing competition; entrepreneurship development programs; Social Responsibility of Business.

Unit III

SWOT analysis, Generation, incubation and commercialization of ideas and innovations. Government schemes and incentives for promotion of entrepreneurship. Government policy on Small and Medium Enterprises (SMEs)/ SSIs. Export and Import Policies relevant to food sector. Venture capital. Contract farming and joint ventures, public-private partnerships. Overview of horti inputs industry. Characteristics of Indian food processing and export industry.
Communication Skills: Structural and functional grammar; meaning and process of communication, verbal and non-verbal communication; listening and note taking, writing skills, oral presentation skills; field diary and lab record; indexing, footnote and bibliographic procedures. Reading and comprehension of general and technical articles, précis writing, summarizing, abstracting; individual and group presentations, impromptu presentation, public speaking; Group discussion. Organizing seminars and conferences.

V. Practical/Assinments/Case studies

- Study of a regulated market,
- Study of a fruit and vegetable market,
- Study of State and Central Warehousing Corporation
- Study of functioning of a regional rural bank and commercial bank for loan.
- Study of food processing enterprise,
- Formulation of project reports for financing food Industry,
- Working out repayment plans,
- Legal Issues in Product Development, Marketing and Market Segments
- Case studies: Innovations in Dairy industry, Bakery industry, fats and oils industry, fruit and vegetable industry, primary and secondary processing of cereals, brewing industry.

Note: In practical of plant design and project engineering a plant design problem should be assigned to a group of (3-4) students. The students should carry out the conceptual design, flow sheeting, material and energy balance calculations, and cost and profitability analysis of any Food Plant.

VI. Suggested Reading

- Hu, R. 2005. *Food Product Design A Computer-Aided Statistical Approach*, Technomic Publishers.
- Moskowitz H R, Saguy S. and Straus T. 2006. *An Integrated Approach to New Food Product Development,* CRC Press
- Moskowitz H R, Porretta S. and Silcher M. 2006. *Concept Research in Food Product Design And Development*, Blackwell Publishing Ltd.
- Peters MS and Timmerhaus KD. 2005. *Plant Designs and Economics for Chemical Engineers*, McGraw Hill, 5th Edition,
- Ahmad T. 2009. *Dairy Plant Engineering and Management*., Kitab Mahal, 8th Edition.

I. Course Title : Research Methodology
II. Course Code : BSH 501
III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to Research, Objective and importance of research, Types of research, steps involved in research, Ethical considerations in research, Defining research problem, Research design, Methods of research design, Laboratory safety considerations.

Unit II

Sampling techniques, Classification of Data, Methods of Data Food informatics Collection, designing of experiments, characteristics of a good design: selection of variables, design matrix, factorial design, fractional factorial design, Principal Component Analysis, Taguchi methods.

Unit III

Data Analysis and interpretation Data analysis, Statistical techniques and choosing an appropriate statistical technique, Optimization techniques, Bioassays- direct and indirect.

Unit IV

Hypothesis, Hypothesis testing, sampling and Non- sampling errors, Data processing software, statistical inference, Interpretation of results.

Unit V

Technical Writing and reporting of research, referencing and referencing styles, Research journals, Indexing and citation of journals, acknowledgement, conflict of interest, Intellectual property, plagiarism.

V. Suggested Reading

- Creswell JW. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage publications, 2013.
- Kumar R. *Research Methodology: A Step by Step Guide for Beginners*, 2nd Edition, SAGE, 2005.
- Kothari CR, Garg G. *Research Methodology Methods and Techniques*, New Age International publishers, Fourth Edition.
- Bower JA. 2009. *Statistical Methods for Food Science*, Blackwell Publishing
- Wilson A. *Handbook of Science Communication*, 1998, CRC Press
- Montgomery DC. 2017. *Design and Analysis of Experiments*, Willey
- Snecdecor GW and Cochran WG. 1991. *Statistical Methods*, 8th Edition, Wiley-Blackwell
- Saguy PI. *Computer aided techniques in Food Technology*, 1983, Taylor and Francis

I. Course Title : Food Informatics

II. Course Code : BSH 502

III. Credit Hours : 2+0

IV. Theory

Unit 1

Informatics: Meaning and purpose, Making food-related information available for food researchers, Smart Data searching, Data Retrieval, File search or text search in file on a system, Meta Search Engines. Major centers of food research in India and abroad,

Unit 2

Data bases and Management in Food Processing, Data storage and distribution by using various information technology tools and methods, Computer vision for food detection, segmentation and recognition, 3D reconstruction for food portion estimation Augmented reality for food monitoring.

Unit 3

Evaluation protocols of dietary monitoring/management systems, Mobile computing for dietary assessment Smartphone technologies for dietary behavioral patterns, Dietary behavioral pattern modelling using sensors and/or smartphones

Unit 4

Laboratory Information Management System (LIMS) introduction and applications, LIMS in the food safety workflow, Wearable Food Intake Monitoring Technologies, Computerized food composition (nutrients, allergens) analysis

Unit 5

Chemometric techniques - to gain fundamental understanding of complex food systems through the combination of data from independent measurement techniques, Product lifecycle tracing and tracking – ICT tools and technique

V. Suggested Reading

- *Food Informatics: Applications of Chemical Information to Food Chemistry* Martinez-Mayorga,
- Karina-Medina-Franco,
- *Food Informatics: Sharing Food Knowledge for Research and Development* Nicole J.J.P. Koenderink1, J. Lars Hulzebos1, Hajo Rijgersberg1 and Jan L. Top

ANNEXURE I

List of BSMA Committee Members for Food Technology

Name	Specialization	Address
1. Dr V.B. Singh	Chairman	Former Dean CDFST and VC, MPUAT, Udaipur, Rajasthan
2. Dr K.L. Khurana	Member	Coordinator, BSMA for ICAR Education Division and Retd. Principal Scientist Education Division, ICAR, New Delhi
3. Dr H.N. Mishra	Member	Professor, Dept of Food Technology, AFED, IIT-Kharagpur
4. Dr Bhupender Singh Khatkar	Member	Dean and Chairperson, Dept of Food Technology, Guru Jambeshwar University of Science & Technology, Hisar, Haryana
5. Dr Pradyuman Kumar	Member	Professor, Dept of Food Engineering & Technology, SLIET, Sangrur, Punjab
6. Dr Uday Annapure	Member	Professor and Head, Dept of Food Engineering & Technology, Institute of Chemical Technology, Mumbai
7. Dr Ashutosh Upadhyay	Member	Professor and Head, Dept of Food Science & Technology, NIFTM, Sonipat
8. Dr L.K. Murdia	Member	Former Dean, CDFST, MPUAT, Udaipur, Rajasthan
9. Dr Sudhir Uprit	Convenor	Dean, College of Dairy Science and Food Technology, Kamdhenu Vishwavidyalaya, Raipur, Chhattisgarh

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VOL. 5

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Fisheries Science

भाकृअनुप
ICAR

Education Division
Indian Council of Agricultural Research
New Delhi

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Agriculture and Allied Sciences
Volume-5

Restructured and Revised
Syllabi of Post-graduate Programmes

Fisheries Science

- Aquaculture
- Fisheries Resource Management
- Aquatic Environment Management
- Fish Genetics and Breeding
- Fish Nutrition and Feed Technology
- Aquatic Animal Health Management
- Fish Biotechnology
- Fish Processing Technology
- Fishing Technology and Engineering
- Fisheries Economics
- Fisheries Extension
- Fish Physiology and Biochemistry

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त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu	Arvind Kumar
Member-Secretary	Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the

syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language*.
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing*.
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

  (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

  (b) An application is made by the student concerned duly supported by the Advisory Committee;

  (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

  (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Preamble and Acknowledgement
BSMA–Fisheries Science 2020

India's Fisheries sector includes aquaculture and capture fisheries with varied resources and potential, engaging over 14.50 million people at the primary level and many more along the value chain. This sunrise sector grew at an impressive Cumulative Average Growth Rate (CGAR) of 8% annually. Aquaculture has surpassed its production than capture fisheries in India by topping second in World's fish and shrimp production. India has witnessed strong growth in exports of fishery products in the last decade. The country is also foremost exporter of fish contributing 5.23% of the Gross Domestic Value to the agriculture sector and 0.96% to the GDP of the country. Indian Council of Agricultural Research, is spearheading national programmes on aquaculture and fisheries research, higher education and frontline extension through a network of Central Research Institutes and State Fisheries Universities.

Major Aquaculture components such as stock improvement, water, energy, health, and feed management and access processing machineries and export markets are responsible for the CGAR. Aquaculture feed and health management has become an important component for sustainable growth and development of the industry. Advanced genetic breeding programs have strongly supported industry growth in the last five years. Besides being a source of health as well as wealth, fisheries and aquaculture provide jobs and livelihood to millions. Globally, fisheries and aquaculture research and education has moved ahead at a rapid pace in response to the diversity and increasing specialisations in the fisheries sector.

Besides the core skills, the sector also requires human assets to support developmental and regulatory processes and entrepreneurship capacity. Highly specialised quality human resources will be one of the central engines which drive the research and development essential to enable fisheries and aquaculture to meet the future demands. The fisheries education curriculum provides the decent knowledge of the subject and the industry but practical skills in bringing entrepreneurial prospects is still lacking for the students. This compilation would pave way for attracting and retaining the talents to fisheries and aquaculture sector for improving fish productivity and consumption at the national level. Fisheries and aquaculture industry is looking for cream of the cream to improve its performance. Thus, the Fisheries education system should be subjected to constant innovations and reforms, particularly with respect to redesigning of curricula and syllabi, innovative pedagogy, developmental orientation, entrepreneurship, soft skill development, etc. It's imperative to prepare the graduates and equip them not only to effectively respond to the emerging needs and challenges, but also to become creative and proactive partners in piloting this knowledge-led revolution.

Presently, four year degree programme in Bachelor of Fisheries Science (B.F.Sc.) is being offered in 40 colleges, while PG programs are offered by 20 colleges. The present yearly intake capacity of B.F.Sc., M.F.Sc. furthermore, Ph.D. programs are around 1500; 500 and 200 respectively, while the yearly out-turn might be around 85-95% of intake. In addition to this, India's Gross Enrolment Ratio (GER) to higher education was found to be >25% and lags behind many developed and developing countries. As aquaculture sector is rewarding the highest CGAR report to its allied farming sectors, it's inevitable that we need to produce more at least 10% of the total agri-graduates produced in the country. Apart from increasing the number of seats, maximum capacity utilization of the available infrastructure facilities would be a long-term value to Higher Education (HE). Strengthening the HE infra by government resources alone may not be adequate to cater to the requirement of human resource development in fisheries sector. All the Fisheries Colleges can take extra efforts to lift the standards of upbringing the competent fisheries professionals by adopting the appropriate Student: Teacher ratio less than 1: 10. Restructuring of postgraduate curricula and syllabi to upgrade the competence and standard of human resource in fisheries is also necessary and for this ICAR has constituted Broad Subject Matter Area specialists (BSMA) committee. The present exercise of revising and reorienting the postgraduate curricula was initiated by ICAR in 2007.

Present BSMA in Fisheries science has given a major thrust to restructuring of syllabus by introducing the contents catering the need of present scenario and future need keeping in view the environmental, societal issues and job opportunities. At present scenario committee recommends 12 disciplines, which is two disciplines less than the recommendation of previous BSMA committee (2013).

Fisheries sector is growing fast and hence it needs compatible and competent human resources for its sustainable development. A set target of 22 mmt has been assigned to achieve by 2030 under the Blue Revolution program of the Govt. Hence, higher education in Fisheries Science will be a driving force to achieve this huge target within coming 10 years. This coincides with the restructuring of the course curriculum of the Master and Ph.D. of Fisheries science as under taken by the BSMA committee. The workshop was fully dedicated for the syllabus revision activities and for discussing the academic reformations. The committee were concerned about sustainability, food safety, consumer demand, climate smart aquaculture, alternative sources and sensory evaluation for GM plants or animals.

Along with restructuring the syllabus some changes in academic rules have been proposed so as to strengthen the soft skill capability of the students. Considering the recent UGC guide lines for the Ph.D as the minimum qualification for the Assistant Professor, overall development of Ph.D students pertaining to quality research, teaching ability and leadership quality have been addressed. Teaching assistantship has been proposed to involve the Ph.D students in teaching programme so as to facilitate the Ph.D students to teaching programme before joining as a Assistant Professor in a college.

Fisheries colleges are rapidly coming up all over the country almost in all the states. ICAR's recommendations for starting of a new college are to be implemented still more effectively in our country. Similarly we cannot wait for a long to implement a newly recommended disciplines, which has its relevance in the present context and may loose its priority in due course of time. Hence, committee request ICAR to facilitate the implementation of these new programs by all the colleges in a specific period of time.

The key issues specially addressed in the revision of course curricula at PG and doctoral levels are: supply of high quality germplasm to farming community, compounded feed supply to intensive aquaculture production units, strategic bio-available micro-nutrient supplements, water use for super and supra intensive aquaculture, production designs for fish rearing amenable to automation and mechanization, clean fish production to be taken up as a national mission, phyto-sanitary measures for traceability and quality assurance of products of fish and fishery products, onward linkages for processing and marketing of the fishes, cold chain infrastructure for fish meats, entrepreneurship building and economic analysis of various fish production including pricing, insurance, credit, technological backstopping and assessment of economic losses associated with inadequate prioritization of the aquaculture enterprise.

The implementation of the new and restructured post graduate course curricula is expected to build knowledge and skill portfolio of the students so as to enhance their employability and marketability as multi-service providers with practical skills and comprehensive knowledge of the entire subject area after masters. The doctorates should, in turn, prove as specialists, in the field of their specialization. The valuable inputs received from the stake holders, viz. eminent academicians, scientists, extension workers, pharmaceutical/aquaculture industry, leading consultants, state fisheries department etc. have immensely helped in preparation of this document.

We are thankful to Dr Arvind Kumar, Vice Chancellor, RLBCAU Jhansi, ICAR and all the members of the BSMA Committee on Fisheries Science and the participants of consultative workshop for their valuable suggestions and contributions for the development of the curricula and syllabi. Our thanks are due to Dr T. Mohapatra Secretary, DARE and D.G, ICAR and the DDG (Edn.), for their support in bringing out this document. We also thank Dr G. Venkateshwarlu Assistant Director General (EQR) Member Secretary, BSMA, for his untiring assistance throughout the consultation process till final documentation. The extensive help rendered by TNJFU and ICAR-CIFE, Mumbai for organizing various BSMA committee meetings with the students and faculty and industry personnels for the syllabus activities is duly acknowledged. We hope that this document will serve as a guide and help in achieving uniformly high standards in postgraduate education in Fisheries Science across the country.

ICAR also can issue a guidelines along with the revamped syllabus of BSMA -2020 to all the institutes to adopt the newly revised syllabus scrupulously with only a little flexibility of 10 %.

The BSMA Committee of Fisheries experts have been of great help for the past many months to work consistently with the Chairman and the Convener to give a shape to the curriculum for the PG and PhD programs of Fisheries Science.

We firmly believe that this exercise of major revamping of the PG and Ph.D Syllabus will naturally raise the bar for the students undergoing these programs and would ensure ‘quality’ in higher education offered in Fisheries Science.

Prof. S. Felix
Chairman

Date: 27.02.2021
Chennai

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Aquaculture

Preamble
(Aquaculture)

India's Fisheries sector includes aquaculture and capture fisheries with varied resources and potential, engaging over 14.50 million people at the primary level and many more along the value chain. This sunrise sector grew at an impressive Cumulative Average Growth Rate (CGAR) of 8% annually. Aquaculture has surpassed its production than capture fisheries in India by topping second in World's fish and shrimp production. India has witnessed strong growth in exports of fishery products in the last decade. The country is also foremost exporter of fish contributing 5.23% of the Gross Domestic Value to the agriculture sector and 0.96% to the GDP of the country. Indian Council of Agricultural Research, is spearheading national programmes on aquaculture and fisheries research, higher education and frontline extension through a network of Central Research Institutes and State Fisheries Universities.

Major Aquaculture components such as stock improvement, water, energy, health, and feed management and access processing machineries and export markets are responsible for the CGAR. Aquaculture feed and health management has become an important component for sustainable growth and development of the industry. Advanced genetic breeding programs have strongly supported industry growth in the last five years. Besides being a source of health as well as wealth, fisheries and aquaculture provide jobs and livelihood to millions. Globally, fisheries and aquaculture research and education has moved ahead at a rapid pace in response to the diversity and increasing specialisations in the fisheries sector.

Besides the core skills, the sector also requires human assets to support developmental and regulatory processes and entrepreneurship capacity. Highly specialised quality human resources will be one of the central engines which drive the research and development essential to enable fisheries and aquaculture to meet the future demands. The fisheries education curriculum provides the decent knowledge of the subject and the industry but practical skills in bringing entrepreneurial prospects is still lacking for the students. This compilation would pave way for attracting and retaining the talents to fisheries and aquaculture sector for improving fish productivity and consumption at the national level. Fisheries and aquaculture industry is looking for cream of the cream to improve its performance. Thus the fisheries education system should be subjected to constant innovations and reforms, particularly with respect to redesigning of curricula and syllabi, innovative pedagogy, developmental orientation, entrepreneurship, soft skill development, etc.Its imperative to prepare the graduates and equip them not only to effectively respond to the emerging needs and challenges, but also to become creative and proactive partners in piloting this knowledge-led revolution.

Presently, four year degree programme in Bachelor of Fisheries Science (B.F.Sc.) is being offered in 34 colleges as, while Master and Ph.D programme are offered by 19 and 8 colleges, respectively. Present yearly intake capacity of B.F.Sc., M.F.Sc. and Ph.D. programmes are 1, 079; 417 and 181 respectively, while the yearly outturn might be around 85-95% of intake. In addition to this, India's gross enrolment ratio to higher education was found to be >15% and lags behind many developed and developing countries. .As aquaculture sector is rewarding the most highest CGAR report to its allied farming sectors, its inevitable that we need to produce more at least 10% of the total agri-graduates produced in the country.Increasing the number of seats alone will not be an ideal solution.Maximum capacity utilization of the available infrastructure facilities would be a long term value to Higher Education (HE) .Strengthening the HE infra by government resources alone may not be adequate to cater to the requirement of human resource development in fisheries sector.All the Fisheries Colleges can take extra efforts to lift the standards of upbringing the competent fisheries professionals by adopting the appropriate Student: Teacher ratio of 1: 10. Restructuring of postgraduate curricula and syllabi to upgrade the competence and standard of human resource in fisheries is also necessary and for this ICAR has constituted broad subject matter area specialists (BSMA) committee. The present exercise of revising and reorienting the postgraduate curricula was initiated by ICAR in 2007, but still more than 40% colleges have no Master programme and 80% have no Ph.D programme. It is high time to give utmost priority to the higher education in Fisheries Science in the country. Hence, ICAR should ensure the implementation of BSMA recommendation in all the fisheries colleges by adopting various strategies. It has been observed that some colleges have only one Master or Ph.D programme, which may not satisfy the credit requirement for major and minor subjects of the on-going programs. At this juncture we are unable to implement all the disciplines recommended by the BSMA on one hand and new emerging disciplines needs to be implemented on the other hand. Hence, a suggestive guidelines from ICAR to be followed for the quick implementation of all the discipline in a phasing manner with a total span of five years. Present BSMA in fisheries science has given a major thrust to restructuring of syllabus by introducing the contents catering the need of present scenario and future need keeping in view the environmental, societal issues and job opportunities. Considering the intensive aquaculture and increased consumption rate of fish in future, the committee felt the need of new courses like Fish Pharmacology and Toxicology and Fish Quality Assurance Management so as to ensure healthy fish production and quality fish products available to the consumer. It may not be easy to run these courses initially by all the colleges due to non-availability of faculty in these specialised disciplines, however, it can be initiated in some few colleges, who have the strength to run these courses and later by others. At present scenario committee recommends 15 disciplines which includes two more disciplines than the recommendation of previous BSMA committee (2013).

Fisheries sector is growing fast and hence it needs compatible and competent human resources for its sustainable development. A set target of 22 mmt has been assigned to achieve by 2030 under the Blue revolution programme of the Govt. Hence, higher education in Fisheries Science will be a driving force to achieve this huge target within coming 10 years. This coincides with the restructuring of the course curriculum of the Master and Ph.D of Fisheries science as under taken by the BSMA committee. The workshop was fully dedicated for the syllabus revision activities and for discussing the academic reformations. The committee were concerned about sustainability, food safety, consumer demand, climate smart aquaculture, alternative sources and sensory evaluation for GM plants or animals.

Along with restructuring the syllabus some changes in academic rules have been proposed so as to strengthen the soft skill capability of the students. Considering the recent UGC guide lines for the Ph.D as the minimum qualification for the Assistant Professor, overall development of Ph.D students pertaining to quality research, teaching ability and leadership quality have been addressed. Teaching assistantship has been proposed to involve the Ph.D students in teaching programme so as tofacilitate the Ph.D students to teaching programme before joining as a Assistant Professor in a college.

Fisheries colleges are rapidly coming up almost in every states. But running the fisheries colleges with inadequate facilities and with a very few faculty compromises the teaching quality for which students are deprived off getting complete knowledge on the whole subjects. ICAR's recommendations for starting of a new college are to be implemented still more effectively in our country. Similarly we can not wait for a long to implement a newly recommended disciplines, which has its relevance in the present context and may loose its priority in due course of time. Hence, committee request ICAR to facilitate the implementation of these new programs by all the colleges in a specific period of time.

The key issues specially addressed in the revision of course curricula at PG and doctoral levels are: supply of high quality germplasm to farming community, compounded feed supply to intensive aquaculture production units, adoption of Fish Pharmacology and Toxicology concepts, strategic bio-available micro-nutrient supplements, water use for super and supra intensive aquaculture, production designs for fish rearing amenable to automation and mechanization, clean fish production to be taken up as a national mission, phyto-sanitary measures for traceability and quality assurance of products of fish and fishery products, onward linkages for processing and marketing of the fishes, cold chain infrastructure for fish meats, entrepreneurship building and economic analysis of various fish production including pricing, insurance, credit, technological backstopping and assessment of economic losses associated with inadequate prioritization of the aquaculture enterprise.

The implementation of the new and restructured post graduate course curricula is expected to build knowledge and skill portfolio of the students so as to enhance their employability and marketability as multi-service providers with practical skills and comprehensive knowledge of the entire subject area after masters. The doctorates should, in turn, prove as specialists, in the field of their specialization. The valuable inputs received from the stake holders viz. eminent academicians, scientists, extension workers, pharmaceutical/aquaculture industry, leading consultants, state fisheries department etc. have immensely helped in preparation of this document.

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Course Title with Credit Load
M.F.Sc. in Aquaculture

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
AQC 501	Freshwater Aquaculture Production Systems	2+1
AQC 502	Coastal Aquaculture and Mariculture Farming Systems	2+1
AQC 503	Hatchery Technology for Finfishes and Shellfishes	2+1
AQC 504	Aquaculture Policy and Planning	1+1
AQC 505	Fish Nutrition and Feed Technology	2+1
AQC 506	Soil and Water Quality Management in Aquaculture	2+1
AQC 507	Therapeutics and Health Management in Aquaculture	2+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a student's major subject)	
AQC 508	Larval Nutrition and Live Feed Production	1+1
AQC 509	Aquaculture Engineering	1+1
AQC 510	Open Water aquaculture	1+1
AQC 511	Commercial Ornamental Fish Breeding and Culture	1+1
AQC 512	Computer Application in Aquaculture Data Processing	0+1
AQC 513	Inland Saline Aquaculture	1+1
AQC 514	Multilevel Integrated Aquaculture Systems	1+1
AQC 515	Coldwater Aquaculture and Recreational Fisheries	1+1
AQC 516	Recirculating Aquaculture Systems	1+1
	Supporting courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 Credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	

Course Code	Course Title	Credit Hours
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters'seminar	**1 Credits**
AQC 591	Masters' Seminar	0+1
	Masters' Thesis Research	**30 Credits**
AQC 599	Masters' Research (Semester III)	0+15
AQC 599	Masters' Research (Semester IV)	0+15
	Total M.F.Sc Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Aquaculture

I. Course Title : Freshwater Aquaculture Production Systems
II. Course Code : AQC 501
III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge and understand the recent advances in freshwater fish and prawn farming under different culture systems.

V. Theory

Unit I

Introduction: Present status, hindrances / problems / constraints and prospects for fish and prawn farming in global and Indian perspective. Development process, different supports and driving factors forproduction enhancement.

Unit II

Aquaculture systems: Extensive, semi-intensive and intensive culture of fish and prawn. Partitioned aquaculture systems: raceways, tanks, flow-through systems, polyculture, and composite fish culture. Cages and enclosure. Peri-urban aquaculture systems: aquaponics, RAS, flow- through systems, bio-floc technology and land based aquaculturesystems.

Unit III

Aquaculture practices for cultivable species: Carps, Catfish, Snakeheads, Featherbacks, Tilapia, Mahseer, Trouts and freshwater Prawn. Grow out practices: pre stocking, post stocking management, harvesting and BMP. Other alternative species for high production. Species selection and crop planning. Economics of different fish farming systems

Unit IV

Freshwater prawn farming: Monoculture practice of prawn in ponds, all-male culture and its advantages, polyculture with carps, prawn farming in inland saline soils. Nursery rearing, sex segregation, pond preparation, stocking, feeding and water quality management, disease prevention and treatment; Harvesting methods, handling and BMP.

Unit V

Integrated farming systems: Design, farming practices, constraints and economics of IFS of fish with vegetables, fodder, paddy, cattle, pig, poultry, duck, rabbit and quail. IMTA, Freshwater pearl culture, multi- level integrated system. Resource utilization and conversion of waste towealth.

Unit VI

Wastewater-fed aquaculture: Water treatment methods, species selection, culture practices, harvesting and depuration process. Merits and demerits of wastewater fed aquaculture systems. Pre-requisites and precautions to be taken in the technology adoption.

VI. Practical

Identification of commercially important cultivable finfish and shellfish species; Assessment of seed quality- stress test; pre-stocking factors evaluation and observation; Calculating carrying capacity of pond and stocking density; Check tray assessment and feed ration calculation; Sampling process and species wise growth estimation; Farm feed production and feeding; Lime and fertilizer requirement calculations; Farm visits and observation; Records keeping and data analysis; Modelling of different culture systems.

VII. Suggested Reading

- AAHRI. 1998. *Health Management in Shrimp Ponds*. Aquatic Animal Health Research Institute (AAHRI), Department of Fisheries, Thailand.
- Agarwal SC. 2008. *A Handbook of Fish Farming*. 2nd Ed. Narendra Publ. House.
- Beveridge MCM and Mc Andrew BJ. 2000. *Tilapias: Biology and Exploitations*. Kluwer.
- De Silva SS. (Ed.). 2001. *Reservoir and Culture Based Fisheries: Biology and Management*. ACAIR Proceedings.
- FAO. 2007. *Manual on Freshwater Prawn Farming*.
- Midlen and Redding TA. 1998. *Environmental Management for Aquaculture*.Kluwer.
- New MB. 2000. *Freshwater Prawn Farming*. CRC Publ.
- Pillay TVR. 1990. *Aquaculture: Principles and Practices*. Fishing News Books, Cambrige University Press, Cambridge.
- Venugopal S. 2005. *Aquaculture*. Pointer Publ.
- Welcomme RL. 2001. *Inland Fisheries: Ecology and Management*. Fishing News Books.

I. Course Title : Coastal Aquaculture and Mariculture Farming Systems

II. Course Code : AQC 502

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge in establishing and managing different fish/shellfish farming systems in coastal zone and marine waters.

V. Theory

Unit I

Introduction: Overview of coastal aquaculture and open sea mariculture; Present trend and future prospects in India. Practices in tropical countries, production levels and adoption of technology. Major bottlenecks in the practices

Unit II

Different farming systems: Cage and pen culture – types, site selection, construction, specifications for different species; Raft and rack culture – Principles, site selection, design and construction; operations and troubles shooting, threats and environmental issues; Land based aquaculture. Principle, design, construction and operations, rules and legislations

Unit III

Aquaculture of finfishes: Distribution, biology, seed collection, nursery rearing, weaning on artificial feed, culture techniques, feeding strategies, constraints and scope (Seabass, milkfish, mullets, pearlspot, sea breams, grouper, snapper, cobia, pompano).

Unit IV

Shrimp farming (*Penaeus monodon, P. indicus, P. semisulcatus, and Litopenaeusvannamei*): Systems of farming – extensive, semi- intensive, intensive and super intensive (Biofloc, RAS, etc.); site selection, design and construction of culture systems, pond preparation, stocking, feed and water quality management, disease prevention and treatment; use of probiotics and prebiotics: harvesting and handling; continuous stocking and harvesting, staggered harvest, management of differential growth; shrimp farming in undrainable ponds. Mud crab fattening, production of soft-shell crabs and Lobster culture.

Unit V

Culture practices for marine molluscs and echinoderms: Present status and future prospects in India, Species cultured (mussels, oysters, pearl oysters, clams, abalone, sea cucumber) distribution, biology, practices followed in India and other Asian countries, farming methods–different types and culture methods; Problems and prospects.

Unit VI

Seaweed farming: Major seaweed species of commercial importance; tissue culture of seaweeds, methods of culture; farming of agar, algin and carragenan yielding species; emerging trends in their farming inopen seas; Integration with other coastal and marine farming systems.

VI. Practical

Identification of commercially important cultivable finfish and shellfish species; Assessment of seed quality, rearing techniques; Feeds for nursery rearing, preparation and evaluation; pre-stocking factors in different systems, valuation and observation; Calculating carrying capacity of pond and stocking density; Cage construction, pen construction and identification of bottlenecks; Sampling process and species wise growth estimation; Construction of rafts and mollusc culture; Seaweed collection and identification; Farm feed production and feeding; Disease identification and management; Visits to cage sites and observation; Records keeping and data analysis; Modelling of different culture systems.

VII. Suggested Reading

- Appukuttan KK, Asokan PK, Mohamed KS, Subramaniam S and G Joseph GK. 2003. *Manual on Mussel Farming*. CMFRI Technical Bulletin 3.
- Bardach EJ, Rhyther JH and Mc Larney WO. 1972. *Aquaculture the Farming and Husbandry of Freshwater and Marine Organisms*. John Wiley and Sons.
- FAO. 2001. *Planning and Management for Sustainable Coastal Aquaculture Development*.
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- Ottolenghi F, Silvestri C, Giordano P, Lovatelli A and New MB. 2004. *Capture-based aquaculture: the fattening of eels, groupers, tunas and yellowtails*. FAO Publ.
- Pillay TVR. 1990. *Aquaculture, Principles and Practices*. Fishing News Books.
- Pillay TVR and Kutty MN. 2005. *Aquaculture: Principles and Practices*. 2nd Ed. Blackwell.

- Sekar M, Ranjan R, Xavier B and Ghosh S. 2016. *Training manual on cage culture of marine finfish*. CMFRI Publ.
- Shepherd J and Bromage N. 1990. *Intensive Fish Farming*. B.S.P. Professional Books.
- Shepherd J and Bromage N. 1990. *Intensive Fish Farming*. B.S.P.Professional Books.
- Syda Rao G, Imelda-Joseph, Philipose KK and Suresh Kumar M, 2013. *Cage aquaculture in India*. CMFRI Publ.

I. Course Title : Hatchery Technology for Finfishes and Shellfishes

II. Course Code : AQC 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn research outlines and recent advances in seed productionand hatchery management of commercially important cultivable finfishes and shellfishes.

V. Theory

Unit I

Introduction: Current status; problems and prospects of seed of different shellfish species – freshwater and marine. Site selection and techniques of collection; identification and segregation of finfish and shellfish seed, handling, packing and transportation. Natural collection processes and their merits and demerits.

Unit II

Reproductive biology: Morphology and reproductive physiology; gonad anatomy; histology of gonad; Hormonal pathways and mode of control; Spermatogenesis and oogenesis; gametology (evaluation of milt and egg); Overview of current developments in reproductive biology of commercially important finfishes and shellfishes.

Unit III

Environmental and nutritional control of reproduction: Reproductive cycles, factors influencing reproduction (Photoperiod, change in water quality and quantity, temperature, lunar cycle, etc.), simulated environment and exogenous hormonal stimuli. Nutritional factors (types of feed - live and prepared feeds, nutritional quality, quantity, feeding management, feed utilisation, etc.) affecting maturation, spawning and nursery rearing.

Unit IV

Induced spawning: Brooder development, quality and its health management, transportation of brooders, hormonal and environmental stimulation, use of different natural, synthetic hormones and analogues and their application; GnRH and LINPE models, PIT tagging, Canulation and volitional spawning, Estimation of spawning efficiency, cryopreservation of gametes.

Unit V

Hatchery management: Indian major and minor carps, exotic carps, catfishes, tilapia, mahseer, murrels, Trout, Seabass, milkfish, mullets, grouper, snapper, breams, pompano, and cobia. Seed production of commercially important prawns (*Macrobrachiumrosenbergii*), shrimps (*Penaeus monodon, P. indicus, P. semisulcatus, and Litopenaeusvannamei*), crabs (*Scylla serrata, Portunuspelagicus*), spiny lobsters (*Panulirus*spp), mussels, edible oysters, pearl oyster and clams. Hatchery protocols, water quality management, larval rearing, estimations, troubleshooting in hatcheries, record keeping, packing and transport of seed, anaesthetics in fish seed transport. Quarantine and Hatchery protocols and biosecurity principles; sanitary and phytosanitary (SPS) measures; Better Management Practices (BMPs); packaging and transport of seed. SPF brood stock development.

Unit VI

Seed quality: Hatchery protocols, water quality management, larval rearing, estimations, trouble shooting in hatcheries, record keeping, packing and transport of seed, anaesthetics in fish seed transport. Quarantine and Hatchery protocols and biosecurity principles; sanitary and phytosanitary (SPS) measures; Better Management Practices (BMPs); packaging and transport of seed. SPF brood stock development. Economics of seed production of different species

VI. Practical

Study of primary and secondary sexual characters; Brooder handling and morphological features recording; Gonadal development observation in carps and other cultivable finfishes; Histological observation of gonads and eggs; Estimation of GSI, Fecundity, Absolute fecundity, Egg parameters, Ovarian features; Collection and identification of cultivable finfish seed; Seed quality character identification; Observation and analysis of inducing agents; Induced breeding of fishes through various inducing agents; Evaluation of carp milt and egg; Cryopreservation of gametes; Preparation of brood and larval feed for different cultivable finfish; Packing and transportation of cultivable finfish seed; Visit to different finfish hatcheries.

VII. Suggested Reading

- Betsy, C.J. and Kumar, J.S.S., 2017. *Cryopreservation and Spermatology in Fishes*. Narendra Publishing House
- Chattopadhay NR. 2016. *Induced fish breeding: a practical guide for hatcheries*. Elsevier Academic Press.
- FAO. 1992. *Manual of Seed Production of Carps*. FAO Publ.
- Gupta SD, Mohapatra PC, Routray P, Sahoo SK, Verma DK, Sarangi N. 2008. *Textbook of breeding and management of carps*. Narendra Publ. House
- ICAR. 2006. *Handbook of Fisheries and Aquaculture*. ICAR.
- Jhingran VG. 1991. *Fish and Fisheries of India*. Hindustan Publ. Corp.
- Jhingran VG and Pullin RSV. 1985. *Hatchery Manual for the Common, Chinese and Indian Major Carps*. ICLARM, Philippines.
- Landau M. 1992. *Introduction to Aquaculture*. John Wiley and Sons.
- Mcvey JP. 1983. *Handbook of Mariculture*. CRC Press.
- Pillay TVR and Kutty MN. 2005. *Aquaculture- Principles and Practices*. Blackwell.
- Rath RK. 2000. *Freshwater Aquaculture*. Scientific Publ.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.

I. Course Title : Aquaculture Policy and Planning

II. Course Code : AQC 504

III. Credit Hours : 1+1

IV. Aim of the course

To gain in depth knowledge to develop aquaculture policies for the sustainable aquaculture practices.

V. Theory

Unit I

Sustainability issues: Environmental and Socio-economic issues; Exotic species introduction; escapement; contamination of indigenous gene pool; salinization of soil and water; environmental impact; over exploitation of wild stocks; mangrove deforestation. EIA, eco-system approach to aquaculture. Conflicts over water and land use; conflicts of interest between aqua farmers and fishermen, aquaculture andother enterprises; social issues; anti-dumping duties.

Unit II

Climate Change Impact: Weather elements of concern in aquaculture, Green house gases, global warming and their impact, Carbon sequestration in aquaculture, Microplastics in Aquaculture, measures and tools to reduce energy use and greenhouse gas emission in aquaculture.

Unit III

Strategies for sustainability: Sustainability concept; food security; biosecurity; organic farming; responsible aquaculture; rotational aquaculture; bioremediation; role of biotechnology, traceability. Energy conservation. Application of renewable energy in aquaculture- solar energy, wind, and tidal energy, Seed certification, Sustainable use of antibiotics, minimal water exchange system, natural productivity, preservation of natural resources.

Unit IV

Guiding principles for sustainable aquaculture: Coastal Aquaculture Guidelines Source Book, FAO Code of Conduct for Responsible Fisheries; Holmenskollen Guidelines for Sustainable Aquaculture. BMP, CRZ implications, CAA and it's role, ecolabelling, organic certification. PCB and State water bodies protection guidelines.

VI. Practical

Visit to conventional aquafarm to see the management of used water; Survey on environmental impact on nearby aquaculture farms; Applications of remote sensing and GIS (geographical information system); Economic evaluation of aquaculture practices. Case studieson environmental issues of different types of farms.

VII. Suggested Reading

- Bardach JE. 1997. *Sustainable Aquaculture*. John Willey and Sons.
- Bardach JE, Rhyther JH and Mc. Larney WO. 1972. *Aquaculture Farming and Husbandry of Freshwater and Marine Organisms*. John Wiley and Sons.
- Beets WC. 1990. *Raising and Sustaining Productivity of Small- Holder Farming Systems in the Tropics*. Agbe Publ.
- Edwards P, Little DC and Demaine H. (Eds.). 2002. *Rural Aquaculture*. CABI.
- FAO 2001. *Planning and Management for Sustainable Coastal Aquaculture Development*. FAO.
- Imai T. 1978. *Aquaculture in Shallow Seas. Progress in ShallowSea Culture*. Amerind Publ.
- James PM. 1983. *Handbook of Mariculture*. Vol. I. Crustacean Aquaculture. CRC Press.
- Leung P, Lee CS and O'Bryen JP. (Eds.). 2007. *Species and System Selection for Sustainable Aquaculture*. Blackwell Publ.
- Midlen and Redding TA. 1998. *Environmental Management for Aquaculture*. Chapman and Hall.

- Selvamani BR and Mahadevan RK. 2008. *Aquaculture, Trends and Issues*. Campus Books International. FAO, 2011. Code of conduct for responsible fisheries. FAO special edition.

I. Course Title : Fish Nutrition and Feed Technology

II. Course Code : AQC 505

III. Credit Hours : 2+1

IV. Aim of the course

To learn the nutritional requirements and feed equipment's of major cultivable to develop new and novel feeds for the commercial aquaculture

V. Theory

Unit I

Introduction: Need for studying the nutritional requirements of cultivable fishes, feed formulation, Methods to study the nutritional requirements, and its need.

Unit II

Feed ingredients and Feed preparation: Commonly used feed ingredients in aqua feeds, Novel feed ingredients, estimation of quality of feed ingredients, Qualities of feed ingredients that determine feed quality, Selection of ingredients, Formulation of feeds, Feed processing and making. Different feed preparation methods.

Unit III

Types of feeds: Floating, semi-floating, sinking and stable feeds for aquaculture, Feed making methods for different feeds, Nutrient leeching in feeds, feed quality determination and feed making, Evaluation of feeds, Simulated system evaluation, lab analysis.

Unit IV

Advanced feeds: High energy feeds, Alternative protein sources for feeds, maturation diets to enhance breeding efficiency, Larval feeds, bio availability in feeds, High FCE and economic benefits of feeding in the farming, Live feed enrichment, Bio-routing of nutrients, Chemo-therapeutants, Other growth promoting agents through live feeds. Evaluation of bio-accumulation and bio-utilisation.

Unit V

Feed processing technology: Common processes in feed manufacture; Grinding, Dosing, Homogenization; Extrusion cooking; Complimentary processes; Drying, crumbling, coating; Use of binders; Feed manufacture productions with high energy diets vacuum coating with lipid. Equipments used in feed manufacture; Pulverizer, grinder, mixer, pelletizer, crumbler, drier, Extruder/Expander, Vacuum coater, fat sprayer

Unit VI

Quality control in fish feed manufacturing: Quality control procedures, raw materials, finished products; Geometrical, and physical feature; Mechanical characteristics in air, Behavioural characteristics in water, Feed economics and evaluation criteria: FCR, AFCR, SGR, PRE, ERE, PER, NPU.

VI. Practical

Nutritional requirements determination for different species; Collection and analysis of different feed ingredients; Feed formulation with different feed ingredients;

Feed quality analysis; Evaluation process in farms and labs; Visit to feed mills and feed making process; Economic analysis of feeding and non feeding systems; Identification of different feed additives; Observation of novel feeds and their utilization

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme), 1980.*Fish Feed Technology*. ADCP/REP/80/11. FAO.
- Ali SA. 2018. *Nutritional feeding of fish and shrimps in India*. MJP Publ.
- Cyrino EP and Bureau D and Kapoor BG. 2008. *Feeding and Digestive Functions in Fishes*. Science Publ.
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture*. Vol. VI. World Aquaculture Society, Baton Roughe.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series.
- Elena M. 2003. *Nutrition, Physiology and Metabolism in Crustaceans*. Science Publishers.
- Ganguly S. 2014. *Potential and recommended feed additives for sustainable aquaculture, livestock and poultry farming practices*. Narerndra Publ.
- Guillame J, Kaushik S, Bergot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publ.
- Halver J and Hardy RW. 2002. *Fish Nutrition*. Academic Press.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fish feed Technology*.Vols. I, II Heenemann, Berlin.
- Hertrampf JW and Pascual FP. 2000. *Handbook on Ingredients for Aquaculture Feeds*. Kluwer.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell.
- Lavens P and Sorgeloos P. 1996. *Manual on the Production and Use of Live Food for Aquaculture*. FAO Fisheries Tech. Paper 361, FAO.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Chapman and Hall.
- Lovell T. 2014. *Nutrition and feeding of fish*. Springer Publ.
- Merrifield D and Ringo E. 2014. *Aquaculture Nutrition: gut health, probiotics and prebiotics*.
- Nates SF, 2016. Aquafeed formulation. Academic Press
- New MB. 1987. *Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture*. FAO – ADCP/REP/87/26.
- Strasbourg LK. 2013. *Fish feeding in integrated fish farming*. Random Exports.
- Wiley Blackwell. Ninawe AS and Khedkar GD. 2009. *Nutrition in aquaculture*. NarendraPubl.

I. Course Title : Soil and Water Quality Management Inaquaculture

II. Course Code : AQC 506

III. Credit Hours : 2+1

IV. Aim of the course

To learn effective soil and water quality management practices foraquaculture

V. Theory

Unit I

Soil and water interaction: Physical and chemical properties of soil and water, Productivity vs. nutrient quality and quantity of soil and water; Aquatic microorganisms and their role in carbon, Nitrogen, Phosphorus and sulphur cycles and impact on aquatic habitats andspecies.

Unit II

Soil and water quality monitoring: Soil and water quality standards; Equipment used for soil and water quality estimations, Automated systems for monitoring, Quality checks and management, aeration system for water quality management.

Unit III

Fertilizers and manures: Different kinds of fertilizers and manures, Fertilizer grade, source, rate and frequency of application, Biofertilizers, Use of treated sewage for pond fertilization, Ecological changes taking place after fertilizing, primary production, degradation of molecules in aquatic environment, Utilization of bioactive compounds by microorganisms.

Unit IV

Soil and water conditioners: Biological indicators, Chemical and physical method of conditioning, Prebiotics, Probiotics, Minerals, Micro-nutrients and additives.

Unit V

Development of suitable soil and water quality: Cat clay/pyrite soil, Seepage, water treatment, Water filtration devices, Aeration, Chlorination, Ozonization and UV radiation, Algal bloom control, Eutrophication, Aquatic weed management, Water quality management in hatcheries.

Unit VI

Waste water treatment practices: Waste discharge standards, Role of microorganisms in fish production, Fish health and fish safety; Microbial load and algal blooms.

VI. Practical

Preparation of water quality charts and maintenance; Equipment used in soil and water analysis; Soil sampling, determination of soil moisture and bulk density; pond filling, Analyses of mud acidity and soil texture; Measurements of temperature, pH, conductivity, salinity, transparency, turbidity and solids; Analyses of dissolved oxygen, alkalinity and hardness, phosphorus, nitrogen; Estimation of primary productivity and chlorophyll; Application of fertilizers and pond liming; Analysis of toxic elements, microbial techniques, Visit to effluent treatment plant.

VII. Suggested Reading

1. Adhikari S and Chatterjee DK. 2008. *Management of Tropical FreshwaterPonds*. Daya Publ. APHA, AWWA, WPCF. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Ed. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington, DC.
2. Boyd, C. E. and Tucker, C. S. 1992. *Water Quality and Pond Soil Analyses for Aquaculture*, Alabama Agricultural Experimental Station, Auburn University.
3. Boyd CE. 1979. *Water Quality in Warm Water Fish Ponds*. Auburn University.
4. ICAR. 2006. *Handbook of Fisheries and Aquaculture*. ICAR.
5. Mcvey JP. 1983. *Handbook of Mariculture*. CRC Press.
6. Parsons TR, Maita Y and Lalli CM. 1984. *A Manual of Chemical and Biological Methods for Seawater Analysis*. Pergamon Press.
7. Rajagopalsamy CBT and Ramadhas V. 2002. *Nutrient Dynamics inFreshwater Fish Culture System*. Daya Publ.
8. Sharma LL, Sharma SK, Saini VP and Sharma BK. (Eds.). 2008. *Management of Freshwater Ecosystems*. Agrotech Publ. Academy.

I. **Course Title** : **Therapeutics and Health Management in Aquaculture**
II. **Course Code** : **AQC 507**
III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To gain knowledge on health management in aquaculture systems through diagnosis, treatment and preventing the disease outbreaks to protect aquaculture production.

V. **Theory**

Unit I

Diseases of fishes: Bacterial, Fungal, Viral diseases of fishes in farm ponds, Natural waters, and incidental outbreaks, Nutritional disorders and environmental diseases, situations for disease outbreaks, Natural immunity and disease control.

Unit II

Control of diseases in aquaculture systems: Control measures for fish diseases, Environmental and nutritional support methods for disease management, Immune modulation, Immunostimulation, Use of vaccines and other preventive methods, Control of diseases in various aquaculture systems, their limitations and benefits.

Unit III

Therapeutics: Concept of therapeutics in aquaculture, effectiveness of medication, Drugs in aquaculture, Herbal therapeutants, Use of and disuse chemicals in aquaculture, Legislation and jurisprudence in therapeutics for aquaculture organisms, Shrimp farming and control mechanism, Drug therapies for ornamental fishes, Biotraceability of antibiotics use in aquaculture.

Unit IV

Health management plans for hatcheries: Special features of hatcheries and health management of brooders, larvae, fry and young ones, Disease impacts on hatchery production, Disinfection protocol, Live feed crash due to diseases, Communicable diseases and their mechanism of spreading, Controlling outbreak of viral infections in all types of hatcheries, Economic benefits of investment in disease management.

Unit V

Modern treatment methods for fishes: Treatment methods currently in practice, isolation, Hospital tanks, Disinfection, Oral drug administration, immersion, Brooder treatment for immunity enhancement, mass treatment protocol, vaccination, advantagesand disadvantages.

Unit VI

Other health management aspects: Health improvement through feeds, Medicated feeds, Chemicals for treatment of external and internal diseases, Parasite treatment, health improvement after treatment, SPF, SPR and SPT seeds, their production protocols.

VI. **Practical**

Identification of disease conditions: Pathological features observation in cultivable fishes; Collection of diseased specimens and identification; Developing treatment protocols for fishes; Analysis of environmental situation favouring disease outbreaks;

Epidemic conditions in farms identification; Preparation of medicated feeds, validation and observation; Hospital tanks and management; Probiotics and prebiotics identification of their effects; Visit to hatcheries and farms to collect the specimens; Economics of different treatment methods.

VII. Suggested Reading

- Andrews C, Excell A and Carrington N. 1988. *The Manual of Fish Health*. Salamander Books.
- Brunton LL. (Ed). 2005. *Goodman and Gilman's The Pharmacological Basis of Therapeutics*. 11th Ed. McGraw-Hill.
- Felix S, Riji John K, Prince Jeyaseelan MJ and Sundararaj V. 2001. *Fish Disease Diagnosis and Health Management*. Fisheries College and Research, Institute, T. N. Veterinary and Animal SciencesUniversity. Thoothukkudi.
- Humphrey J, Arthur JR, Subasinghe RP and Phillips MJ. 2005. *Aquatic Animal Quarantine and Health Certification in Asia*. FAO Publ.
- Jorge E, Helmut S, Thomas W and Kapoor BG. 2008. *Fish Diseases*. Science Publ.
- Riviere JE and Papich MG. (Eds.). 2013. *Veterinary Pharmacology and Therapeutics* 9th ed. John Wiley and Sons.
- Sandhu HS and Rampal S. 2006. *Essentials of Veterinary Pharmacology and Therapeutics*. 1st Ed. Kalyani Publishers.
- Sindermann CJ. 1990. *Principal Diseases of Marine Fish and Shellfish*.Vols. I, II. 2nd Ed. Academic Press.
- Treves-Brown KM. 2013. *Applied Fish Pharmacology* (Vol. 3). Springer Science and Business Media.

I. Course Title : Larval Nutrition and Live Feed Production

II. Course Code : AQC 508

III. Credit Hours : 1+1

IV. Aim of the course

To learn the nutritional requirements of fish/shellfish larvae and techniques on mass culture and bio-enrichment of live food organisms.

V. Theory

Unit I

Larval nutrition: Nutritional requirements of finfish and shellfish larvae, Nutritional quality of commonly used live feed, Comparison of live feeds against the prepared feeds, Nutritional disorders in larvae, Larval feeds utilization and advantages.

Unit II

Formulation and preparation of artificial feeds: For larval rearing, Micro particulate diets, Particulate and microencapsulated diets, High energy feeds, energy sparing nutrients in larval feeds.

Unit III

Biology of live feeds: Important live feeds and their biological features, Identification of new live feeds, Live feed use in different forms, Advantages and disadvantages. Important microalgae, rotifers, artemia, infusoria, cladocerans, copepods, oligochaetes, nematode and insect larvae. Bio-enrichment of live feed, Biofilm/periphyton and its use, Culture of single cell proteins and their nutritional quality.

Unit IV

Live feeds research in India, Around the world, New techniques developed in live feed use. Quality determination and cost benefit analysis, Production methods for different micro feeds, lab analysis of quality.

VI. Practical

Collection, identification and isolation of live feed using various techniques, Preparation of various culture media, Preparation and maintenance of stock microalgal culture; Preparation of formulated feeds for rearing finfish and shellfish larvae; Mass culture of microalgae, cladocerans, copepods and rotifers; Hatching of artemia and enrichment; Culture of infusoria, earthworms and chironomidlarvae; Evaluation of different prepared feeds.

VII. Suggested Reading

- CIFE. 1993. *Training Manual on Culture of Live Food Organisms for AQUA Hatcheries*. Central Institute of Fisheries Education, Versova, Mumbai.
- Finn RN and Kapoor BG. 2008. *Fish Larval Physiology*. Science Publ.
- Gopinathan CP. 1993. *Handbook on Aqua Farming - Live Feed*. MPEDA Publication
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer.
- Joan Holt G. 2011. *Larval fish nutrition*. Wiley Blackwell Publ.
- Lee CS., O'Bryen, PJ, Marcus NH. 2005. Copepods in aquaculture. Blackwell Publishing.
- MPEDA. 1993. *Handbook on Aqua Farming - Live Feed. Micro Algal Culture*. MPEDA Publication.
- Muthu MS. 1983. *Culture of Live Feed Organisms*. Tech. Paper 14.Summer Institute in Hatchery Production of Prawns Seeds. CMFRI, Cochin.
- Ojha JS. 2005. *Aquaculture Nutrition and Biochemistry*. Daya Publ.
- Santhanam R, Ramnathan M and Venkataramanujum. 1997. *A Manual of Methods in Plankton*. Fisheries College and Research Institute, Tamil Nadu Veterinary and Animal Sciences University, Tuticorin.
- Sorgeloos P and Pandian KS. 1984. *Culture of Live Food Organisms with Special Reference to Artemia Culture*. CMFRI Spl. Publ. No. 15.
- Tonapi GT. 1980. *Freshwater Animals of India*. Oxford and IBH.

I. Course Title : Aquaculture Engineering

II. Course Code : AQC 509

III. Credit Hours : 1+1

IV. Aim of the course

To learn basic aspects of different aquaculture farm designing for effective management and optimum yield.

V. Theory

Unit I

Site selection: Criteria for site selection, Correction factors, Survey methods, Earth work calculations and cost estimation; water resources and their suitability, Suitability of soil from stability and productivity point of view; Land conversion effects and Environmental Impact Assessment (EIA).

Unit II

Estimation in farm construction: Area and volume calculations for an aquafarm and water bodies, surveying and leveling (chain, compass and plain table survey, dumpy level and the odolite).

Unit III

Design, layout planning and construction of different types of production systems: Types of ponds, shape, size and orientation, Design of embankments, Ponds and tanks, Water distribution, canals and exchange structures (inlets, outlets, sluice gates, and monks); Design of feeder channels and drainage systems. Pens, cages (fixed, floating, semi-submerged and tray cages) raceways, Flow-through systems and re-circulatory aquaculture systems (RAS), aquaponics, Feed dispensers, Demand feeders and effluent treatment systems (ETS), Automation in aquaculture.

Unit IV

Design and construction of hatcheries: (carp, freshwater prawn, shrimp and trout). Selection of aquaculture equipment and implement: Selection criteria and maintenance of water pumps, Water filtration systems, Principles of aeration, Aerators, Oxygen budgeting, Aeration grid, Automatic and demand feeders, Soil and water samplers. Aquifers, soil permeability, Hydraulic conductivity, Water budgeting, Water harvesting, Multiple uses of water, Economic impactof modernization in aquafarms

VI. Practical

Estimation in construction, Model development, Visit to aqua farms and hatcheries, Survey - contour survey and mapping, chain and compass survey, Dumpy leveling, Evaluation of performance of seepage control measures, Layout planning and design of hatcheries (carp, freshwater prawn, shrimp and trout) and farms including their costing and evaluation, Estimation of pump capacity, Estimation of construction cost of ponds, Hatchery shed, Aeration devices and Evaluation of their capacity.

VII. Suggested Reading

- Creed R. 2017. *Aquaculture and Fish Farming*. Syrawood Publ.
- Bose AN. 1991. *Coastal Aquaculture Engineering*. Oxford and IBH Publ.
- Ivar LO. 2007. *Aquaculture Engineering*. Daya Publ. House.
- Lekang OI. 2013. *Aquaculture Engineering*. Wiley-Blackwell Publ.
- Pillay TVR and Kutty MN. 2005. *Aquaculture- Principles and Practices*. Blackwell.
- Thomas L. 1995. *Fundamentals of Aquacultural Engineering*. Chapman and Hall.
- Wheaton FW. 1977. *Aquacultural Engineering*. John Wiley and Sons.

I. Course title : Open Water Aquaculture

II. Course code : AQC 510

III. Credit Hours : 1+1

IV. Aim of the course

To learn about the open water aquaculture for production enhancement

V. Theory

Unit I

Introduction: Overview of global scenario of aquaculture in open waters, open water resources in India, Present status, Utilization, Prospects of production augmentation, Utilization of open water bodiesfor aquaculture to enhance production

Unit II

Different culture systems: Cages, pens and enclosures in open waters, Seed stocking, quality and quantity, Cages for sea, estuaries, reservoirs, lakes and canals, Pen culture, Selection of site for sea farming, Different designs of open sea farming structures-construction of cages-bioengineering problems and solutions, Species selection for open water aquaculture, Rearing of fingerlings, advanced fingerlings and table size fish in open water bodies.

Unit III

Practices: Ranching in open waters, species quality and quantity, Natural feed enhancement, Supplementary feeding in cages, Stock assessment, Harvesting and conflicts with irrigation, Drinking water and hydroelectric projects on open water farming.

Unit IV

Environmental impact of Open water Aquaculture: Salinity intrusion, Effluent, discharge, Eutrophication, Chemical residues including antibiotics and hormones, Destruction of natural habitat including paddy field and mangroves, Social issues and conflicts with other users on resources

VI. Practical

Different types of cage materials, fabrication of cages and pens and their installation. Determination of stocking density in cages and pens, Feeding in cages and pens, Stock assessment in cages and pens; Environmental impact of cages and pens, Visit to cages and pen sites.

VII. Suggested Reading

- Beveridge MCM. (Ed.). 2004. *Cage Aquaculture*, 3rdEdition. Blackwell Publishing.
- Beveridge M. 2008. *Cage Aquaculture*. Oxford Publ.
- Burnell G, Allan G. 2009. *New Technologies in Aquaculture*. 1st Edition. Woodhead Publishing House.
- Chiu Liao I, Kwei Lin C. 2000. *Cage aquaculture in Asia: Proceedings of the First International Symposium on Cage Aquaculture in Asia*, AFS and WAS Publ.
- FAO. 2018. *The State of World Fisheries and Aquaculture -Meeting the Sustainable development goals*. Rome.
- NFDB. 2018. *Guidelines for Sea Cage Farming in India*.
- Syda Rao G, Imelda-Joseph, Philipose KK and Suresh Kumar M, 2013. *Cage Aquaculture in India*. CMFRI Publ.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Commercial Ornamental Fish Breeding and Culture

II. Course Code : AQC 511

III. Credit Hours : 1+1

IV. Aim of the course

To gain knowledge on advanced ornamental fish production technologies and aquatic ornamental plant propagation.

V. Theory

Unit I

Introduction: Global status of ornamental fish trade, present status and prospects of ornamental fish farming and trade in India, Indian ornamental fish diversity and its status, Prospects of production of new strains / varieties, Ornamental fish breeding techniques towards strain development.

Unit II

Design and construction: Self-maintained aquarium, species compatibility, High value species, Aquarium maintenance and care, Common aquarium plants and their identification, Gadgets used in freshwater and marine aquarium, aerators, Filters (UV, trickling and biofiltration), Protein skimmers, Ozonizer, thermostatic heater, Chiller, Lighting, Water conditioners, etc.

Unit III

Captive Breeding techniques: Mass production of commercially important freshwater and marine ornamental fishes, Nursery and grow out culture of commercially important ornamental fish species in Raceways, RAS etc., Hybrids development, Feed and feeding, Color enhancement through pigmented feed, Novel feeds, Common diseases, and control, Water quality management.

Unit IV

Transportation and Trading of Ornamental Fishes: Medicines and chemicals used in the ornamental fish industry, Anaesthetics, packing, transportation and marketing strategies. Culture unit for entrepreneurship development, Socio-economic upliftment through backyard ornamental fish farming, Micro-traders in ornamental fish marketing.

VI. Practical

Identification of common ornamental fishes; Plants and gadgets used in aquariums; Breeding of commercially important ornamental fishes, Visit to ornamental fish units, Aquarium fabrication, Setting and maintenance, Application and use of medicines/chemicals.

VII. Suggested Reading

- Ahilan, B., Felix, N., Santhanam, R., 2008. *Textbook of Aquariculture*. Daya Publishing House, Delhi.
- Axelrod HR and Vorderwinkler W. 1978. *Encyclopaedia of Tropical Fishes*.TFH Publ.
- Axelrod HR and Sweenen ME. 1992. *The Fascination of Breeding Aquarium Fishes*. TFH Publ.
- Axelrod HR. 1967. *Breeding Aquarium Fishes*. TFH Publ.
- Mills D. 1981. *Aquarium Fishes*. Kingfisher Books.
- Sanford G and Crow R. 1991. *The Manual of Tank Busters*. Salamander Books.
- Saxena A. (Ed.). 2003. *Aquarium Management*. Daya Publ.
- Spotte S. 1979. *Fish and Invertebrate Culture*. John Wiley and Sons.
- Thabrow De WV. 1981. *Popular Aquarium Plants*. Thornbill Press.

I. Course Title : Computer Application In Aquaculture Dataprocessing

II. Course Code : AQC 512

III. Credit Hours : 0+1

IV. Aim of the course

To understand the scope on the computer application in the aquaculture process flow and systems

V. Practical

Computer application basics; Different common software installation and application; Identification of farm based software; Installation and application; Application of SPSS, SAS, SYSTAT and STATISTICA for analysis and presentation of fisheries data; Basic concepts of database management systems: Introduction to MS-ACCESS, ORACLE (RDBMS); Exercise on analysis of data using MS-EXCEL, SPSS, SAS, FISAT, SYSTAT and STATISTICA; Creation of Database using MS-ACCESS, ORACLE, Linear modelling of Feed formulation software installation and use.

VI. Suggested Reading

- Cody RP and Smith JF. 1997. *Applied Statistics and SAS Programming Language*. Elsevier.
- Economics of vertical integration in hybrid striped bass aquaculture, in *Aquaculture: Models andEconomics* (Ed.) U. Hatch and H. Kinnucan, Boulder: Westview Press, pp. 91-105.
- FAO. 2018. *The State of World Fisheries and Aquaculture -Meeting the sustainable development goals*. Rome.
- Griffin, W.L., Hanson JS, Brick RW and Johns MA. 1981. Bioeconomic modelling with stochastic elements in shrimp culture. *J. World Maric. Soc.* 12: 94-103.
- Griffin, W.L., Jensen LA and Adams C.M. 1983. A generalized budget simulation model for aquaculture. TAMU-SG-83-202, Texas A and M University, 131 pp.
- Haakanson, L. and Wallin M. 1991. Use of ecometric analysis to establish load diagrams for nutrients in coastal areas, in *Marine Aquaculture and the Environment* (Ed.) T. Maekinen, pp. 9-23.
- Johnson, F.C. 1974. Hatch—a model for fish hatchery analysis.U.S. National Bureau of Standards, Washington, D.C. Report NBSIR 74-521, 51 pp.
- Landou S and Everitt BS. 2004. *A Handbook of Statistical Analyses Using SPSS*. Chapman and Hall/CRC.
- Lester, L.J., Perkins S and Wong BT. 1987. *Microcomputer use in aquaculture genetics*.
- Lee, P.G. 1993. *Computer Automation for Recirculating Aquaculture Systems*, in *Techniques for Modern Aquaculture* (Ed.) J. K. Wang, St. Joseph, Minnesota: American Society of Agricultural Engineers, pp. 61-70.
- Paulraj R. 1997. *Aquaculture Feed: Handbook on Aquafarming*. MPEDA Publ.

I. Course title : Inland Saline Aquaculture

II. Course code : AQC 513

III. Credit Hours : 1+1

IV. Aim of the course

To understand the scope for expanding aquaculture in inland saline waters for effective use

V. Theory

Unit I

Introduction: Inland saline waters, surface and ground water, Quality parameters of inland saline water in India, Global and national status of inland saline soils and underground saline water, Causes and process of salinization, geo-morphological changes, Problems of salinization, Potential for aquaculture.

Unit II

Soil and water characteristics: Comparison with coastal waters, Ionic amendment, water conditioning, Technological and engineering interventions for water quality improvement, Nutrient sparing and chelation in inland saline water.

Unit III

Potential candidate species: Sea bass, pearl spot, milk fish, mullet, shrimps, freshwater prawn, tilapia, cobia, pompano and selective carps for culture, Constraints and solutions, Alternate species with breeding possibilities, Metabolic interactions and growth promotion in altered water systems, Different farming systems.

Unit IV

Socio-economic Importance of Inland Saline Aquaculture: Nutritional intervention in inland shrimp farming; Economics of various finfish and shellfish culture in inland saline arenas; Integrated inland saline aquaculture systems; Recommendations for an action plan.

VI. Practical

Inland saline soil and water sample collection, analysis and ionic amendments, Visit to inland saline water farms, Case studies of inland saline farms, Evaluation of different systems with regard to species cultured, Trials with different species in known inland saline water bodies.

VII. Suggested Reading

- Boyd CE. 2000. *Water Quality: an Introduction*. Kluwer Academic.
- Burnell G and Allan G. 2009. *New Technologies in Aquaculture, Improving Production Efficiency, Quality and Environment Management*. Woodhead Publ.
- CIFE 2014. *Training Manual on Inland Saline Water Aquaculture Management Practices*.
- Garg SK and Arasu ART. 2003. *Proceedings of 3rd Interaction workshop, Fish Production using Brackishwater in Arid Ecosystem*.
- Pillay TVR and Kutty MN. 2005. *Aquaculture - Principles and Practices*. Blackwell.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Multilevel Integrated Aquaculture Systems

II. Course Code : AQC 514

III. Credit Hours : 1+1

IV. Aim of the course

To gain knowledge on advanced integration practices along with aquaculture for enhancing aquaculture production.

V. Theory

Unit I

Integrated fish farming: Global status, integration with agricultural (paddy), horticultural crops (vegetable and fruits) and livestock (cattle, poultry, ducks, pigs and other terrestrial animals). Effective recycling of wastes, nutrient budgeting in different integrated farming systems. Production levels and economics.

Unit II

Bioprocessed manures in integration: Vermicompost, farmyard manure/ compost, biogas slurry, etc. Advantages of biomanures, Control of microbial interactions, Fermentation of manures.

Unit III

Concepts: Integrated multitrophic aquaculture systems and design of an IMTA unit, Aqua tourism. Aquaponics: concept, Principles, types and operation, Multilateral interaction and reserve management.

Unit IV

Bio-resource flow in integrated aquaculture system: Discharge of nutrient wastes from integrated aquafarms; environmental effects, and potential for integrated multi-trophic aquaculture, An economic analysis of different integrated culture systems.

VI. Practical

Preparation of vermicompost; Analysis of nutrient value of different manures; Design of various integrated farming models; Different models of aquaponics; Nutrient analysis and management in aquaponics; Visit to integrated farms; Economics of different integrated systems with case studies.

VII. Suggested Reading

- Ahilan, B., Ravaneshwaran, K., Kumaravel, P., 2011. *Integrated Aquaculture*. Daya Publishing House.
- Little D, Edwards P. 2003. *Integrated Livestock-fish Farming Systems*. FAO Publ.
- Mathias JA, Charles AT and Baotong H. 1994. *Integrated Fish Farming*. CRCPress
- Pandey N and Davendra SM. 2008. *Integrated Fish Farming*. Daya Publ. House
- Sherman RL, Arancon NQ and Edwards CA. 2010. *Vermiculture Technology: Earthworms, Organic Wastes, and Environmental Management*. CRC Press.
- Soto D. 2009. *Integrated Mariculture a Global Review*. FAO Publ.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Cold Water Aquaculture and Recreational Fisheries

II. Course Code : AQC 515

III. Credit Hours : 1+1

IV. Aim of the course

To learn about the breeding and culture of different cold water fishes and their importance as sport fisheries or sport fish

V. Theory

Unit I

Introduction: Status of cold water fisheries in World with special reference to India, Biology, breeding and culture of trouts (*Oncorhynchus mykiss, Salmo truttafario, Schizothoraichthys esocinus, S. longipinnis, S. niger, Schizothorax richadsonii*), Mahseer (*Tor putitora, Tor tor, Tor khudree*), Common carp (*Cypinuscarpio cummuinis, Cyprinuscarpio specularis*). Specific environmental parameters pertaining to cold water fish culture and metabolic interaction, Feeds suitable for cold water aquaculture.

Unit II

Culture of coldwater fishes: Construction and management of coldwater fish farms, Effect of exotic fish introduction on indigenous fish fauna, Polyculture of exotic carps in mid hill region based on three Chinese carps, post-harvest and harvest issues in trouts with regards to cold water species, Special factors for consideration in cold water fish seed production and nursery rearing.

Unit III

Introduction to sport fisheries: Sports fishes and their life history, Equipments for sports fishing, fishing methods, area suitable for sports fishing, etc. Management and conservation of sports fisheries through aquaculture, Sport fisheries and tourism, recreational aquaculture.

Unit IV

Issues and Desired Interventions: Potential and Innovative Strategies for the Development of Cold water Aquaculture in India- problems encountered in fisheries development of rivers supporting cold water fisheries.

VI. Practical

Identification of cold water fish species; Primary and secondary sexual characters in coldwater fishes; Different breeding methods for coldwater fishes; Identification of larval stages of trout and mahseer; Preparation of hatchery layout for coldwater fishes; Studies on different types of sports fishing equipment; Visit to cold water fish hatchery.

VII. Suggested Reading

- Boghen, A.D., 1989. Cold-water aquaculture in Atlantic Canada. Institut Canadien de recherche sur le developpement regional, Atlantic Coast, Canada
- ICAR. 2006. *Handbook of Fisheries and Aquaculture*.
- Jhingran VG and Sehgal KL. 1978. *Cold Water Fisheries of India*. J.Inland. Fish. Soc. India. Sp. Publ.
- Jhingran VG. 1991. *Fish and Fisheries of India.* 3rd Ed. Hindustan Publ.
- Mahanta, P.C., Sarma, D., 2010. *Coldwater Fisheries Management*. ICAR
- Singh, H.R. and Lakra, W.S., 2008. *Coldwater Aquaculture and Fisheries*. Narendra Publishing House.
- Singh AK, Sarma D, Akhtar, MS and Baruah D. 2017. Souvenir – National seminar on stratagies, innovations and sustainable management for enhancing coldwater fisheries and aquaculture. ICAR-DCFR, Bhimtal.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ.

I. Course Title : Recirculating Aquaculture Systems (RAS)

II. Course Code : AQC 516

III. Credit Hours : 1+1

IV. Aim of the course

To gain complete knowledge about the recirculating aquaculture systems and its recent developments

V. Theory

Unit I

Introduction: Evolution of intensive culture technologies, Need for intensification in aquaculture, Land and water constraints, Conflicts between enterprises for water use, Need for RAS, Current status and prospects of RAS in world with special reference to Asian countries.

Unit II

System engineering: Basic needs for the construction of RAS, Design of RAS, water re-use methods, Water budgeting, culture tanks, shape and size, Special features, waste solids removal, Cornell dual-drain system, Settling basins and tanks- design, Fabrication and construction, Water collection and sludge removal

Unit III

Filters: Mechanical filters, Biofilters- trickling towers, Floating bead filters, Fluidized sand beds, Down flow micro-bead biofilter, Moving bed bioreactors; aerators.

Unit IV

Management of RAS: Waste management, feeding management. Animal health management in RAS. Economic viability of RAS for various commercially important finfishes. Challenges in uplifting RAS practices.

VI. Practical

Species for RAS; Calculating stocking density of fishes in RAS; Determining the controlling flow rate; Calculating required design flow rate for DO; Calculating tank sizes; Feeding management in RAS; Waste water management in RAS; Visit to RAS units

VII. Suggested Reading

- Burnell G, Allan G. 2009. *New Technologies in Aquaculture*. 1st Edition. Woodhead Publishing House.
- Bregnballe J. 2015. *A Guide to Recirculation Aquaculture*. FAO Publ.
- Christenson K. 2014. *Aquaponics: Aquaculture – An Introduction to Aquaculture for Small farmers*.
- Davion A. 2018. *Recirculating Aquaculture Systems: a Guide to Farm Design and Operations*.
- Hendry lau. 2015. *Aqauculture Production system*
- Hughston M. 2015. *Hydroponics: Hydroponic Gardening And Growing Vegetables Without Soil*.
- Kaul SN, Juwarkar AS *et al*. 2002. *Utilization of Wastewater in Agriculture and Aquaculture*. Scientific Publishers.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley- Blackwell.
- Timmons MB, Guerdat, T, Vinci, BJ. 2019. *Recirculating Aquaculture*. Ithaca Publishing Comp.
- Yoram, A., 2015. *Biofloc Technology: a Practical Guidebook*. WAS Publ.

Course Title with Credit Load
Ph.D. in Aquaculture

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
AQC 601	Hi-tech Aquaculture Production Systems	2+1
AQC 602	Seed Production and Hatchery Management	2+1
AQC 603	Aquaculture Ecosystem Management and Climate Change	2+1
AQC 604	Fish and Shellfish Physiology and Endocrinology	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
AQC 605	Feed Management in Aquaculture	1+1
AQC 606	Applied Biotechnology in Aquaculture	1+1
AQC 607	Automation in Aquaculture Systems	1+1
AQC 608	Aquaculture Medicine	1+1
	Supporting courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
AQC 691	Doctoral Seminar-I	0+1
AQC 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 Credits**
AQC 699	Doctoral Research (Semester II)	0+5
AQC 699	Doctoral Research (Semester III)	0+15
AQC 699	Doctoral Research (Semester IV)	0+15
AQC 699	Doctoral Research (Semester V)	0+20
AQC 699	Doctoral Research (Semester VI)	0+20
	Total Ph.D Program Credit Hours	100 Credits

Course Contents
Ph.D. in Aquaculture

I. Course Title : Hi-tech Aquaculture Production Systems
II. Course Code : AQC 601
III. Credit Hours : 2+1

IV. Aim of the course

To learn the advanced aquaculture production system research for different species globally

V. Theory

Unit I

Introduction: An overview of global aquaculture production, demand- consumption scenario and emerging trends, Present status, Constraints and future prospects in India and the world, Aquaculture practices indifferent parts of the world, Enhancing carrying capacity in culture systems.

Unit II

Biofloc technology: Principles of biofloc, Different carbon sources, Design of aeration system and biofloc reactor, Carrying capacity, C: N ratio, harvesting of biofloc, Biofloc quality and quantity, Biofloc as feed ingredient, Stocking of fish and shellfish species. Bioremediation in wastewater aquaculture.

Unit III

Minimal water exchange aquaculture systems: Principles of closed system farming, RAS, Components, design of mechanical and biological filters for the water reuse system, Sludge removal, disposal of wastes and control of pollution to the environment, Design of RAS, biofiltration and nitrifiers, Suitable cultivable species for indoor culture systems, polyhouses.

Unit IV

Aquaponics: Principles, Components and design of different aquaponics systems, Components in aquaponics, ratio of fish and plants, Water quality and system maintenance, Resource utilization, Nutrient recycling and zero discharge of nutrients.

Unit V

Running water systems: Flow-through system, Raceways (IPR), IMTA, Partitioned Aquaculture Systems (PAS), Aquamimicry systems.

Unit VI

Other farming methods: Cluster farming, Organic farming, Satellite farming, co-operative farming and conservation aquaculture, Network of production and marketing aspects, Economics of super intensive farming systems, Advantages and disadvantages.

VI. Practical

Design, fabrication and performance evaluation of biofloc systems; Different equipment in closed grow-out system; Aerators, Biofilters, RAS, Raceways, IMTA, PAS and aquaponics systems; Plankton and microbial analysis of biofloc. Studies on different C: N ratio; Nutrient analysis in aquaponics; Visit to hatcheries with super-intensive models. Identification and understanding the network of the systems; Market analysis for the produces; Analysis of economic advantages, case studies

VII. Suggested Reading

- Avnimelech Y. 2015. *Biofloc Technology- a Practical Guidebook*. 3rd edition. World Aquaculture Society
- Chakrabarti NM. 2014. *Biology, Culture and Production of Indian Major Carps*.
- Felix S. 2008. *Biosecured Aquaculture- Principle and Prototype*. Agrobios (India)
- Soderberg RW. 1995. *Flowing Water Fish Culture*. Lewis Publishers.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Seed Production and Hatchery management

II. Course Code : AQC 602

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge in the latest research in seed production methods for finfishes and shellfishes along with hatchery management technology.

V. Theory

Unit I

Reproductive biology: High value cultivable fishes, Crustaceans and molluscs. Reproductive behaviour of fishes, Sex determination, Anatomy and morphology of reproductive organs, Gametology and factors influencing the gamete quality.

Unit II

Broodstock management: Factors affecting the maturation and spawning of cultivable finfishes and shellfishes, Nutritional and environmental requirement for brood stock and their manipulation for early maturation, Criteria for the selection of brood stock, selective breeding strategies, Tagging, Transportation of broodstock, Natural and synthetic anaesthetics for transport, Vaccines and therapeutics for health management of brood stock, Brood stockquality determination and hormonal dynamics.

Unit III

Induced Spawning: Inducing agents, Factors behind the development of inducing agents, Analogues development, Comparative evaluation of commercially available inducing agents, Artificial insemination in crustaceans and molluscs; cryopreservation of gametes and embryos in finfishes and shellfishes, Artificial fertilization protocols.

Unit IV

Larval Nutrition: nutritional requirement of larvae and post larvae, live food culture, nutritional enrichment of live food organisms, different live feed products like powdered algae, algal paste, micronized algae, vitamin fortified algal products, formulation of artificial diets.

Unit V

Hatchery management: Water quality management in hatcheries; physico-chemical and biological approaches; Strategies to control diseases in hatcheries, Diagnosis, quarantine procedure, Prebiotics, Probiotics use in hatcheries, Seed quality testing methods and seed certification, Use of immunostimulants and immune modulators in hatcheries, SPF and SPR, Effluent treatment in hatcheries, Seed transportation methods.

Unit VI

Seed production and hatchery technology: Advances in seed production of commercially important finfishes and shellfishes, Artificial propagation of seaweeds (tissue culture), Recent technologies for enhancing survival and growth in nurseries, Nursery technology for different finfishes and shellfishes, Legal issues in seed quality and marketing.

VI. Practical

Determination of brood stock quality; Quantitative and qualitative determination of fish gametes like sperm motility, viability, counts; Cryopreservation of fish and shellfish gametes; Artificial fertilization in fishes; Project preparation for constructing hatchery (freshwater fish, marine fish, shrimp, molluscs); Broodstock quarantine in hatcheries; Live feed culture; Methods to identify quality of seeds (stress test, microscopic examination); Water quality management in hatcheries; Disease identification and treatment in hatcheries; Visit to hatcheries.

VII. Suggested Reading

- Allan, G. and Burnell, G. 2013. *Advances in Aquaculture Hatchery Technology*. Woodhead Publishing Limited.
- Betsy, C.J. and Kumar, J.S.S. 2017. *Cryopreservation and Spermatology in Fishes*. Narendra Publishing House.
- Betsy, C.J. and Kumar, J.S.S., 2017. *Biotechnological Applications in Fish Seed Production*. Narendra Publishing House.
- Diwan, A.D., 2018. *Biotechnology of penaeid shrimps*. Narendra Publ.
- FAO. 1992. *Manual of Seed Production of Carps*. FAO Publ.
- Elsa Cabrita, Vanesa Robles, Paz Herraez, 2015. *Methods inReproductive Aquaculture*.
- Gjedrem, T. and Baranski, M., 2009. *Selective Breeding in Aquaculture: an Introduction*. Springer.
- Gjedrem, T. (Ed.)., 2005. *Selection and Breeding Programs in Aquaculture*. Springer.
- Gupta SD, Mohapatra PC, Routray P, Sahoo SK, Verma DK, Sarangi N. 2008. *Textbook of Breeding and Management of Carps*. Narendra Publ. House
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer.
- ICAR. 2006. *Hand Book of Fisheries and Aquaculture*. ICAR.
- Jhingran VG and Pullin RSV. 1985. *Hatchery Manual for the Common, Chinese and Indian Major Carps*. ICLARM, Philippines.
- Muthu MS. 1983. *Culture of Live Feed Organisms*. Tech. Paper 14.Summer Institute in Hatchery Production of Prawns Seeds. CMFRI, Cochin.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ.

I. Course Title : Aquaculture Ecosystem Management and Climate Change

II. Course Code : AQC 603

III. Credit Hours : 2+1

IV. Aim of the course

To learn the impact of aquaculture on ecosystem management and climate change effects.

V. Theory

Unit I

Aquaculture and ecosystem relationship: Ecosystems and productivity, Biotic interaction within ecosystems and ecological homeostasis, Climate; Weather elements of concern in aquaculture, Greenhouse gases, Global warming and their impact.

Unit II

Impact of environment on aquaculture: Raw water source, Physical and chemical characteristics, Contaminants and pollutants (algae, pathogens, heavy metals, pesticides) and their effect on productivity.

Unit III

Impact of aquaculture on environment: Waste water discharge, Its quality and quantity, Impacts of effluents on ecosystems, Chemical degradation of soil and water.

Unit IV

Environment monitoring: Problems and preventive measures of antibiotic and drug residues, Salinization of soil and water, Eutrophication, Environment impact assessment and environmental audit.

Unit V

Sensor based monitoring: Biosensors in aquatic environment, Toxicity assessment, eco-labeling and traceability, Environment management.

Unit VI

Environment threats: Introduction of exotics and escape of farmed fish, Pathogens in aquatic environment, Safety of aquaculture products, Role of microbes in aquatic environment, Assessment of probiotic impact in aquaculture.

VI. Practical

Waste water analysis, Toxicity assessment studies; Eco-labelling and traceability, Isolation, nutrients budgeting, Quantification and administration of solid and liquid doses, Physical and chemical characteristics of soil, Design and construction of effluent treatmentplant.Carbon credit/ budgeting.

VII. Suggested Reading

- Black KD. 2001. *Environmental Impacts of Aquaculture*. CRC Press.
- Holmer M, Black K, Duarte CM, Marba N and Karakassis I. (Eds.). 2008. *Aquaculture in the Ecosystem*. Daya Publ. House.
- Midlen, A. and Redding, T., 1998. *Environmental Management for Aquaculture*. Chapman and Hall.
- Mischke, C.C., 2014. *Aquaculture Pond Fertilization - Impacts of Nutrients Input on Production*.

- Mustafa, S. and Shapawi, R. (Eds.), 2015. *Aquaculture Ecosystems- Adaptability and Sustainability*. Wiley Blackwell.
- Phillips BF, Ramirez, M.P. (Eds.), 2018. *Climate Change Impacts on Fisheries and Aquaculture- a Global Analysis*. Vol. I. Wiley Blackwell.
- Rajagopalsamy CBT and Ramadhas V. 2002. *Nutrient Dynamics in Freshwater Fish Culture System*. Daya Publ.
- Saha, R.K., 2013. *Soil and Water Quality Management for Sustainable Aquaculture*.
- Sharma LL, Sharma SK, Saini VP and Sharma BK. (Eds.). 2008.*Management of Freshwater Ecosystems*. Agrotech Publ. Academy.

I. Course Title : Fish and Shellfish Physiology and Endocrinology

II. Course Code : AQC 604

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge on finfish and shellfish endocrinology and physiological aspects.

V. Theory

Unit I

Endocrine system: Endocrine glands in fishes, Hormones and their kinetics, Structure and function of neuro-endocrine system in finfish and shellfish, Hormonal control of physiology.

Unit II

Hormones: Chemical nature of hormones, synthesis, storage, Release and control of hormones, Homeostasis, Endocrine control of growth and metabolism in fishes, Exogenous hormone administration, Implication, Impact on the general health and wellbeing of fishes.

Unit III

Influence of hormones: Eco-physiology, Adaptive mechanisms - reversible and irreversible changes, Physiology of migration and behaviour.

Unit IV

Neurophysiology: Neurosecretory system in fishes, Crustaceans and molluscs, Neurotransmitters, Physiology of ecdysis.

Unit V

Reproductive physiology: Endocrine control of maturation, spermatogenesis, oogenesis, spawning vitellogenesis.

Unit VI

Respiratory physiology: Gas exchange concept, Excretion and osmoregulation.

VI. Practical

Dissection of finfish and shellfish to study endocrine glands, Hormone assay – ELISA, Histological techniques to study reproductive and endocrine glands, Identification of moult stages, Application of respirometer and osmometer.

VII. Suggested Reading

- Babin PJ, Lubzens E. 2007. *The fish oocyte: from basic studies to biotechnological applications*. Springer Publ.
- Bernier NJ, Van Der Kraak G, Farrrell AP, Brauner CJ. 2014. *Fish neuroendocrinology*.

Fish physiology series Vol. 2, Elsevier Publ.
- Diwan AD. 2018. *Biotechnology of penaeid shrimps*. Narendra Publ.
- Farrell AP 2011. *Encyclopedia of fish physiology* Vol. I-III. Academic Press.
- Hara TJ and Zielinski BS. 2014. *Sensory systems neuroscience*. Fish physiology series Vol. 25, Elsevier Publ.
- Hoar WS and Randall DJ. 2014. *Fish Physiology* Vol. The Endocrine System. Academic Press
- Hoar WS, Randall DJ and Donaldson EM. 2014. *Fish Physiology* Vol. 9 A Reproduction: Endocrine Tissues and Hormones. Academic Press
- Hoar WS. 2014. Fish Physiology Vol. 9B. Academic Press
- Hoar WS and Randall DJ. 2014. *Fish Physiology* Vol. 4 The Nervous System, Circulation and Respiration. Academic Press
- Modayil MJ and Diwan AD. 2007. *Physiology of marine white shrimp Fenneropenaeusindicus*.
- Norris DO and Lopez KH. 2011. *Hormones and Reproduction of Vertebrates*. Vol. I Fishes. Academic Press.
- Perry SF, Tufts BL. 2014. *Fish respiration, Fish physiology* series, Vol. 17. Elsevier Publ.
- Reinecke M, Giacomo S, Kapoor BG. 2006. *Fish Endocrinology*. CRC Press.
- Samantaray K. 2015. *Physiology of finfish and shellfish*. New India Publ. Agency
- Shashikala KB, Sahoo AK. 2018. *Histology of Indian Major Carps* - A Colour Atlas.
- Sherwood NM and Hew CL. 2014. *Fish Physiology* Vol. 13. Molecular Endocrinology of fish. Academic Press

I. Course Title : Feed Management in Aquaculture

II. Course Code : AQC 605

III. Credit Hours : 1+1

IV. Aim of the course

To learn the latest research in the lines of understanding the influence of environment on nutrient utilization

V. Theory

Unit I

Nutrient dynamics: Influence of nutrient cycles on web/chain, Influence of detrital food web on nutrient distribution, Nutrient loading through feed and fertilizer, Natural feed augmentation for increasing fish production, Different food chains in aquatic ecosystem, Feeding behavior and feeding niche, Effect of environmental parameters on appetite of fish.

Unit II

Eco-friendly feed: Use of exogenous phytase and acidifiers, high energy diets, methods of enhancing feed digestibility, biofloc and probiotics influences.

Unit III

Nutritional pathology: Deficiency and imbalance diseases: essential amino acids, essential n-3 and n-6 fatty acids deficiencies, Micronutrients: fat-soluble vitamins, water-soluble vitamins; Macro- elements, trace-elements and mineral toxicity, Influence of stress on feed intake, Digestion and absorption, Stress indicator and nutritional strategies for mitigate stress.

Unit IV

Feed Management: Impact of feed and nutrition on environment, Nutrients affecting the water quality, Nutritional strategies to reduce the nutrient flow in aquaculture system, Contribution of feed waste to organic load of aquaculture production systems, Role of additives in reducing environmental pollution.

VI. Practical

Practical Study of influence of thermal stress, Hypoxia, Salinity and pH, Stress enzyme. (LDH, catalase, SOD, glutathione peroxidase), Stress hormone (Cortisols) and sex steroid hormone.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed Technology. ADCP/REP/80/11. F.A.O., Rome.
- De Silva, S. S. and Anderson, T. A. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver, J. E. 1989. *Fish Nutrition*, Academic Press, San Diego, California.
- Halver, J. E and Tiews, K. T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver, J. E. and Hardy, R. W. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher, B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell, R. T. 1998. *Nutrition and Feeding of Fishes*. KluwerAcademic Publishers.

I. Course Title : Applied Biotechnology in Aquaculture

II. Course Code : AQC 606

III. Credit Hours : 1+1

IV. Aim of the course

To learn about applied biotechnology aspects in aquaculture.

V. Theory

Unit I

Introduction: Scope of biotechnology in fisheries and aquaculture research. Vaccination in fishes- DNA vaccines, sub Unit Vaccines and Biofilm Vaccines.

Unit II

Feed biotechnology: Probiotics, single cell proteins, Neutraceuticals, Gnotobiotics. Recombinant proteins of commercial importance: enzymes, hormones, bioactive compounds, therapeutic proteins. Anti- microbial Peptides and their applications.

Unit III

Environmental Biotechnology: Bioremediation, biosensors, biofouling, treatment of waste water, Applications of biotechnological tools: Transgenic technology, Recombinant DNA, Monoclonal antibodies, Cell lines and stem cell culture, DNA markers and MAS, Biotechnological instrumentation in Aquaculture.

Unit IV

Constraints and Limitations: Biochemical and Molecular Markers; Commercial applications of Fish Biotechnology; Government regulation of Transgenic fish and Biotechnology products.

VI. Practical

Cell culture and cell lines; Development of hybridoma and production of monoclonal antibodies; Preparation of chromosomes from embryos and young fish Ploidy determination by RBC measurement and chromosome numbers; DNA markers; Gene transfer experiments; Northern blotting and southern blotting for integration and expression of transgenes.

VII. Suggested Reading

- Betsy CJ and Kumar JSS. 2017. *Biotechnological applications in fish seed production*. Narendra Publishing House.
- Diwan AD. 2018. *Biotechnology of penaeid shrimps*. Narendra Publ.
- Felix S and Ninawe AS. 2014. *Aquariculture Biotechnology*. Daya Publishing House.
- Fletcher GL, Rise ML. 2012. *Aquaculture Biotechnology*. Wiley Blackwell.
- Gautam NC. 2007. *Comprehensive Biotechnology*- Vol. 4 Aquaculture Biotechnology. Shree Publishers and Distributors
- Greglutz C. 2001. *Practical genetics for aquaculture*. Wiley Blackwell Publ.
- LakraWS, Abidi, SAH, Mukherjee, SC, Ayyappan S. 2014. *Fisheries biotechnology*.
- Montet D and Ray RC. 2009. *Aquaculture Microbiology and Biotechnology*. Vol. 1. Science Publishers.
- PreethiKartan, 2017.*Aquaculture Biotechnology*
- Richard Reece, 2017. *Analysis of genes and genomes*.
- Se-Kwon Kim, 2017. *Springer handbook of marine biotechnology*.
- Sunita R. 2015. *Fish Biotechnology*. Random Publications.

I. Course Title : Automation in Aquaculture Systems

II. Course Code : AQC 607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the possible automation in aquaculture systems for efficient management and enhanced income

V. Theory

Unit I

Introduction: Automation principles and procedures, Economic benefits of automation, Comparison of automation in agriculture and allied enterprises, History of automation in aquaculture, Scope for automation and need for automation in aquaculture, Evolution of machines and mechanisation in aquaculture, Advantages and disadvantages of automation, Current status and prospects of automation in World and India.

Unit II

Artificial Intelligence: Definition and application of AI in aquaculture, operating systems, system architecture, modules, AI software and its characteristics; AI in aquaculture, advantages of AI

Unit III

Robotics in aquaculture: Scope for Robotics in aquaculture, ROV, AUV, Drones, ASV, Automation for water quality management and health management in aquaculture, Novel automated systems in the world, technologies in aquaculture.

Unit IV

Software's used in Automation: Use of data acquisition systems in aquaculture. Biological models related to automatic control in aquaculture; Artificial intelligence software focuses on niche markets, A plug-and-play machine vision application for aquaculture.

VI. Practical

Automated systems description and application; Preparation of automation plans for individual systems; Robotics systems and application modules preparation; Drones and their utilization; Energy monitoring systems design and use; Trial automation in any one system.

VII. Suggested Reading

- Balchen, J.G. (Ed), 1986. *Automation and Data Processing in Aquaculture: Proceedings of the IFAC Symposium*, Trondheim, Norway, 18-21 August 1986 (Ifac Symposia Series) 1st Edition
- https://www.ntnu.edu/documents/919518/18708867/Giancarlo+Marafioti+NTNU+kybern etikk+ (uten+film).pdf
- https://www.eolss.net/Sample-Chapters/C18/E6-43-35-05.pdf
- https://www.sciencedirect.com/science/article/pii/014486099400 002I
- https://pdfs.semanticscholar.org/ae37/7b22085fbb6b975855f5f3 426c2357294be9.pdf
- http://ijsrcseit.com/paper/CSEIT172254.pdf
- Unbehauen, H.D., 2009. *Control Systems, Robotics And Automation*–Volume XIX: Industrial Applications of Control Systems-II. EOLSS Publications.

I. Course Title : Aquaculture Medicine

II. Course Code : AQC 608

III. Credit Hours : 1+1

IV. Aim of the course

To understand the pharmacokinetics of aquaculture drugs and chemicals

V. Theory

Unit I

Anaesthetics: Anaesthetics and methods of anaesthetizing fish and shellfish.

Unit II

Amendments in Aquaculture: Different chemicals and drugs used in aquaculture and dosages, Use of probiotics and immunostimulants in aquaculture

Unit III

Drug Mechanism: Action of different drugs in finfish and shellfish.Bioaccumulation and toxicity

Unit IV

Antibiotics: Antibiotics – use and misuse including development of antibiotic resistant bacteria and their impact on environment and human health

VI. Practical

Antibiotic sensitivity test, Estimation of dose, Estimation of antibiotic residues, Detection of gut colonization by probiotic bacteria

VII. Suggested Reading

- Andrews C, Excell A and Carrington N. 1988. *The Manual of Fish Health*. Salamander Books.
- Brunton LL. (Ed). 2005. *Goodman and Gilman's. The Pharmacological Basis of Therapeutics*. 11th Ed. McGraw-Hill.

- Riviere JE and Papich MG. (Eds.). 2013. Veterinary pharmacology and therapeutics 9th ed. John Wiley and Sons.
- Sandhu HS and Rampal S. 2006. *Essentials of Veterinary Pharmacology and Therapeutics*. 1st Ed. Kalyani Publishers.
- Treves-Brown KM. 2013. *Applied Fish Pharmacology* (Vol. 3). Springer Science and Business Media.

List of Suggested Journals

- *Aquaculture*
- *Aquacultural Engineering*
- *Aquaculture International*
- *Aquaculture Nutrition*
- *Aquaculture Research*
- *Reviews in Aquaculture*
- *Aquaculture Economics and Management*
- *Journal of the World Aquaculture Society*
- *Journal of Fish Diseases*
- *Fisheries Science*
- *Fisheries Research*
- *Fish and Fisheries*
- *Fish and Shellfish Immunology*
- *Fisheries Management and Ecology*
- *FEMS Microbiology Ecology*
- *FEMS Microbiology Letters*
- *Current Science*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *British Journal of Environment and Climate Change*
- *Biotechnology Letters*
- *Asian Fisheries Science*
- *Asian Journal of Animal Sciences*
- *Aquatic Sciences*
- *Aquatic Toxicology*
- *African Journal of Aquatic Science*
- *Turkish Journal of Fisheries and Aquatic Sciences*
- *Indian Journal of Animal Nutrition*
- *Journal of Fish Physiology and Biochemistry*
- *Journal of Applied Icthyology*
- *Journal of Aquaculture in Tropics*
- *Journal of Aquatic Living Resources*
- *Journal of Biotechnology*
- *Journal of Fish Physiology and Biochemistry*
- *Annual Review of Nutrition*
- *Annual Review of Physiology*
- *Journal of Plankton Research*
- *Water Research*
- *World Journal of Microbiology and Biotechnology*
- *Ecotoxicology and Environmental Safety*
- *Environment and Ecology*
- *Environmental Pollution*
- *Environmental Science*
- *Environmental Studies*
- *Environmental Technology*
- *Environmental Toxicology*
- *Indian Journal of Agricultural Statistics*
- *Indian Journal of Cytology and Genetics*

- *Indian Journal of Genetics and Plant Breeding*
- *Indian Journal of Statistics*
- *Journal of Animal Breed and Genetics*
- *Journal of Animal Science*
- *Journal of Applied Statistics*
- *Indian Journal of Fisheries*
- *Indian Journal of Experimental Biology*
- *Indian Journal of Entomology*
- *Indian Journal of Animal Research*
- *Indian Journal of Animal Sciences*
- *Journal of Statistical Software*
- *Journal of Statistics Education*
- *Indian Journal of Agricultural Economics*
- *Indian Journal of Agricultural Marketing*
- *Indian Journal of Pharmacology*
- *International Journal for Parasitology*
- *Journal of Applied Microbiology*
- *Journal of Aquatic Animal Health*

List of suggested e-Resources

- https://www.icar.org.in/
- http://www.fao.org/home/en/
- https://www.worldfishcenter.org/
- http://epubs.icar.org.in/ejournal/
- https://lib.icar.gov.in/full_text_ebooks.html
- https://lib.icar.gov.in/Open_Access_Journal.html
- https://www.aquaculturealliance.org/
- https://www.sciencedirect.com/
- http://www.ciba.res.in/
- http://www.cmfri.org.in/
- http://www.cife.edu.in/
- http://cifa.nic.in/
- http://www.nbfgr.res.in/ http://www.dcfr.res.in/
- http://www.cift.res.in/
- http://www.tnjfu.ac.in/
- https://www.was.org/
- https://www.asianfisheriessociety.org/
- https://www.aquaeas.eu/
- https://www.curtin.edu.au/
- https://www.tp.edu.sg/
- https://www.arizona.edu/
- https://mpeda.gov.in/MPEDA/
- http://dof.gov.in/
- http://www.caa.gov.in/
- http://www.fao.org/fishery/statistics/en
- http://kufos.ac.in/
- http://www.auburn.edu/
- https://www.stir.ac.uk/
- https://www.ugent.be/en

Suggested Broad Areas for Master's and Doctoral Research

- Recirculating aquaculture systems (RAS)
- Development of genetically improved broodstock
- Cryopreservation of gametes and embryos
- Development of vaccines for larvae

- Renewable energy in aquaculture
- Replacement of fish meal ingredient in shrimp and fish feed
- Development of novel feed ingredients
- Ontogeny of digestive system in fish larvae
- Cell lines and stem cell culture
- Inland saline aquaculture
- Dessert Aquaculture
- Arid land aquaculture
- Defense mechanisms and immunity
- Cage and pen culture of marine finfishes
- Study of nutrient dynamics in ponds
- Nutraceuticals for aquaculture feed
- Impact of climate change in aquaculture
- Statistical tools in Aquaculture
- Microbiomes in host environment interactions
- Status of seafood consumption and promotion
- Climate resilient aquaculture
- Carrying capacity and environmental impact in aquaculture
- Development of high resistant materials in the fabrication of cages
- Designing the cost effective probes for the water management
- Automation in aquaculture
- Development or restructuring of the aquaculture systems
- Integration of ANNAMOX nitrogen removal
- Nitrogen removal using Heterotrophic bacteria
- Algal culture and its impact in aquaculture systems
- Development of innovative and advanced filters and sludge units
- Open Ocean Aquaculture
- Aquaponics
- Open water IMTA and land-based IMTA
- Breeding and seed production of new candidate species
- Natural history of the cultured animal throughout its life stages.
- Biology of the cultured animal in terms of an aquaculture perspective
- The management of microbiome in the gut of the fish
- Novel and rapid diagnostic methods for the emerging diseases of commercial importance in Aquaculture
- Hi-Tech Aquaculture systems
- Quality control in feed and feed supplements
- Nutritional requirement of commercially important fishes
- Precision farming in Aquaculture
- Development of Phytogenic compounds to combat the diseases
- Electron-beam irradiation for the major deactivation of anti-nutritional factors.
- Supplementation of Exogenous enzymes to remove anti-nutritional factors
- Supplementation of nutraceuticals in mitigating multiple stressors
- The stress management strategies of super intensive culture
- The Nutrigenomic studies involving transcriptomics, proteomics and metabolomics
- Evaluating flesh quality using different feed supplements.
- Altering the dietary protein/energy ratio to increase the product shelf life.
- Integration of proteomic approaches with genomics and transcriptomis is the need of the hour.
- Bioinformatic capabilities to integrate omics technologies with aquaculture.
- Germplasm study and the analysis of the genetic diversities
- Larval fish nutrition
- Impact of aquaculture amendments
- Organic aquaculture
- Impact of Algal driven aquaculture

- Soil and water quality management
- Functional feed ingredient supplements in aquaculture
- Physiology of the major organs in finfishes and shellfishes
- Gene expression on growth stimulating factors in fishes
- Induce breeding and sex reversal
- Bioremediation and waste management
- Importance of fermentation and fermented products in aquaculture
- Micro and trace minerals requirements for the commercial candidate species
- Development of phyto sanitary measures and Standard operating procedures
- Disease surveillance, forecasting and development of field level diagnostic kits.
- Pigment enhancement studies in Ornamental aquaculture
- Hybridization of cultivable species
- Participatory aquaculture development models
- Control of cyanobacteria in aquaculture systems
- Bio-enrichment of live feed
- Microscopic studies on the microbial community
- Pharmacodynamics of drugs in fish, drug delivery systems, excretion of drugs, residual assays, herbal compounds as therapeutic drugs
- Characterization of parasites infecting fish and shellfish
- Host-parasite relation of various parasites and their biology
- Therapeutic approaches for control of infections
- Histopathological investigations of specific disease conditions
- Economic analysis of aquaculture practices
- Development of tissue specific cell expression systems
- Genetically engineered microorganisms for recombinant protein production
- Design of viral vectors for efficient gene delivery
- Digestibility due to plant to animal ingredient ratio
- Enhancement of digestibility of plant feed ingredients

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fisheries Resource Management

Preamble
(Fisheries Resource Management)

Fisheries is one of the important and fast growing sector in the country which is 1.28% of the national GVA and 7.28% of the Agricultural GVA. It provides livelihood to more than 25 million fishers and fish farmers.

With a coastal length of over 8, 000 km, an EEZ of around 2.02 million sq. km and with vast freshwater resources, fisheries play a vital role. It generates employment for a large coastal and other population, raises nutritional standards, increases food supply and earns foreign exchange. The marine fish landings stood around 3.56 million tonnes (CMFRI, 2019). Due to increasing the demand for the fisheries, fishing vessels are increased drastically to capture these protein rich resources. Unlike mineral resources, fisheries resources are self-renewable if it is properly managed.

During recent years, production from capture fisheries has been stagnating. Unregulated access to these fisheries resulted in significant overcapacity, especially of medium and small trawlers that compete over dwindling fishery resources with mostly impoverished small-scale fishers. The fishery resources are affected due to overexploitation in shore waters, bycatch, habitat alteration and anthropogenic actives. While it is difficult, if not impossible, to regenerate and improve open water fisheries, even small improvements in average yield would significantly enhance national fish production, because of the large extent of open water resources. Hence, it is necessary to recognize appropriate conservation and management measures to improve and sustain production. These resources should be sustainably managed and protected for the following reasons.

- Sustain, protect and increase national seafood supply
- Maintain and improve subsistence fishing
- Protect ecosystem health and sustainability
- Create jobs, support related economic and social benefits, and sustain community resilience

In the absence of a database on standing stocks, catch statistics, gear selectivity, fish behaviour, etc. of both inland and marine stocks, and oceanographic parameters, it would not be possible to come up with any management solutions for conservation of depleting stocks and increased exploitation of underexploited stocks.

Strenuous efforts are needed at central and state levels to upgrade the country's capacity to manage its natural fisheries resources. In this regard, the fisheries resource management discipline will provide the basis for the conservation and management of fisheries resources and it stems from the biological characteristics. According to the FAO definition fisheries resource management is the integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives.

To undertake these tasks, it is essential to understand the fisheries resource through proper education in the field of fisheries resources and its management. The following reasons substantiate the education and research in fisheries resource management.

- To study the biodiversity and biology of threatened and commercially important finfish and shellfishes
- To provide an insight into the various coastal and inland resources, multi user issues and anthropogenic effects on the resources and to devise resource management plans and protect the coastal and inland resources.
- To know the present level of exploitation of marine resources through stock assessment and biodiversity studies and to impart knowledge on conservation measures
- To advance the research on the reproductive endocrinology of threatened and commercially important finfish and shell fishes
- To judiciously exploit fishery resources
- To establish management measures to prevent overfishing, allocate fishing quotas to different fishing groups, implement gear restrictions, and protect sensitive habitats.
- To comply national and international treaties, act and rules
- To meet the sustainable development goals 2, 3, 4, 12, 13 and 14

Accordingly, the syllabus for Fisheries Resource Management is evolved as a multi-disciplinary PG program of study that provides exposure to all dimensions of modern fisheries resource management. This will empower the graduates to take management decisions for sustainable exploitation of national or regional fisheries and achieve the Sustainable development goals.

The following new courses were introduced at Master's level:

1. *FRM 501 Sustainable Fisheries Management	2+1
2. *FRM 503 Climate Change and Fisheries Resource	2+1
3. *FRM 505 Trophodynamics in Aquatic Systems	2+1
4. *FRM 506 Reproductive Biology of Finfish and Shellfish	2+1
5. FRM 509 Bio Systematics of Aquatic Fauna	1+2
6. FRM 512 Advanced Fish Anatomy and Physiology	2+1
7. FRM 513 Fish Histology and Histochemistry	1+1
8. FRM 514 Field techniques in Fisheries Resource Management	0+2

The following courses were suitably revised to study the biodiversity and stock.

1. *FRM 502 Fish Biodiversity and Conservation Biology	2+1
2. *FRM 504 Fish Stock Assessment	2+1
3. *FRM 507 Developmental Biology of Finfish and Shellfish	1+1
4. *FRM 508 Modern Techniques in Fisheries Biology	2+1

The following courses were removed.

1. FRM 505 Fisheries Regulations	2+1
2. FRM 506 Remote Sensing and GIS for Fisheries Management	1+1
3. FRM 50 Integrated Coastal Zone Management	2+1
4. FRM 508 Aquatic Floral Resources	2+1
5. FRM 511 Fishing and Allied Technologies	2+1

At Ph.D. level the following new courses were introduced:

• FRM 603 Functional Physiology of Fishes	(2+1)
• FRM 604 GIS Use in Fisheries Resources	(2+1)
• FRM 605 Fisheries Legislations, Governance and Treaties	(1+1)

The following two courses were suitably revised. Software based course is introduced to derive exploitation status of the fish stock.

- FRM 601 Fisheries Resource Conservation and Restoration Biology (2+1)
- FRM 606 Software Applications in Fish Stock Assessment (1+1)

The following three courses were removed as the subjects overlap with related disciplines:

- FRM 602 Applications of Fisheries Models in Stock Assessment (2+1)
- FRM 605 Data Collection and Estimation of Exploited Fisheries Resources (0+2)
- FRM 606 Fisheries Environmental Assessment (2+1)

Course Title with Credit Load
M.F.Sc. in Fisheries Resource Management

Course Code	Course Title	Credit Hours
	Major courses	
FRM 501	Sustainable Fisheries Management	2+1
FRM 502	Fish Biodiversity and Conservation Biology	2+1
FRM 503	Climate Change and Fisheries Resource	2+1
FRM 504	Fish Stock Assessment	2+1
FRM 505	Trophodynamics in Aquatic Systems	2+1
FRM 506	Reproductive Biology of Finfish and Shellfish	2+1
FRM 507	Developmental Biology of Finfish and Shellfish	1+1
	Minor courses	**8 Credits**
	(From the subjects closely related to a student's major subject)	
FRM 508	Modern Techniques in Fisheries Biology	2+1
FRM 509	Bio Systematics of Aquatic Fauna	1+2
FRM 510	Inland Fisheries Resources Management	2+1
FRM 511	Marine Fisheries Resources Management	2+1
FRM 512	Advanced Fish Anatomy and Physiology	2+1
FRM 513	Fish Histology and Histochemistry	1+1
FRM 514	Field techniques in Fisheries Resource Management	0+2
	Supporting courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 Credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its Management in Agriculture	
	4. Basic Concepts in Laboratory Techniques	
	5. Agricultural Research, Research Ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	**1 Credit**
FRM 591	Masters' Seminar	0+1
	Masters' Thesis Research	**30 Credits**
FRM 599	Masters' Research (Semester III)	0+15
FRM 599	Masters' Research (Semester IV)	0+15
	Total M.F.Sc Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fishereis Resource Management

I. Course Title : Sustainable Fisheries Management
II. Course Code : FRM 501
III. Credit Hours : 2+1

IV. Aim of the course

To understand the major inland and marine fisheries resources of the world and India. To discuss the major sustainability issues in the inland and marine fisheries sectors. To understand the ways and means to resolve the issues for sustainable fisheries resource management.

V. Theory

Unit I

Inland fisheries: Major inland fisheries resource of the world-India-Overview-State of the fisheries- Fishing gears-and crafts- Catch composition

Unit II

Marine fisheries: Major marine fisheries resources of the world and india-Overview- State of the fisheries -Fishing gears -Catch composition-pelagic, Demersal, Oceanic, Deep sea

Unit III

Sustainability issues in fisheries: Ghost fishing- Overexploitation, Overcapacity, pollution, Habitat degradation/ biodiversity loss, Damming of rivers, Interlinking of rivers , Environmental flows; Fishing conflicts-Exotics; Trans-boundary issues, IUU fishing, Interlinking of rivers-Climate change, By catch and discards.

Unit IV

Sustainable fishing: Components of sustainability, Indicators and goals of sustainability, Eco-friendly fishing, Ecosystem Based Fisheries Management-resilient fishery system

Unit V

Principle of fisheries management-Management approaches: By catch reduction- Rebuilding fishery, Rebuilding stock, Co-management- right based fishing-input control (fishing efforts, mesh regulations, fishing ban, licensing, capital investments, etc)-output control (catch quotas, minimum legal size, etc)- - Fishery reserve-technical measures, Spawning aggregates; trade agreement- Market-based instruments; Access right- Catch sharing-balanced fishing-Subsidy-certification and traceability-Sustainable management approach in lake, Reservoir and bheels.

Unit VI

Responsible fishing practices Precautionary management -Fisheries Co-management: Right based fishing- Catch sharing access right- Balanced fishing.-Technical Guidelines of CCRF for responsible fishing; National and International treaties (National policy on marine fisheries-2017; National policy on inland fisheries-2019; MFRA's; UNCLOS; UNFSA; IOTC)

VI. Practical

Capture fisheries observation at lakes, reservoirs, river stretches, and marine landing centres, Species landings analysis, Interaction with managers Co-operative societies and stakeholders Fleet capacity assessment, Visit to fishery reserves to understand management, Field survey and observation of fisheries issues, Development of management plan.

VII. Suggested Reading

- Bal DV and Rao KV. 1990. *Marine Fishes of India.* 1st Revised Ed. Tata McGraw Hill.
- Blaber JM. 1997. *Fish and Fisheries in Tropical Estuaries* Chapman and Hall.
- Chandra P. 2007. *Fishery Conservation, Management and Development.* SBS Publ. Dholakia AD. 2004.
- E. Eric Knudsen, Donald McDonald, 1999. *Sustainable Fisheries Management: Pacific Salmon.* 1st Edition. CRC Press p. 752 .
- FAO. Technical Papers on Freshwater Fisheries.
- Greene, C. M. and and G.R. Pess. 2009. *Multi-species modeling for salmon: alternatives, challenges, and opportunities.* 429-454 in E.E. Knudsen and J.H. Michael Jr., editor. Pacific salmon environmental and life history models: advancing science for sustainable salmon in the future. American Fisheries Society, Symposium 71, Bethesda, Maryland.
- Hilborn, R. C. and C. J. Walters. 1992. *Quantitative fisheries stock assessment*, ed. Chapman and Hall. New York, New York
- Jhingran VG and Pathak V. 1987. *Ecology and Management of Bheels in Assam: A case study of DhirBheel.* In: Workshop on Development of Bheel Fisheries in Assam, held at Assam Agricultural University, Guwahati from 21st to 22nd April.
- Jhingran VG. 1991. *Fish and Fisheries of India.* 3rd Ed. Hindustan Publ.
- Moyle PB and Joseph JC Jr. 2000. *Fishes – An Introduction to Ichthyology.* 4th Ed. Prentice Hall.
- Murawski SA, Matlock GC. *Ecosystem science capabilityies required to support* NOAA's mission in the year 2020. US Dept. Comm. NOAA Tech. Memo. NMFS-F/SPO-74. 2006.
- Peter BM and Joseph JC. Jr. 2000. Fishes- An Introduction to Ichthyology. 4th Ed. Prentice Hall.
- Samuel CT. 1968. *Marine Fisheries in India.* Narendra Publ. House.
- Sugunan VV. 1997. *Reservoir Fisheries of India.* Daya Publ. House
- Yadav BN. 1997. *Fish and Fisheries.* 2 nd Ed.Daya Publ. House.

I. Course Title : Fish Biodiversity and Conservation Biology

II. Course Code : FRM 502

III. Credit Hours : 2+1

IV. Aim of the course

To appreciate the biodiversity of various major aquatic fauna and flora, To understand the major threats to this aquatic biodiversity, To develop management strategies for the conservation of aquatic biodiversity

V. Theory

Unit I

Fish diversity: Fresh water fish diversity- Marine fish diversity-Quantification and importance of biological diversity- abundance- distribution.

Unit II

Species concept for conservation related decisions: Unique species- umbrella species-flagship species, Keystone species, state fish concept, -Endangered species-extinction-recovery-CITES- NBA- Migratory stock- Essential Habitat-EBSA.

Unit III

Biodiversity conservation methods: IUCN criteria - Red List, Marine Protected Areas, Sanctuaries and Biosphere reserves, Establishment of National marine parks, in situ and ex situ conservation, Participatory approach- Conservation value index – criteria – Medicinal and biological, IBI –stock resilience-recovery. Wildlife protection act, Biodiversity Act, International treaties and conventions (CITES, CMS, RAMSAR Convention).

Unit IV

Impacts of anthropogenic intervention on fisheries biodiversity: Exotic species, Damming of rivers, Construction of shore protection walls, Micro hydral power stations, Oil rigs.

Unit V

Aquatic biodiversity: Threats-Over exploitation, habitat reclamation, pollution, habitation, planning and management, tools for conservation, participatory approach -Impact of climate change on the ecosystem biodiversity, health and productivity

Unit VI

Conservation biology of biodiversity: Concept of hotspots- Ecological integrity: Minimum population sizes, Inbreeding depression, Genetic tolerance of extreme conditions, Restoration of populations at risk of extinction, Conservation – management of invasive species- Economic valuation of biodiversity and ecosystems

VI. Practical

Identification of scheduled aquatic organisms and exotic species, Predators of endangered animals, Visit to various aquatic ecosystem for recording the biodiversity, Conservation strategies (case studies), Calculation of trophic levels, Biodiversity indices-IBI, Conservation value Index, Presentation of field study.

VII. Suggested Reading

- Brian G. 1992. *Global Biodiversity - Status of the Earth's Living Resources*. Chapman and Hall.
- Denton TE. 1973. *Fish Chromosome Methodology*. Charles Thomas Publ.
- Elliott A. Norse (Ed.) 1993. *Global Marine Biological Diversity*. Inland press, Washington, D.C.383p. 4. Gunderson DR. 1993. *Surveys of Fisheries Resources*. John Wiley and Sons. New York. 248 p.
- Khanna DR, Chopra AK and Prasad G. 2005. *Aquatic Biodiversity in India*. Daya Publ. House.
- Kumar U and Asija M. J. 2000. *Biodiversity Principles and Conservation*. Agrobios.
- Lakra WS, Abidi R, Singh AK, Sood N, Rathore G and Swaminathan TR. 2000. Fish *Introductions and Quarantine: Indian Perspective*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Lambshead PJD, Paterson GLJ and Gage JD. 1997. *Biodiversity Professional*. Version 2. National History Museum and the Scottish Association of Marine Science.
- Magurran AE. 1988. *Ecological Diversity and its Measurement*. Taylor and Francis.
- Mahanta PC and Tyagi LK. 2003. *Participatory Approach for Fish Biodiversity Conservation in North East India*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.

- Ponniah AG and Gopalakrishnan A. (Eds.). 2000. *Endemic Fish Diversity of Western Ghats*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Zoological Survey of India. 2007. *National Symposium on Conservation and Valuation of Marine Biodiversity*.

I. Course Title : Climate Change and Fisheries Resource

II. Course Code : FRM 503

III. Credit Hours : 2+1

IV. Aim of the course

To become familiar with causes and effects of climate change, To understand the models and methods available for estimating climate change effects, To develop strategies for the mitigation of climate change effects for the management of fisheries resources.

V. Theory

Unit I

Introduction to climate science: Climate and biosphere, Climatic forcing factors, history of earth's climate, Climate change: The physical basis in marine and freshwater systems; Anthropogenic activities, greenhouse gases; Role of oceans; Diagnosing climate change-Scenarios.

Unit II

Climate change threats to fisheries resource: Temperature, Freshwater precipitation and sea level rise- Climate-induced degradation and loss of critical fish habitats. –Resilience - Tolerance limit-Temperature, pH and Salinity- Global warming and ocean acidification on fish early life stages.

Unit III

Climate change: Interaction between biodiversity - Effect on aquatic population –critical habitats-marine -freshwater-estuarine-high seas- endemic resources-Indicators of climate change - Climate change and invasive species.

Unit IV

Impact of Climate change on fish: On fish biology, Reproduction and life stages, Distribution and abundance- Migration patterns-fish physiology- Disease prevalence, Adaptation strategies of fishes towards climate change.

Unit V

Models on climate change and capture fisheries: Trophic dynamics model-Methods for estimating effects of climate change on fishery resources-Long term monitoring- Survey on effects of climate change on fisheries resources -Developing vulnerability index.

Unit VI

Policies and strategies on climate change: Impact of climate change on livelihood, Mitigation (emission reduction, life cycle assessment, carbon sequestration, improved governance) and adaptation strategies (resilience, vulnerability and risk assessment, institutional mechanisms) to climate change-Policy on climate change - IPCC, UNFCCC - Harvesting strategies - fishing right-Fishery resource management- key indicator species monitoring.

VI. Practical

Fish production trend analysis- India- global, Thermal effect on fish biology and reproduction, Climate change effect on fish early life stages- Fish physiology. Biodiversity- Threshold limits-temperature-pH and Salinity, Generation of fish distributional map. Group discussion on climate change, impact and mitigation strategies, Presentation of case studies.

VII. Suggested Reading

- AmielleDeWan, Natalie Dubois, Kathleen Theoharides, Judith Boshoven, 2010. *Understanding the impacts of climate change on fish and wildlife in North Carolina*- A review of climate change science, impacts, and planning options. for sensitive species and habitats. Defenders of Wildlife Washington D.C accessed through http://www.defenders.org 209 p.
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- Oehlert Gary W. 2000. *A first course in design and analysis of experiments*. 1st Edition.WH Freeman, New York, NY.
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- Robert Buchsbaum, Judith Pederson, and William E. Robinson(eds.,) 2005. *The Decline of Fisheries Resources in New England: Evaluating the Impact of Overfishing, Contamination, and Habitat Degradation*., MIT Sea Grant College Program, Massachusetts . 175 p.
- Sinclair M. 1988. *Marine Populations: an Essay on Population Regulation and Speciation*. University ofWashington Press, Seattle
- Tasker M. (Ed.). 2008. The effects of climate change on the distribution and abundance of marine species in the OSPAR maritime area. *ICES Cooperative Research Report*, 293. 45p.
- Thomann R, Mueller J. 1987. *Principles of surface water quality modeling and control*. Harper and Row, lnc, New York.
- Vivekanandan E. 2011. *Climate Change and Indian Marine Fisheries*. CMFRI Special Publication No. 105, CMFRI, Kochi.
- Janardhanan Sundaresan, KM Santosh, Andrea Deri, Rob Roggema and Ramesh Singh., eds.2013. *Geospatial Technologies and Climate Change*. 299p.
- Waggoner PE (ed) *Climate change and U.S. water resources*. John Wiley and Sons, New York,
- Weisberg S. 2005. *Applied linear regression*. 3rd edition. John Wiley and Sons, Inc., Hoboken, NJ.

I. Course Title : Fish Stock Assessment
II. Course Code : FRM 504
III. Credit Hours : 2+1

IV. Aim of the course

- To understand the stock concept and principles of fisheries management
- To understand the application of various models and their applications in fisheries management. To get an idea of the interaction of fish population in the ecosystem.

V. Theory

Unit I

Concept of stock and fish stock assessment: Distribution and types of stock - unit stock-mixed stock- straddling stock; Characterization of stock (life history traits, truss network, environmental signals, otolith shape; genetic analyses, applied marks); Principle and general procedure of fish stock assessment; Features of tropical and temperate fish stocks; Role of fish stock assessment in fisheries management.

Unit II

Sampling and measurements for fish stock assessment: Data requirement; Methods of sampling commercial catch, Sampling design and fish measurements; Assessment of fishery under data poor conditions; Survey methods for inland fisheries.

Unit III

Concept of growth and mortality: Principles of growth; Growth parameters-estimation of growth parameters employing hard parts and size frequency, Separation of cohorts, Mortality -Decay curve; types of mortality; Estimation of total, natural and fishing mortality rates.

Unit IV

Recruitment and gear selectivity: Timing and size of recruitment; Factors influencing recruitment; Principle and estimation of gear selectivity – trawl net and gill net selectivity; Eumetric fishing; Stock recruitment relationship– Cushing-Rickers- Beverton and Holt models.

Unit V

Fish stock assessment models: Analytical models: Cohort dynamics and life history; Virtual population analysis; Prediction models (Thompson and Bell model; Yield per recruit model and Relative Yield per Recruit model); Prey-predatory model; Surplus production models / Holistic models: Schaefer's model, Fox model, Swept area method, Stochastic model, Estimation of technical reference point MSY and other yield base reference point; economic and social reference points, Bio-economic modelling, Economic models - MEY, Swept area method - Box model-Bayesian Stochastic models, Multispecies models.

Unit VI

Trophic models: Ecosystem based models– Principles, Applications; Productivity models; Ecopath with Ecosim.

VI. Practical

Cohort analysis; Characterization of fish stock, 11-measurements; Truss network analysis, Otolith shape estimation of growth and mortality parameters (hard parts/ length based/age based), Gear selectivity, Stock recruitment relationship; Analytical models – VPA, Thompson and Bell model, Beverton's Yield per recruit and Relative yield per recruit model, Holistic models - Schaefer and Fox models; Swept area method, MSY, Use of FiSAT, LFDA, CEDA, YIELD. Presentation of case studies on use of ecosystem models.

VII. Suggested Reading

- Beverton RJH and Holt SJ. 1957. On the dynamics of exploited fish population. *Fish. Invest. Ser. II*, Vol. 19: 533p. Min. of Agriculture and Fisheries, London.
- Callucci VG, Saila SB, Gustafson DJ and Rothschild BJ. 1996. *Stock Assessment. Quantitative methods and applications for small scale fisheries*. Lewis publishers. Boca Raton, P. 527.
- Devaraj M. 1983. *Fish Population dynamics: a course manual*, CIFE Bulletin 3 (10): 98p
- Gulland JA. 1977. *Fish population dynamics.* Johnwiley and sons. Chichester. P. 422.
- Gulland JA. 1992. *A review of length based approaches to assessing fish stocks*. FAO technical paper. 323. p.100.
- Hilborn R and CJ Walters. 1992. *Quantitative Fisheries Stock Assessment – Choice, Dynamics and Uncertainty*. Pub. Chapman and Hall. 570p.
- King M. 1995. *Fisheries Biology, Assessment and Management.* Pub. Fishing News Books. 341p.
- Manual FAO. *Fisheries Technical paper* No: 301. FAO Rome. p407.
- Nikolsky GV. 1980. *Theory of fish population dynamics.* As the biological background for rational exploitation and management of fishery resources. BishensinghMahendra Paul singh and Otto Koeltz Science Publishers. P. 323.
- Pauly D. 1980. *Selection of simple methods for the assessment of tropical fish stocks*. FAO Fish. Circ., (729): 54p.
- Quinn TJ and RB Deriso. 2003. *Quantitative fish dynamics.* Pub. Academic Press.
- Ricker WE. 1971. *Methods for the Assessment of Fish Production in Freshwaters.* Blackwell, Oxford and IBH.
- Sparre P and Venema SC. 1998. *Introduction to Tropical Fish Stock Assessment.* Part 1 Manual. FAO. Fisheries Tech.Paper No.301, Rome
- Vivekanandan E. 2005. *Stock assessment of tropical marine fishes*. Indian Council of Agricultural Research, New Delhi.

I. Course Title : Trophodynamics in Aquatic Systems

II. Course Code : FRM 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the various methods of gut content analysis and various feeding indices To understand the relationship within a community, energy flow To develop linkages between biota and environment

V. Theory

Unit I

Food and feeding adaptations: Food and feeding habits of different types of finfish and shellfishes -Morphological and anatomical adaptation for feeding; Feeding behaviour-Ontogenic changes in food and feeding.

Unit II

Digestion : Food digestion - Energetics- Food partitioning- Larval feed- Gut development.

Unit III

Food web: Food web - food web in nearshore reef, Seagrass and unvegetated ecosystems - Biomarkers - Stable isotopes and fatty acids markers

UNIT IV

Prey predator interaction : Prey density - Predator density—Prey predatory interaction forage theory—Species succession - Food availability - Fishing effect on prey and predator

Unit V

Trophodynamics: Concept of trophodynamics-Methods in food and feeding analysis-Diet analysis -Diet breath- Diet overlapping indices- Energy flow and trophic indices and modelling- Calculation of trophic level.

Unit VI

Application of information on trophodynamics in fisheries management: Trophodynamic indicators- Ecopath with Ecosim model, SEAPODYM model.

VI. Practical

Morphological and anatomical adaptations in finfishes and shellfishes with different feeding habits. Analysis of gut contents, Gastro somatic Index, Use of indices in feeding, digestion and food consumption rates of fishes, Calculation of trophic levels- Mean trophic level, Comparison of mean trophic level between gears-season-space, Analysis of diet breath and diet overlap, Case studies using available data sets.

VII. Suggested Reading

- Aquaculture. ADCP/REP/87/26.F.A.O., Rome
- Baton Roughe LA, De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Bone Q.N.B. Marshall and JHS Blaxter. 1995. *Biology of Fishes* (2nd edition) Black ie Academic and professional, New york. 332 p.
- Boyd CE. 2015. *Water quality: an introduction*. Springer.
- Carl E Bond. 1979. *Biology of Fishes (2nd edition).* Saunders college publishing Harcount Brace college publishers, New york. 750 p.
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutritional: Advances in Aquaculture* Vol. 6. World Aquaculture Society,
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Kaushik SJ. 1998. *Nutritional bioenergetics and estimation of waste production in non-salmonids*. Aquat living resour 11(4): 211-217
- Khanna SS. 1993. *An introduction to fishes*. Central Book of Depo, Allahabad, 530 p.
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- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and crustaceans*. National Academy Press, Washington.
- Venkataramanujam K and N Ramanathan. 1994. *Preparation and Preservation of Compound Feeds for Shrimp and Fish* Manual of Finfish Biology. Oxford and IBH publishing Co. pvt. Ltd 1108.

I. Course title : Reproductive Biology of Finfish and Shellfish

II. Course code : FRM 506

III. Credit Hours : 2+1

IV. Aim of the course

To familiarise with the reproductive system and physiology of reproduction of teleost, elasmobranch, shrimps and molluscs

V. Theory

Unit I

Fish reproduction: Types – Gonads - Sexual differentiation, Reproductive biology: Gonado Somatic Index, Fecundity, Length at first maturity-breeding migration-Environmental influence of breeding cycle.

Unit II

Male reproductive system of finfish and shellfish: Endocrinology-spermatogenesis-sperm morphology.

Unit III

Female reproductive system of finfish and shellfish: Endocrinology- Oogenesis-Ovulation- Atresia- Vitellogenesis.

Unit IV

Physiological control of reproduction in finfish: Fish reproduction –Fish-hormone- Hormone Dynamics- Maturation and spawning, Hormones in spermatogenesis, oogenesis, Yolk formation, Mechanism of sex reversal; Pheromone. hormone based induced reproduction.

Unit V

Physiological control of reproduction in crustaceans (shrimp, crab and lobsters): Maturation and spawning, spermatogenesis, Oogenesis, Yolk formation, Mechanism of sex reversal- Eye stalk ablation.

Unit VI

Physiological control of reproduction in molluscs: Maturation and spawning, Spermatogenesis, oogenesis, Yolk formation, Mechanism of sex reversal – sex Control; Early Embryonic Development Maturity cycle and hormone

VI. Practical

Sexual dimorphism, Study of reproductive organs in finfish and shellfish by dissection, Maturity stage observation, Length at maturity estimation- intra-ovarian periodicity, Dissection of reproductive glands; fish sperm quality analysis – morphology, quantification and motility; Egg quality analysis – morphology, fecundity estimation; Histological techniques- study gonadal maturity stages; Identification of moult stages

VII. Suggested Reading

- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea. Biology Reviews*. Agarwal NK. 2008. Fish Reproduction. APH Publ.
- Adiyodi K.G, *Reproductive Biology of Invertebrates*: Vol-X P.B Prog in Developmental Endocrinology, Narendra Publishing House Publishers and Distributors
- Agarwal, N.K. 1996. *Fish reproduction* APH publishing corporation, New Delhi. 155p.
- Barrington, E.J.W.1981. *Invertebrate structure and Function* (2nd Edition). The English

Language Book society and Nelson, Great Britain. 765p.
- Bell TA and Lightner TA. 1988. *A Handbook of Normal Penaeid Shrimp Histology*. World Aquaculture Society.
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- Carl E. Bond. 1979. *Biology of Fishes* (2nd edition). Saunders college publishing Harcount Brace college publishers, New york. 750 p.
- Ghosh R. 2007. *Fish Genetics and Endocrinology*. Swastik Publ. and Distr.
- Hoar WS, Randall DJ and Donaldson EM. 1983. *Fish Physiology*. Vol. IX.Academic Press.
- Hoar, W.S. and D.J Randall (Ed.) 1969. *Fish Physiology* vol.III Academic press, New york. 415p.
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- Malcolm Jobling 1995. *Environmental Biology of Fishes*, Chapman and Hall London. 455 p.
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- Maria RJ, Augustine A and Kapoor BG. 2008. *Fish Reproduction. Science*. Publ.
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- Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
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- Thomas, P.C. Rath, S.C. and Mahapatra, K.D. 2017. *Breeding and Seed Production of Finfish and Shellfish*. DayaPublsihing house. 402 pp.
- Venkataramanujam, K. and N. Ramanathan 1994. *Manual of Finfish Biology*. Oxford and IBH publishing Co. pvt. Ltd 1108.

I. Course Title : Developmental Biology of Finfish and Shellfish

II. Course Code : FRM 507

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on the collection and identification of eggs and larvae of commercially important finfish and shellfish To understand developmental biology of aquatic organisms.

V. Theory

Unit I

Fish eggs and larvae: Morphology and identification of eggs and larvae of commercially important finfishes, crustaceans, molluscs and echinoderms-morphometry.

Unit II

Methods in Fish eggs and larval study: Quantitative sampling of fish eggs and larvae; Spatial and temporal distribution, Dispersion of eggs and larvae, Effect of environmental parameters on eggs and larvae.

Unit III

Eggs and larval dynamics: Reproductive cycle in fish- Spawning – Environmental cues- Recruitment assessment-Natural food of commercially important finfish and shellfish larvae from egg to adult.

Unit: IV

Larval development: Developmental biology of fish- Shellfish-sea urchin- Stages of development- Cell fate and commitment, Embryonic induction, Differentiation—Organogenesis- Morphogenetic movements,

VI. Practical

Identification of eggs and larvae commercially important species of crustacean and molluscan, Morphometry of eggs and larvae of finfishes, identification keys, Quantitative sampling- finfish and shellfish larvae; Food and feeding habits of larval stages of finfish and shellfishes.

VII. Suggested Reading

1. Barrington EJW. 1981. *Invertebrate Structure and Function*. 2nd Ed. The English Language Book Society and Nelson.
2. Diwan AP and Dhakad NK. 2004. *Embryology of Fishes*. Recent Advances in Embryology Series-1. Anmol Publ.
3. Ede DA. 1978. *An Introduction to Developmental Biology*. Blackie.
4. Hoar WS and Randall J. (Ed.). 1988. *Fish Physiology*. Vol XI. The Physiology of Developing Fish. Part B. Viviparity and Post hatching Juveniles. Academic Press.
5. Jobling M. 1995. *Environmental Biology of Fishes*. Chapman and Hall.
6. Khan SA, Raffi SM and Lyla PS. 2003. *Larvae of Decapod Crustaceans*. Centre of Advanced Study in Marine Biology, Parangipettai, TamilNadu.
7. Silas EG. 1983. *Development of Penaeid Prawns*. CMFRI Bull. No. 28.8.Werner A. Muller, 1996. Developmental Biology, Springer. 328p.

I. Course Title : Modern Techniques in Fisheries Biology

II. Course Code : FRM 508

III. Credit Hours : 2+1

IV. Aim of the course

To be aware of the modern / including molecular techniques that can be applied in fisheries biology

V. Theory

Unit I

Introduction: Advances in molecular technology – DNA extraction and PCR-quality and size of DNA- Sequencing-RNA extraction

Unit II

Electrophoresis: Principles – Types of electrophoresis- Identification of fish using agarose gel electrophoresis- SDS-Page- Staining protein gels- Digital electrophoresis analysis- Other electrophoresis techniques.

Unit III

PCR: Principle; PCR as a rapid detection method- Quantitative real-time PCR-Multiplex PCR- Nested PCR -Developments in molecular genetic techniques in fisheries.

Unit IV

Molecular genetic techniques in fisheries: Metagenomics and meta-transcriptomics- molecular techniques in population studies.

Unit V

Molecular methods in taxonomy: Cytological and Molecular Systematics and DNA Barcoding-barcode analysis.

Unit VI

Fish genetic markers and their applications in fisheries: Use of microarrays and RT-PCR- D-loop polymorphism analysis -Single Nucleotide Polymorphism -Restriction Length polymorphism analysis.

VI. Practical

Molecular laboratory safety issues- Extraction of DNA/ RNA, Barcode generation and analysis, Phylogenetic tree construction using barcode, Allozyme variation, Protein assay -2D gel electrophoresis.

VII. Suggested Reading

- Brown TA. (Ed.). 2002. *Essential Molecular Biology*. Vols. I, II. 2nd Ed. Oxford University Press.
- Carvalho Gary R. Molecular Genetics in Fisheries
- Cocolin, L Rajkovic, A., Rantsiou, K., .Uyttendaele M. 2011. The challenge of mergingfood safety diagnostics needs with Real-time PCR platforms. *Trends in Food Science and Technology*. 1-9
- Cooksey K. 1997. *Molecular Approaches to the Study of the Oceans*. Chapman and Hall.
- *Environmental Microbiology*. 2014 Eds Pepper, I.L., Gerba, C.P., Gentry, T.J Elsevier Academic Press ISBN-13: 978-0123946263
- FAO. 2000. *DNA Based Molecular Diagnostic Techniques*.
- Harvey Lodish and Arnold Berk, Chris A. Kaiser, and Monty Krieger; 2008. *Molecular Cell Biology* Ed. 6th; W H Freeman and Company; New York;
- Kocher TD and Carol AS. (Ed.). 1997. *Molecular Systematics of Fishes*. Academic Press.
- Le Gal Y and Halvorson HO. 1998. New Development in Marine Biotechnology. Plenum Press.
- Mayer E. 1977. *Principle of Systematic Zoology*. Tata McGraw Hill.
- Ponniah AG and George J. 1998. *Fish Chromosome Atlas*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Sambrook, J., Fritsch, E.F., Maniatis. *Molecular Cloning, A laboratory Manual*. Third edition. 2001. Cold SpringHarbor Laboratory, USA
- Whitmore DH. 1990. *Electrophoretic and Isoelectric Focusing Techniques in Fisheries Management*. CRC Press.
- Wilson, K. and Walker, J. (eds.). *Practical Biochemistry – Principles and Techniques:* Cambridge University Press, UK.

I. Course Title : Bio Systematics of Aquatic Fauna

II. Course Code : FRM 509

III. Credit Hours : 1+2

IV. Aim of the course

To acquire in-depth knowledge on the basics and recent developments in systematics and taxonomy of aquatic fauna

V. Theory

Unit I

Principles of taxonomy: Systematics, Taxonomy and Classification; Importance of taxonomy, Describing and naming of a new species, International Code of

Zoological Nomenclature, and its amendments and rules of Binomial Nomenclature; Zoo Bank and its policies, Morphology, Morphometric, Meristic, Osteology and Soft anatomical characters.

Unit II

Classification of Commercially important finfish: Classification of modern fishes up to order and family levels - Elasmobranchii (Cartilaginous fishes) and Actinopterygii (bony fishes).

Unit III

Classification of Commercially important shellfish: Classification of commercially important invertebrate up to family level: Arthropoda (Prawns, Shrimps, Lobsters and Crabs); Mollusca (Gastropods, Bivalves, Cephalopods and Scaphopods); Echinodermata (Sea Cucumbers), Preparations of dichotomous key.

Unit IV

Methods in taxonomy: Phylogeny and Zoo geography, Modern tools of taxonomy: Cytotaxonomy, Basics of biochemical taxonomy (Electrophoretic studies of muscle myogen, eye-lens protein, enzyme pattern and serology), PCR based methods and DNA finger printing, mitogene in fish identification. Identification of fish through auto-image processing.

VI. Practical

Collections and preparation of field data; Preservation techniques of specimens: Morphology, Graphical representation and statistical analysis of meristic, Morphometric, Osteological and soft anatomical characters; Key Pattern – Dichotomous key – Type of keys –Dichotomous, Bracket, Indented, Branching, Pictorial and computer keys; Protocols followed for describing of a new species, Use of distribution maps; curation and sorting protocols, Visit to freshwater, brackishwater and marine waters (markets; landing centres) of the locality and inventorying of commercially important fishes, Mollusca, Crustacea, Echinodermata (diagnostic characters of the orders, families and species), Modern taxonomical tools. Cytotaxonomy: Karyotyping – preparation and identification of chromosomes, Electrophoresis studies (muscle myogen, eye-lens protein, enzyme pattern and serology), Molecular markers–PCR, RAPD, RFLP, Microsatellites, mini satellites and Mitochondrial DNA and their application in fish phylogenetic studies; Barcoding

VII. Suggested Reading

- Apte D. 1998. *The book of Indian Shells*. Oxford University Press. Calcutta, Chennai, Delhi, Mumbai. p 115.
- Barman RP and SS Mishra. 2012. *Nemipteridae, Polynemidae, Mullidae* (Separate compilation for each family).
- Barman RP, SS Mishra, S Kar, P Mukherjee and SC Saren. 2012. *Marine and estuarine fishes of Maharashtra*. Zool. Surv. India, Fauna of Maharashtra, state fauna series, 20 (part 1): 369-480, 2012.
- Cooksey K. 1997. *Molecular Approaches to the Study of the Oceans*. Chapman and Hall, London. ICZN: International code for Zoological Nomenclature Publ: International Commission 1999.
- Day F. 1878. *The Fishes of India*. Published by William Dawson and sons Ltd.
- FAO. 2000. *DNA based molecular diagnostic techniques*.
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- Hamilton F. 1822. *Fishes of the River Ganges and its branches*. Publ. Edinberg
- Holden MJ and Raitt FS. 1974. *Manual of Fisheries Science*, Part II - Methods of Resource, Investigation and their Application. FAO Fish Technical Paper 115 Review Page 1-224.
- Jayaram KC. 2010. *The freshwater fishes of the Indian Region* II edition. Narendra Publishing house New Delhi.
- Jayaraman KC. 2002. *Fundamentals of Fish Taxonomy*. Publ.
- Lagler, Karl F, John E Bardach, Robert R, Miller and Dora R, May Passino. 1977. *Ichthyology* II edition. John Weily and Sons.
- Le Gal Y and Halvorson HO. 1998. *New Development in Marine Biotechnology*, Plenum. Marine species identification portal for crustaceans (crabs and prawns etc).
- Mayr E. 1977. *Principles of Systematic Zoology*. Tata Mc Graw Hill Publishing Co. Ltd. New Delhi, p. 428.
- Michael M Cox and David L Nelson. 2010. *Leninger Principles of Biochemistry*, Fifth Edition. W.H. Freeman and company, New York.
- Moyle PB and JR Cech. 1996. *Fishes – An Introduction to Ichthyology*. Prentice Hall Inc. N. Jersey, 594p.
- Munro ISR. 2000. *The Marine and Freshwater Fishes of Ceylon*. Narendra Publishing house, New Delhi. 351 p.
- Nelson JS. 2006. *Fishes of the World*, IVth edition, John Weily and sons.
- Ponniah AG and George John. 1998. *Fish Chromosome Atlas*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow publication.
- Poutiers JE. 1998. Bivalves; Gastropods. In: K. E. Carpenter, V H. Niem (eds.), FAO species identification guide for fisheries purposes. The living marine Resources of the Western Central Pacific. Volume I. Seaweeds, corals, bivalves And gastropods. Pp.123-686.FAO, Rome, ISBN 92-5-104051-6.
- Raje SG, S Sivakami, G Mohanraj, PP Manojkumar, A Raju and KK Joshi. 2007. *An atlas of the elasmobranch fishery resources of India*. CMFRI special Publication no.95.
- Subramanuam TV, KR Karandikar and NN Murthy. 1949. *Marine Pelecypods of Bombay* Part I. J. Bombay University. Vol 17. 50-81.
- Subramanuam TV, KR Karandikar and NN Murthy. 1951. *Marine Gastropods of Bombay* Part I. J. Bombay University. Vol 3. 21-34.
- Subramanuam TV, KR Karandikar and NN Murthy. 1952. *Marine Gastropods of Bombay* Part II. J. Bombay University. Vol 21. 26-73.
- Talwar PK and Jhingran AG. 1991. *Inland fishes of India and adjacent countries*, Delhi Oxford and IBH Publishing Co.Pvt. Ltd. 1158 p. Vol. I and II
- Talwar PK and Kacker RK. 1984. *Commercial Sea Fishes of India*. Published by ZSI, Kolkata. 997 p.
- Thomas D, Kocher and Carol A Stepien (Ed.). 1997. *Molecular Systematics of Fishes*. Academic Press. New York. 314p.
- Whitmore DH. 1990. *Electrophoretic and Isoelectric focusing techniques in fisheries management*. 350pp.

I. Course title : Inland Fisheries Resources Management

II. Course code : FRM 510

III. Credit Hours : 2+1

IV. Aim of the course

To understand the present exploitation and future potential of inland Fisheries. To learn the methodologies for assessments of Inland Fisheries Resources

V. Theory

Unit I

Freshwater fisheries resources India-world: Ponds, Lakes, Bheels, Tanks, Estuaries, Brackish water lagoons, Wetlands, Biosphere reserves and mangroves and derelict water bodies their problems and management aspects, Assessment of carrying capacity of different inland water bodies; Water budgeting, Community participation in fishery resource management.

Unit II

Bheel fisheries resources of India: Open and closed bheels, Productivity conditions, Capture scenario, Prospects of culture based systems.

Unit III

Riverine fisheries resources in India: Present trend of dwindling fisheries resources, Direct and Indirect effects of human intervention in rivers, habitat modification and improvement (rehabilitation of channels and flood plains), Protection and restoration of fish movements (different types of fish passes and enhancement of fish migration), Management and repair of riverine vegetation, Stock enhancement strategies like introduction of new species, Pre- and post-stocking management, Potential risk of stocking.

Unit IV

Cold water fisheries of India: Present trends, Problems due to habitat destruction, Management aspects, Prospects of sports fisheries in India.

Unit V

Reservoir Fisheriesin India: Classification of reservoirs, Present productivity levels, Management practices.

Unit VI

Estuarine fisheries in India: Classification of estuaries- Present productivity level potential; Problem – Management practices.

VI. Practical

Freshwater fish identification, Tagging – different types of tags, Visit to nearest freshwater body; catching methods – catch data analysis on major freshwater resources- Bheels- Estuaries - Reservoirs – lakes, Biodiversity indices – Gear selectivity.

VII. Suggested Reading

- Blaber JM. 1997. *Fish and Fisheries in Tropical Estuaries* Chapman and Hall.
- FAO. Technical Papers on Freshwater Fisheries.
- Jhingran VG and Pathak V. 1987. *Ecology and Management of Bheels in Assam*: A case study of DhirBheel. In: Workshop on Development of Bheel Fisheries in Assam, held at Assam Agricultural University, Guwahati from 21st to 22nd April.
- Jhingran VG and Sehgal KL. 1978. *Cold Water Fisheries of India. J. Inland. Fish. Soc. India*. Sp. Publl.
- Jhingran VG. 1991. *Fish and Fisheries of India*. 3rd Ed. Hindustan Publ.
- Sugunan VV. 1997. *Reservoir Fisheries of India*. Daya Publ. House.

I. Course Title : Marine Fisheries Resources Management

II. Course Code : FRM 511

III. Credit Hours : 2+1

IV. Aim of the course

To know the present level of exploitation of marine resources and to impart knowledge on conservation measures. To learn the recent methodologies of sustainable exploitation of renewable resources.

V. Theory

Unit I

Status of marine fisheries: Major fishing nations of the world, Major fishing regions, present trend of marine capture fisheries.

Unit II

Marine fish resources: Important finfish and shellfish resources in demersal and pelagic systems; Conservation strategies.

Unit III

Fishery management: Mud bank fishery- wadge bank fishery-Commonly used tools for input and output regulations, Principles of management of fisheries resources, Objectives of management, Issues and challenges of managing multi-gear fisheries.

Unit IV

Sustainability: Principles, Socio-economic, Ecological, Biological and Legal issues-Fisheries co-management - Case studies of fisheries conflicts between sectors, states and nations, Conflict management.

Unit V

Fisheries and fishing methods in open waters: Inshore fisheries (up to 50 m depth), Offshore fisheries (50-200 m depth) -High sea fisheries.

Unit VI

Conservation aspects: Marine Biodiversity of selected areas including coral reef conservation, Biodiversity principles, Categorization of species into endangered; Indeterminate and extinct varieties- Managing the highly exploited fishery resources.

VI. Practical

Marine fishery resources – visit to nearest marine landing centres, Length frequency analysis – catching method, Catch data analysis on marine fishery resources of India. Closed season studies – gear selectivity.

VII. Suggested Reading

- Bal DV and Rao KV. 1990. *Marine Fishes of India*. 1st Revised Ed. Tata McGraw Hill.
- Chandra P. 2007. *Fishery Conservation, Management and Development* .
- *Fisheries and Aquatic Resources of India*. Daya Publ. House.
- FAO. *Technical Papers on Marine Fisheries*.
- Kurian CV and Sebastian VO. 1986. *Prawns and Prawn Fisheries of India*. Hindustan Publ. Corp.
- Peter BM and Joseph JC. Jr. 2000. *Fishes- An Introduction to Ichthyology*. 4th Ed. Prentice Hall.
- Samuel CT. 1968. *Marine Fisheries in India*. Narendra Publ. House.
- Shanbhogue SL. 2000. *Marine Fisheries of India*. ICAR.
- Yadav BN. 1997. *Fish and Fisheries*. 2 nd Ed. Daya Publ. House.

I. **Course Title** : **Advanced Fish Anatomy And Physiology**

II. **Course Code** : **FRM 512**

III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To impart an in depth knowledge on anatomy and physiological regulations in fishes for better fisheries resource management

V. **Theory**

Unit I

Principles of Fish anatomy: Study of internal anatomy of important groups of finfish and shellfish, Body form, swimming mechanisms and buoyancy regulation- bioenergetics, strategies for buoyancy regulation- Fish behaviour and regulatory mechanism- alarm reaction-transduction mechanism, Sense organs and their functions. Hearing mechanism and specialization. Physiology of photoreceptors and pineal organ.

Unit II

Anatomy and physiology of digestive system: Digestive organ and their mechanism, Functions, Feed ingestion and feeding mechanism - Feeding mechanisms and their control, Effect of starvation.

Unit III

Anatomy and physiology of excretory system: Excretory organs in fish and shellfish and their functions, Mechanism of excretion of nitrogenous waste, Osmoregulation in freshwater fishes, Marine fishes, Elasmobranches, Crustaceans and molluscs.

Unit IV

Muscle physiology: Striated and smooth muscle, Adaptations of muscles for various activities, Neuronal control of muscle contraction, Electric organs, Stenohaline and Euryhaline animals and their tolerance capacity.

Unit V

Endocrine and exoocrine glands: Hormones and their role in appetite, Osmoregulation, Calcium metabolism, Cardiovascular regulation and behaviour, hormone receptors, Endocrine disruption, Mechanism of hormone synthesis, Release, transport and action, Hormone receptors and their characteristics, Neuroendocrine regulation of gametogenesis, Maturation and ovulation processes.

Unit VI

Adaptations to Stress: Basic concept of environmental stress, Acclimatization, Avoidance and tolerance, Stress and Hormones.

VI. **Practical**

Dissection of different shellfishes and finfishes to understand their internal organs. Influence of temperature and salinity on metabolism, Display of visceral organs; dissection of fish bones and skeleton, Oxygen consumption in relation to body size/ stress/anesthesia, Chronic and acute responses to environmental changes (temperature and salinity) on metabolism, Collection and analysis of body fluids, blood sampling; gamete collection, Oxygen consumption in relation to body size/

stress/anesthesia, Haematology, Acute and chronic stress markers (estimation of glucose, cortisol, total protein, AST, ALT, LDH), Analysis of digestive enzyme activities. Measuring osmoregulatory parameters. measuring reproductive hormones; Audio visual recording of behaviour in simulated experiment.

VII. Suggested Reading

- Alan GH. 1995. *Water Pollution and Fish Physiology*. CRC Press.
- Chavin W. (Ed.). 1973. *Responses of Fish to Environmental Changes*. Charles C Thomas Publ
- Conn EE and Stumpf PK. 1987. *Outline of Biochemistry*. Wiley.
- Diwan, 2007. *Physiology of Marine White Shrimp: Fenneropenaeusindicus*. Delhi Narendra Publishing House: "x, 245p." ISBN: 81-85-375-93-3
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes*. CRC Press.
- Evans. 2014. *Physiology of fishes*. Boca Raton CRC Press 2014 Edition: 4th: "xiv, 453p" ISBN: 978-1-4398-8030-2
- Hoar WS and Randall DJ.1988. *Fish Physiology*. Academic Press.
- Jobling M. 1995. *Environmental Biology of Fishes*. Springer.
- Johnston, 2014. *Fish physiology* (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014: "v, 318p" ISBN: 978-93-5107-130-3
- Nielsen , 1983. *Animal Physiology: Adaption and Environment* New York Cambridge University Press Edition: 3rd: "xii, 619p"
- Northcutt RG and Davis RE. 1983. *Fish Neurobiology*. University of Michigan Press
- Pickering AD. 1981. *Stress and Fish*. Academic Press.
- Rankin JC and Jensen FB. 1996. *Fish Ecophysiology*. Chapman and Hall.
- Reinecke, 2006. *Fish Endocrinology*, Vol. 1": Enfield "Science Publishers, Inc.: "xx, 440p" ISBN: 9781578083183
- Reinecke , 2006. *Fish Endocrinology*, Vol. 2": Enfield "Science Publishers, Inc.: "xx, 441-871pp" ISBN: 978-1-57808-415-9
- Rocha, 2008. *Fish reproduction*. Enfield "Science Publishers, Inc. xiii, 629p" ISBN: 978-1-57808-331-2
- Samantaray, 2015. *Physiology of Finfish and Shellfish*.: New Delhi New India Publishing Agency 2015: "xviii, 230p" ISBN: 978-93-83305-68-1
- Scharrer E. 1963. *Neuroendocrinology*. Columbia University Press.
- Smith, Lynwood S." 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- Val , 2006. *Physiology of Tropical Fishes*. California Elsevier Academic Press: "xiv, 634p"; 23cm ISBN: 0-12-350445-7
- William O. Reece, Eric W. Rowe, 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5th Edition. ISBN: 978-1-119-27086-7, Wiley-Blackwell p. 576.

I. Course title : Fish Histology and Histochemistry

II. Course code : FRM 513

III. Credit Hours : 1+1

IV. Aim of the course

To know the present level of exploitation of marine resources and to impart knowledge on conservation measures. To learn the recent methodologies of sustainable exploitation of renewable resources.

V. Theory

Unit I

Fundamentals of histology: Epithelial, Connective, Muscular, Nervous and other specialized tissues.- Tools in histology: Principles, design and functioning of microtomes, Automated microtomes, Ultra microtome, Cryostat, Problems and troubleshooting.

Unit II

Techniques in histology: Sample preparation, Obtaining tissue samples, Handling reagents, Fixatives (types of fixatives and effect on tissue), Processing of fixed samples, dehydration (procedure and significance), Embedding, Block making, Staining (staining methods histochemical and immunohistologial methods), dyes and Dye binding reactive groups, Mordants and mordanting, Temporary and permanent preparations, Whole mount preparation

Unit III

Fundamentals of histochemical techniques: Principle and practice, Detection of glycogen, Neutral and acid mucopolysaccharides, Detection of basic proteins, Detection of specific and nonspecific lipids, detection of nonspecific esterases, Detection of acid /alkaline phosphatase.

Unit IV

Systemic Histology: Study of Microscopic structure of the organs of digestive, Respiratory, Urinary, Reproductive, Nervous and cardiovascular systems, Sense organs, endocrines and Lymphoid organs of fish and shellfish.

VI. Practical

Histology slide preparation- studying the general architecture of various tissues- staining- vital staining- histochemistry, Enzyme detection: acid phosphatase, Alkaline phosphatase, Esterases, Nucleic acid staining: Methyl green, Pyronine, Feulgen stain. Study of different types of tissue with help of permanent slides, Effect of fixatives, fixation of tissues, Block preparation and sectioning, Mucolpolysaccharide staining, AB pH 1.5, 2.5. Proteins and lipid staining, Microscopic examination and identification of tissues.

VII. Suggested Reading

- Doaa M, Mokhtar. 2018. *Fish Histology: From Cells to Organs*. 1st Edition Apple Academic Press p. 264.
- Franck Genten, Eddy Terwinghe, André Danguy 2009. *Atlas of Fish Histology*, 1st EditionReference – 224 Pages – 440 Color Illustrations, ISBN 9781578085446
- *Histology:* Roland lesson and Thomas Leesan WB Saunders company Co., Canada
- *Histochemistry* Vol. I II III A G E pearse Churchill Livingstone NY
- Jonathan AC, Roques, Omaimah Maghrabi. 2019. *Fish Histology*.p. 326.
- Sonia Mumford; Jerry Heidel; Charlie Smith; John Morrison; Beth MacConnell; Vicki Blazer. *Fish Histology and Histopathology Contributing*.
- *Text book of Histology* Roland lesson DL. WB Saunders Company, Tokyo.

I. Course Title : Field Techniques In Fisheries Resource Management

II. Course Code : FRM 514

III. Credit Hours : 0+2

IV. Aim of the course

To learn field skills in fishery biology and resources management

V. Practical

Planning a fish survey- survey protocol, Fishery dependant sampling- Netting and trapping: Seine nets; Trawl nets; Hand nets, throw nets and push nets; Gill nets and trammel nets (Set nets); Traps- hook and line, Assessing CPUE, Fishery independent sampling Snorkelling- SCUBA survey – line transect- manta survey- Tagging, Underwater Visual Census; Hydro–Acoustics-Electrofishing, Egg and larval collection-abundance estimation.

VI. Suggested Reading

- Anderson RO. 1976. *Management of small warm water Impoundments*. Fisheries (Bethesda, Maryland) 1(6): 5-7, 26-28.
- Anderson RO. 1980. Proportional stock density (PSD) and relative weight (Wr): interpretive Indices for fish populations and communities. 27-33 in S. Gloss and B. Shupp, editors. *Practical Fisheries management: more with less in the 1980's*. Workshop proceedings, New York Chapter, American Fisheries Society, Ithaca, New York, USA.
- Dartnall AJ and Jones M. 1986. *A manual of survey methods for living resources in coastal areas*. Australian Institute of Marine Science, Townsville, Australia. 167pp.
- English S, Wilkinson C and Baker V. 1994. *Survey manual for tropical marine resources*. ASEAN Australian Marine Science Project: Living Coastal Resources, Townsville. 368pp.
- Gabelhouse DW Jr. 1984. A length-categorization system to assess fish stocks. North *American Journal of Fisheries Management* 4: 273-285.
- Richmond MD. 1997. *A guide to the seashores of eastern Africa and the Western Indian Ocean islands*. Sida-SAREC, Sweden. 448pp
- Veron JEN. 1986. *Corals of Australia and the Indo- Pacific, Townsville*. Australian Institute of Marine Science. 644pp.
- Wege GJ and RO Anderson. 1978. *Relative Weight (Wr): a new Index of condition for largemouth bass*. 79-91 in GD Novinger and J.G. Dillard, editors. New approaches to the management of small impoundments. Special Publication 5, North Central Division, American Fisheries Society, Bethesda, Maryland, USA

Course Title with Credit Load
Ph.D. in Fisheries Resource Management

Course Code	Course Title	Course Hours
	Major courses	**12 Credits**
FRM 601	Fisheries Resource Conservation and Restoration Biology	2+1
FRM 602	Assessment of Aquatic Biodiversity and Ecosystem	2+1
FRM 603	Functional Physiology of Fishes	2+1
FRM 604	GIS Use in Fisheries Resources	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a student's major subject)	
FRM 605	Fisheries Legislations, Governance and Treaties	1+1
FRM 606	Software Applications in Fish Stock Assessment	1+1
FRM 607	Coral Reef Management	1+1
	Supporting courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctoral Seminars	**2 Credits**
FRM 691	Doctoral Seminar-I	0+1
FRM 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 Credits**
FRM 699	Doctoral Research (II semester)	0+15
FRM 699	Doctoral Research (III semester)	0+15
FRM 699	Doctoral Research (IV semester)	0+15
FRM 699	Doctoral Research (V semester)	0+15
FRM 699	Doctoral Research (VI semester)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fisheries Resource Management

I. Course Title : Fisheries Resource Conservation and Restoration Biology

II. Course Code : FRM 601

III. Credit Hours : 2+1

IV. Aim of the course

To understand the protection needs of fisheries resources and aquatic system and restore them to sustain the fisheries resources

V. Theory

Unit I

Functions and importance of Aquatic habitats: Mangrove, Corals, Seagrass beds, and dunes, Turtle nesting grounds, horseshoe crab habitat; Role and functions of aquatic habitat; Human activities and pollution sources; Effects of Conservation Practices on Aquatic Habitats and Fauna.

Unit II

Aquatic habitat conservation: Freshwater habitat and Marine water habitat; Erosion and sediment control-transplantation-stocking-population stabilisation.

Unit III

Restoration and Management: Restoration of freshwater and marine water; Storm water management; Restoration challenges of aquatic habitats, Spawning/ feeding ground protection, Fish refugee-ex-situ conservation.

Unit IV

Marine parks: Formation guidelines- Ecosystem stability- Population viability-effect-coral restoration- Seagrass meadow formation-artificial reef-Heritage sites-Protection of spawning aggregates-.ranching- Relocation-critical stock/ Critical viability stock-Bio-augmentation.

Unit V

Land development guidelines for protection of aquatic habitats: Beach creation and beach maintenance –Aquatic habitat protection and restoration programs, Projects and policies; Governance and regulation

Unit VI

Ecosystem Valuations: Carbon sink- carbon Budgeting –Economic and financial aspects; Economic value of aquatic habitat.

VI. Practical

Visit to natural aquatic habitats like ponds, lakes, rivers, streams, springs, estuaries, bays, and various types of wetlands. Visit to Marine national parks- Eco-sensitive zones. Sampling methods; Isolation, identification and enumeration of aquatic organisms from diverse aquatic habitats; Suggest management plan for aquatic habitat protection- permit application form. Valuation of ecosystems – awareness on fisheries resource conservation. Visit to reservoir and assess the threats and developing plan for stock rebuilding. Seagrass, Mangrove restoration. Reservoir stock/ ranching

VII. Suggested Reading

- Arthur. 2008. *Integrated monitoring protocol for seagrass ecosystems: a field manual* Description: New Delhi The United Nations: 43p
- Ben-Yami M. 1989. *How to make and set FADs: fish aggregating devices*
- Dawson CL and Hellenthal RA. 1986. *A Computerized System for the Evaluation of Aquatic Habitats Based on Environmental Requirements and Pollution Tolerance* Associations of Resident Organisms. EPA/600/S3-86/019. Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, Oregon.
- Larkum. 2007. *Seagrass: biology, ecology and conservation*. Dordrecht Springer: xvi, 691p" ISBN: 978-1-4020-2942
- Leber 2004. *Stock enhancement and sea ranching: developments, pitfalls and opportunities*. Blackwell Publishing Inc., (Malden) 2nd.Description: xii, 562p. 1-4051-1119-4.
- Lim 1998. *Carrying capacity assessment of PulauPayar Marine Park*, Malaysia. Chennai BOBP 1998: 129 Books
- McClanahan. 2000. *Coral reefs of the Indian ocean: their ecology and conservation*. Oxford Oxford University Press: "xxiii, 525p" ISBN: 0-19-512596-7
- Nath S. (Ed.). 2008. *Recent Advances in Fish Ecology Limnology and Eco Conservation*. Vol. VII. Narendra Publ. House
- Ramachandra, 2005. *Aquatic ecosystems: conservation, restoration and management*. Description: New Delhi: Capital Publishing Company: "xiii, 348p"; 25cm ISBN: 81-85589-38-0
- Ramasubramanian, 2004. *Mangroves forest restoration in Andhra Pradesh,* India Description: Chennai MS Swaminathan Research Foundation: 26p Books
- Rogers Caroline S. 1994. *Coral reef monitoring manual for the Caribbean and western atlantic* Food and Agricultural Organization of the United Nations, Rome.
- Thorpe JE, Gall GAE, Lannan JE and Nash CE. (Eds.). 1995. *Conservation of Fish and Shellfish Resources*, Managing Diversity.
- Young TP. 2000. *Restoration Ecology and Conservation Biology*. Biological Conservation.

I. Course Title : Assessment of Aquatic Biodiversity And Ecosystem

II. Course Code : FRM 602

III. Credit Hours : 2+1

IV. Aim of the course

To enrich the knowledge on aquatic biodiversity, assessment of healthiness using indices, threats and conservation needs.

V. Theory

Unit I

Introduction to Aquatic Biodiversity assessments: Measurement, Methods for sampling and analysis, Scales and indices of biodiversity assessment – Biodiversity monitoring- Biotic integrity index-fish- Benthos-Plankton.

Unit II

Biodiversity assessment in ecosystems: (Inland and Marine Resources) Rivers, lakes, estuaries intertidal (mangrove and coral reefs) and gulf and island ecosystem.

Unit III

Threats to biodiversity: Over exploitation, Land reclamation, Exotic species – pollution, habitation, Climate change, Conversion of agricultural land and aquacultural farms (case studies pertaining to sensitive marine/estuarine/freshwater hot spots).

Unit IV

Impacts of anthropogenic intervention on aquatic biodiversity: Damming of rivers, Linking of rivers, Construction of sea walls, Micro hydel power stations, oil rigs, Biodiversity loss, extinction risk and endangered species management.

Unit V

Conservation and Restoration: Declaration of mangrove sanctuaries and mangrove afforestation, Marine protected areas, Riverine ecosystem and diversity management Plan, Introduction of exotic species and their implications, Bio-monitoring, Genetic diversity and conservation.

Unit VI

Ecosystem Conservation Acts: Legal and institutional acts, Regimes of biodiversity: International and national conventions, Biodiversity Acts- Biodiversity Boards/Authority, Benefit sharing mechanism- IUCN criteria – Red List, Wildlife protection act, International treaties, ETP species.

VI. Practical

Preparation of records and inventories of biodiversity of any three critically important ecosystems based on secondary data and field visits. Comparison of biodiversity indices; assessment of biotic integrity index. Compilation of all important International and National laws and conventions related to biodiversity. Collection and identification of flora and fauna from biodiversity hotspot. Identification of scheduled aquatic fauna. Data sheet preparation on IUCN criteria. Assess threats to aquatic biodiversity. Development of conservation plans. Analysis of earlier biodiversity study reports.

VII. Suggested Reading

- Brian G. 1992. *Global Biodiversity – Status of the Earth's Living Resources*. Chapman and Hall.
- Denton TE. 1973. *Fish Chromosome Methodology*. Charles Thomas Publ.
- Elliott A. Norse (Ed.) 1993. *Global marine Biological Diversity*. Inland press, Washington, D.C.383p.
- Gunderson DR. 1993. *Surveys of Fisheries Resources*. John Wiley and Sons. New York. 248 p.
- Khanna DR, Chopra AK and Prasad G. 2005. *Aquatic Biodiversity in India*. Daya Publ. House.
- Kumar U and Asija MJ. 2000. *Biodiversity Principles and Conservation*. Agrobios.
- Lakra WS, Abidi R, Singh AK, Sood N, Rathore G and Swaminathan TR. 2000. *Fish Introductions and Quarantine: Indian Perspective*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Lambshead PJD, Paterson GLJ and Gage JD. 1997. *Biodiversity Professional*. Version 2. National History Museum and the Scottish Association of Marine Science.
- Magurran AE. 1988. *Ecological Diversity and its Measurement*. Taylor and Francis.
- Mahanta PC and Tyagi LK. 2003. *Participatory Approach for Fish Biodiversity Conservation in North East India*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Mahanta PC and Tyagi LK. 2003. *Participatory Approach for Fish Biodiversity Conservation*

in North East India. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Menon AGK. 2004. *Threatened Fishes of India and their Conservation*. Fisheries Survey of India.
- Michael RR. 1997. *Fisheries Conservation and Management*. Prentice Hall.
- Ponniah AG and Gopalakrishnan A. (Eds.). 2000. *Endemic Fish Diversity of Western Ghats*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Pascoe S. 2005. *Bycatch Management and the Economics of Discarding*. Daya Publ. House.
- Thorpe JE, Talbot C and Miles MS. (Ed.) 1995. *Conservation of Fish and Shell Fish Resource; Managing Diversity*. Academic Press.
- WCMC. 1992. *Global Biodiversity: Status of the Earth's Living Resources*. Chapman and Hall.
- Zoological Survey of India. 2007. *National Symposium on Conservation and Valuation of Marine Biodiversity*.

I. Course Title : Functional Physiology of Fishes

II. Course Code : FRM 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand advanced concepts in physiology of finfish and shell fishes

V. Theory

Unit I

Growth and metabolism: BMR- SDA- Bioenergetics-energy requirement of fish-energy budgeting-digestion-liver function-starvation effect.

Unit II

Sense organs and their functions: Hearing mechanism and specialization, Vision and mechanosensation – photoreceptors; Olfaction. Vision

Unit III

Neurophysiology: Nerve gap junction, Potential, Nerve Pulse, Passage, Circadian rhythm.

Unit IV

Endocrinology physiology: Migration physiology, Endocrine glands, Hormone, Endocrine disruptor- Osmoregulation; Excretion, Blood parameters and hormones, Regulation of electrolytes and ions.

Unit V

Reproductive physiology: Reproductive behaviour – hormones, embryonic development – Pheromones and other signals, Ecomorphology; strategies for buoyancy regulation.

Unit VI

Stress physiology: Stress resistance, Stress tolerance- General Adaptive Syndrome-Immune system – Responses to temperature, Hypoxia and anoxia

VI. Practical

Fish anesthetisation. Analysis of blood composition –blood volume measurement. Histological analysis of gills. Energy requirement studies. Estimation of gross energy and digestible energy of feed. Measuring osmoregulatory parameters. Measuring of cortisol –water regulation. Measuring reproductive hormones. Electro-olfactograms.

Chronic and acute responses to environmental changes. Stress study- symptoms. Observe embryonic development.

VII. Suggested Reading

- Alan GH. 1995. *Water Pollution and Fish Physiology*. CRC Press.
- Conn EE and Stumpf PK. 1987. *Outline of Biochemistry*. Wiley.
- Diwan, 2007. *Physiology of marine white shrimp: Fenneropenaeus indicus*. Delhi Narendra Publishing House: “x, 245p.” ISBN: 81-85-375-93-3
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes*. CRC Press.
- Evans, 2014. *Physiology of Fishes*. Boca Raton CRC Press 2014 Edition: 4^{th} : “xiv, 453p” ISBN: 978-1-4398-8030-2
- Hoar WS and Randall DJ.1988. *Fish Physiology*. Academic Press.
- Johnston, 2014. *Fish Physiology* (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014 : “v, 318p” ISBN: 978-93-5107-130-3
- Nielsen , 1983. *Animal Physiology: adaption and environment* New York Cambridge University Press Edition: 3^{rd} : “xii, 619p”
- Northcutt RG and Davis RE. 1983. *Fish Neurobiology*. University of Michigan Press
- Reinecke, 2006. *Fish Endocrinology*, Vol. 1": Enfield “Science Publishers, Inc. : “xx, 440p” ISBN: 9781578083183
- Reinecke , 2006. *Fish Endocrinology*, Vol. 2": Enfield “Science Publishers, Inc. : “xx, 441-871pp” ISBN: 978-1-57808-415-9
- Samantaray, 2015. *Physiology of Finfish and Shellfish.*: New Delhi New India Publishing Agency 2015 : “xviii, 230p” ISBN: 978-93-83305-68-1
- Scharrer E. 1963. *Neuroendocrinology*. Columbia University Press.
- Smith Lynwood S. 1999. *Introduction to fish physiology*. Narendra Publishing House
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- Val. 2006. *Physiology of tropical fishes*. California Elsevier Academic Press : “xiv, 634p”; 23cm ISBN: 0-12-350445-7
- Rocha 2008. *Fish reproduction*. Enfield “Science Publishers, Inc. Xiii, 629p” ISBN: 978-1-57808-331-2
- William O. Reece, Eric W. Rowe, 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5^{th} Edition. ISBN: 978-1-119-27086-7 , Wiley-Blackwell p. 576.

I. Course Title : GIS use in Fisheries Resources

II. Course Code : FRM 604

III. Credit Hours : 2+1

IV. Aim of the course

To apply the knowledge in GIS for assessment and management of fisheries sector.

V. Theory

Unit I

GIS in Fisheries: Applications of Geographical Information Systems (GIS) based on spatial decisions in fisheries resources.

Unit II

GIS applications in MPA: Application of GIS to evaluate efficiency of Marine Protected Areas (MPA) in India.

Unit III

GIS in shrimp aquaculture: Applications of GIS for sustainable management of shrimp culture in India.

Unit IV

Fish modelling: Modelling of essential fish habitats based on remote sensing, spatial analysis and GIS.

Unit V

Geographical Information Systems: Their past, present and future use in global marine fisheries.

Unit VI

GIS applications in Mangroves: Application of GIS in the management of mangrove forests and Marine Protected Area.

VI. Practical

Applications of GIS software in fisheries resource management. Mapping of fisheries resources using GIS. Exercises in Arc GIS/ Open sources software.

VII. Suggested Reading

- Boca Raton. 2014. *GIS: fundamentals Wise Description*: CRC Press Edition: 2nd: "xv, 322p" ISBN: 978-1-4398-8695-3
- Carocci. 2009. *Geographic information systems to support the ecosystem approach to fisheries: status, opportunities and challenges* FAO Fisheries and Aquaculture Technical Paper; No. 532. Description: Rome Food and Agriculture Organization of the UN: "xv, 101p" ISBN: 978-92-5-106433-7
- COPEMED**.** 2001b. *GIS in fisheries management, Training manual, Higher national diploma in fisheries science for the Mediterranean countries*. Rome, Italy, Department of fisheries and aquaculture (Malta), University of Plymouth (UK) and COPEMED (FAO). 135 pp. Description: New York Routledge: xvi, 471p ISBN: 978-0-415-82906-
- FAO. 2003. *Geographic Information Systems in fisheries management and planning. Technical manual*, by G. De Graaf, F.J.B. Marttin, J. Aguilar-Manjarrez and J. Jenness. FAO Fisheries Technical Paper No. 449. Rome. 162p.
- FAO. 1996. *Geographical information systems. Applications to marine fisheries*, by G.J. Meaden and Do Chi. FAO Fisheries Technical Paper No. 356. Rome. 335 pp. (available at: http://www.fao.org/DOCREP/003/W0615E/W0615E00.HTM).
- FAO. 1997a. *A strategic assessment of the potential for freshwater farming in Latin America*, by J.M. Kapetsky and S.S. Nath. FAO COPESCAL Technical Paper No. 10. Rome. 128 pp. (available at: http://www.fao.org/DOCREP/005/W5268E/W5268E00.HTM).
- Faiz Sami. 2013. *Geographical information systems and spatial optimization*. Boca Raton CRC Press: xxii, 154p ISBN: 978-1-4665-7747-3
- Jeff Thurston Thomas K Poiker and J Patrick Moore. 2000. *Integrated Geospatial Technology – A Guide to GPS, GIS and Data Logging*. John Wiley and Sons.
- Kraak MJ and Ferjan O. 2003. *Cartography, Visualization of Spatial Data*. Prentice Hall.
- Meaden GJ and Kaptesky JM. 1991. *Geographical Information Systems and Remote Sensing in Inland Fisheries and Aquaculture*. FAO Fisheries Tech. Paper No. 318, Rome.
- Pandey. 2014. *Geographic information system*. New Delhi The Energy and Resources Institute 2014: "xvii, 151p" ISBN: 978-81-7993-537-8
- Patel AN and Singh S. 1992. *Remote Sensing – Principles and Applications*. Scientific Publ.
- Sahu. 2008. *Textbook of remote sensing and geographical information system*. New Delhi Atlantic Publishers and Distributors 2008: x; 499
- Schuurman. 2003. *GIS; a short introduction.: Malden "Blackwell Publishing Inc*., xiii; 169 ISBN: 0-631-23532-9
- Valavanis VD**.** 2002. *Geographic Information Systems in Oceanography and Fisheries*. London, Taylor and Francis. 209 pp. Morain, Stanley A.1999. *GIS solutions in natural resource management*.

- Valavanis VD. 2002. *GIS System in Oceanography and Fisheries*. Taylor and Francis.
- Zhu Xuan. 2016. *GIS for environmental applications: a practical approach*.

I. Course Title : Fisheries Legislations, Governance and Treaties

II. Course Code : FRM 605

III. Credit Hours : 1+1

IV. Aim of the course

To familiarise various legislation, agreement under international law which govern responsible utilisation of fisheries resources

V. Theory

Unit I

Overview of legislation: Critical review of fisheries regulatory and developmental setup in centre and states (spheres of responsibility and division of power); Need for fisheries management; Regulatory, Legal and enforcement regimes. Developmental planning for fisheries; Plan allocation, Programs and performance of fisheries sector; Regional disparities and balanced development; Political economy of fisheries development political ecology.

Unit II

National policies and regulations: Objectives, Salient features and amendments: Indian Fisheries Act, Biodiversity Act, The Environmental (Protection) Act; Policy and regulatory environment in marine fisheries and mariculture Sector (National Policy on Marine Fisheries, MFRA, Deep sea fishing policy, Guidelines for deep sea vessels, Policy on Mariculture, seed certification), Inland Fisheries and Aquaculture Sector (National Policy on Inland Fisheries and Aquaculture), Wet lands, Heritage sites, Hot spots; Brackishwater Aquaculture Sector (CAA), Processing Sector (MPEDA Act; HACCP/ ISO Standards / Food safety/ Quality Safety Management Systems). Fish Marketing and Trade policies, institutionalization of stakeholder participation and Developing policy framework for fisheries.

Unit III

International policy and regulatory scenario in fisheries sector: FAO's CCCRF; IUU; MCS; UN's Law of the Sea and other conventions; treaties; SAARC, NACA, CBD, CITES, MARPOL, IWC, EU's Common Fisheries Policy, RAMSAR-SDG- RFMOs; Fisheries policy and regulation of selected countries in Asian American and Australian regions, Eco-labeling and Certification.

Unit IV

Governance: Need for fisheries governance and institutional framework, Formal and traditional, Fisheries Law, Rights based fisheries, Improve fisheries governance, Multi-stakeholder processes in governance, Case studies in self-governance in the fisheries sector.

VI. Practical

Review of the existing fisheries policies: suggest and draft ideal inland and marine fishery legislations for India. Fisheries regulatory, legal and enforcement regimes-responsibilities of the centre and states of India. Preparation of management plans for specific fisheries. Visit to appropriate Government organizations/research, institutions/NGOs and preparation of working report. Impact survey on regulations-group discussion on fisheries regulations. Comparison of policies and acts with neighbouring countries. Comparison of Fisheries Regulation Acts of different states.

VII. Suggested Reading

- Anon. 1998. *Maritime Law of India in the International Context*. Bhadarkar Publ.
- Brahtz JFP. 1972. *Coastal Zone Management*. U.N. International Economic and Social Affairs, New York.
- Burke William T. 1992. *Fisheries regulations under extended jurisdiction and international law*: "Food and Agricultural Organization of the United Nations.
- Christy Lawrence C. 1980. *Fisheries legislation in Somalia*. "Food and Agricultural Organization of the United Nations," 1980
- Churchill RR and Lowe AV. 1988. *Law of the Sea*. Manchester University Press.
- Dixit 2013. *Regulating oceanic fishing: international laws and treaties*. Delhi Swastik Publications: "viii, 264p" ISBN: 978-93-81991-04-6
- Gray 2005. *Participation in Fisheries Governance*. Dordrecht Springer: xxv; 363 ISBN: 978-1-4020-3777-1
- Henkin L, Pugh RC and Smit H. 1993. *International Law: Cases and Materials*. West Publ. Co.
- Kumar. U. *Biodiversity Principles and Conservation*, Narendra Publishing House Publishers and Distributors.
- Pandey. 2014. *Fisheries governance and legislation in India*. Delhi Narendra Publishing House 2014: "xviii, 182p" ISBN: 978-93-82471-85-1
- Ponniah AG and A Gopalakrishnan (Eds.). 2000. *Endemic Fish Diversity of Western Ghats* NBFGR, Lucknow 347 p.
- Raval 2013. *Combating Marine Pollution: International Laws and Regulations*. New Delhi Cyber Tech Publications 2013: "viii, 264p"; 21x13cm ISBN: 978-93-5053-150-1
- Sinha RK. (Ed.). 1996. *Marine Resources and Applicable Laws* (World Environmental Series – 009). Commonwealth Publ.
- Verghese CP. 1989. *Fishing Regulation in India's Territorial Waters*. World Fishing.

I. Course Title : Software Applications in Fish Stock Assessment

II. Course Code : FRM 606

III. Credit Hours : 1+1

IV. Aim of the course

To familiarise various software available for stock assessment and use for taking decision to optimally exploit the stock.

V. Theory

Unit I

Introduction to sampling and data collection: Collection of fishery data, Field procedure, Abundance estimation, Transect Study, Sampling-survey, Fish landing centre, Exploratory survey, Fishery independent survey, Non-extractive abundance sampling, Catch effort assessment.

Unit II

Models: single species, Biomass dynamics, Cohort analysis, YPR, Depletion model; Multispecies – Descriptive multispecies, Dynamic multispecies, Aggregate system and Dynamic system models.

Unit III

Softwares: Software for fish stock assessment-open source. Computer based softwares, FiSAT/CEDA/LEDA/LFDA

Unit IV

R program: basics- Application of R program in fisheries.

VI. Practical

Collection of fishery data at landing centres from different gears separately. Details of craft and gear of landing centres and recording of data in the entry forms. Collection of length frequency data for various groups of finfish and shellfish. Estimation of age and growth based on length frequency data. Growth, mortality, population and stock parameters employing computer based softwares, FiSAT/ CEDA/LEDA/LFDA, YIELD and PAR Fish Length structured VPA, Thompson and Bell yield stock prediction for single and multi-fleet version. RAPFISH. Types of simulation model: yield-per-recruit and dynamic logistic model. Multispecies model-Multispecies Virtual population dynamcis. Beverton and Holt yield-per-recruit model; biomass-per-recruit. Relative yield-per-recruit model and yield isopleth. ECOPATH With ECOSIM. Introduction to R program in fisheries. R-programme in stock assessment.

VII. Suggested Reading

- Christensen V, CJ Walters and D Pauly. 2005. *Ecopath with Ecosim: a User's Guide*. Fisheries Centre, University of British Columbia, Vancouver. November 2005 edition, 154 p. (available online at www.ecopath.org)
- FAO. 2995. FISAT II - FAO-ICLARM Stock Assessment Tools II: User's Guide (Computerized Information Series: Fisheries) Paperback – Import, 15 Dec 2005
- Gayanilo FC, Jr. Soriano M, Pauly D. 1988. *A draft guide to the complete ELEFAN*. ICLARM Softw. (2): 65p.
- Keller G. 2001. *Applied Statistics with Microsoft Excel*. Duxbury.
- Paul Med ley. 2003. *Participatory Fisheries Stock Assessment Software*.p.71.
- Sparre, P. 1987. *Computer Programs for Fish Stock Assessment: Length-based Fish Stock*. p.218.

I. Course Title : Coral Reef Management

II. Course Code : FRM 607

III. Credit Hours : 1+1

IV. Aim of the course

To enhance the knowledge on coral reefs, their importance, conservation and restoration management:

V. Theory

Unit I

Introduction: Type of coral reefs and their distribution. Origin of coral reefs – coral reefs of the world, Ecology of coral reefs, factors influencing growth, Productivity of coral reefs, Plants and animals associates of living reef corals and fringing reefs.

Unit II

Reef types: Types of corals - Soft coral, Hard corals, Biology of corals (Nutrition, production, larval dispersal and settlement), Coral resource, Field assessment.

Unit III

Bioactive substances: Bioactive substances of soft and hard corals, Extraction, Analysis, identification, Classification of biactive compounds.

Unit IV

Coral reef management: Economic importance of coral reefs, Ecological role, Threats, Sedimentation in coral reef environment, Restoration.

VI. Practical

Collection and identification of soft and hard corals, Survey of corals and mapping, identification of associated organisms, preparation of checklist and associated organisms of Indian coast- Predatory animals of corals, Extraction of bioactive substances from soft and hard corals. Observations of destructive methods of corals and coral reef fishes. Coral restoration-valuation.

VII. Suggested Reading

- Bakus GJ. 1994. *Coral reef ecosystem*. Oxford and IBH publish co. pvt. Ltd. P. 232.
- Biswas KP. 2008. *Corals of tropical oceans*, Daya publishing House, Delhi. 228 p.
- Caroline S, Rogers *et al*. 1999. *Coral reef monitoring manual for the Caribbean and western Atlantic*. National Park service, Virgin Islands National Park.
- Eugene Rosenberg and Yoss Loya (Eds.). 2004. *Coral Health and disease*. Springer, Bartin -488p.
- Frank Talbot and Clive Wilkinson. 2001. *Coral reefs, management and seagrasses*. A source book for managers. Australian Institute of Marine suck Australia, 193p.
- Frederic M, Bayer Manfred Gracshotf, Jakob Verseveldt. 1983. *Illustrated trilingual glossary of morphological and anatomical terms applied to octocorallia*, E.J., Brill, Dr W. Backhuys Leiden 75 p.
- James PSBR. 1986. *Recent advances in marine biology*. (Dr Johnes 70th Birthday commemoration volume. Today and tomorrow printers and publishers. P. 591.
- McClanahan. 2000. *Coral reefs of the Indian ocean: their ecology and conservation.* Oxford Oxford University Press: "xxiii, 525p" ISBN: 0-19-512596-7
- Peter Sale. Ed. 2006. *CORAL REEF FISHES: Dynamics and Diversity in a Complex Ecosystem*, Pb Academic Press
- Pillai CGS. *Coral reefs of India*
- Polunin NVC and CM Roberts. 1996. *Reef fisheries.* Chapman and Hall, London. P.477.
- Rogers Caroline S. 1994. *Coral reef monitoring manual for the Caribbean and western Atlantic.*

VIII. List of Suggested Journals

- *Advances in Marine Biology*
- *African Journal of Marine Science*
- *American Journal of Physiology - Endocrinology and Metabolism*
- *Annual Review of Cell and Developmental Biology*
- *Applied Entomology and Zoology*
- *Aquaculture*
- *Biodiversity and Conservation*
- *BioTechniques*
- *Bulletin of Marine Science*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *Canadian Journal of Remote Sensing*
- *Canadian Journal of Zoology*
- *Climate Change*
- *Climate Change and Environmental Sustainability*
- *Conservation*
- *Conservation Biology*
- *Conservation Letters*
- *Coral Reefs*

- *Developmental Biology*
- *Ecological Management and Restoration*
- *Environment and Ecology*
- *Environmental Biology of Fishes*
- *Environmental Conservation*
- *Environmental Modeling and Software*
- *Fish and Fisheries*
- *Fish and Shellfish Immunology*
- *Fish Physiology and Biochemistry*
- *Fisheries and Fisheries*
- *Fisheries management and ecology*
- *Fisheries Research*
- *Fisheries technology*
- *Flora and Fauna*
- *General and Comparative Endocrinology*
- *Histology and Histopathology*
- *Histopathology*
- *ICES Journal of Marine Science*
- *Ichthyological Exploration of Freshwaters*
- *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*
- *IEEE Transactions on Geoscience and Remote Sensing*
- *Indian Journal of Fisheries*
- *Indian Journal of Geo-Marine Sciences*
- *International Journal of Remote Sensing*
- *International Journal of Sustainable Development and World Ecology*
- *Japanese Journal of Applied Entomology and Zoology*
- *Journal fisheries biology*
- *Journal for Nature Conservation*
- *Journal of Animal Ecology*
- *Journal of Animal Physiology and Animal Nutrition*
- *Journal of Applied Ecology*
- *Journal of Applied Physiology*
- *Journal of Biodiversity*
- *Journal of Biology*
- *Journal of Coastal Conservation*
- *Journal of Coastal Research*
- *Journal of Comparative Neurology*
- *Journal of Ecology, Ecosystems and Ecophysiology*
- *Journal of Ecophysiology and Occupational Health*
- *Journal of Environment and Bio-sciences*
- *Journal of Environmental Biology*
- *Journal of Experimental Marine Biology and Ecology*
- *Journal of Fish and Shellfish Immunology*
- *Journal of Fish Behaviour*
- *Journal of Fish Biology*
- *Journal of Fish Diseases*
- *Journal of Fish Physiology and Biochemistry*
- *Journal of the Indian Society of Remote Sensing*
- *Journal of the Marine Biological Association of India*
- *Journal of Zoology*
- *Marine Biology*
- *Molecular Ecological Notes*
- *Molecular Marine Biology and Biotechnology*
- *New Zealand Journal of Marine and Freshwater Research*
- *North American Journal of Fisheries Management*

- *North American of Journal of Aquaculture*
- *Oceanography and Marine Biology*
- *Remote Sensing*
- *Restoration Ecology*
- *Reviews in Fish Biology and Fisheries*
- *Seaweed Research and Utilisation*
- *Sustainability*
- *Weed Biology and Management*
- *Weed Research*
- *Weed science*

List of Suggested e-Resources

- http://www.iucnffsg.org/
- http://www.ncseonline. org/WHPRP/cms.cfm?id=2524, April 20 2009
- http://tafcc.forestry.oregonstate.edu/.
- http://www.csiro.au/news/Climate-Change-Hits-Fish.html
- http://www.fao.org/fishery/topic/16072/en
- http://www.stat.uiowa.edu/~rlenth/Power.
- https://bhuvan.nrsc.gov.in/bhuvan_links.php
- https://cran.r-project.org/web/packages/TropFishR/TropFishR.pdf
- https://earth.esa.int/web/guest/missions/3rd-party-missions/current-missions/oceansat-2
- https://earthexplorer.usgs.gov/
- https://ecopath.org/
- https://gisgeography.com/gvsig-software/
- https://github.com/tokami/TropFishR
- https://i0.wp.com/geoawesomeness.com/wp-content/uploads/2017/06/GLOVIS.jpg?ssl=1
- https://mrag.co.uk/sites/default/files/fmspdocs/R7947/R7947_Guide.pdf
- https://nctc.fws.gov/resources/course-resources/fish-histology/Fish_Histology_Manual_v4.pdf
- https://neo.sci.gsfc.nasa.gov/
- https://palaeo-electronica.org/2001_1/past/issue1_01.htm
- https://www.cites.org
- https://www.esri.com/
- https://www.iucn.org/resources/conservation-tools/iucn-red-list-threatened-species
- https://www.iucnredlist.org/
- https://www.worldwildlife.org/
- www.barcodinglife.org
- www.bhuvan.org.
- www.cites.org
- www.cmfri.org.in/
- www.fao.org
- www.fishbase.org.
- www.icun.org
- www.indiaenvironmentportal.org.in
- www.devbio.com
- http://people.ucalgary.ca/~browder/virtualembryo/dev_biol.html

Suggested Broad Areas for Master's and Doctoral Research

- Mapping of fisheries resources in different freshwater, brackish water and marine water bodies
- Impact of intensive-aquaculture activities on biodiversity of coastal ecosystems
- Fish stock assessment in different freshwater bodies using FiSAT
- Analysis of productivity in different freshwater bodies
- Assessment of bycatch from trawl, bottom set gillnet and other gears
- Sea ranching and effect of ranching in the marine ecosystem

- Biology and assessment of deepsea fishery resources
- Estimation of biodiversity and abundance of endangered species of sponges, corals, gastropods, bivalves, sea cucumbers, fishes, sea snakes, turtles, birds and marine mammals
- Effect of conservation measures in the restoration of depleting fish stocks
- Development of proper guidelines for commercial deep sea fishing
- Impact of Coastal Regulation Zone on the stock replenishment
- Monitoring, Control and Surveillance (MCS) systems for inland and marine capture fisheries
- Collection of satellite information on various aquatic resources and ground truthing Interpretation of satellite pictures for resource management
- Use of remote sensing for Potential Fish Zone
- Estimation of flora and faunal diversity of mangroves and coral reefs.
- Estimation of fleets and catches at landing sites for effective fisheries management
- Neurohormones controlling the reproduction of commercial crustacean Species
- Identification of commercially important species of finfish and shellfish eggs and larvae, spat.
- Forecasting the fishery potential through the study of abundance of finfish and shellfish eggs and larval in the marine ecosystem.
- Studies on migratory pattern of fishes
- Food and feeding habits of larval stages of shell and finfishes.
- Catalogue preparation of commercially important fishes (FW, BW and Marine)
- Studies on biodiversity estimates for coastal resources, fresh water bodies.
- Upgradation of food and feeding habit of commercially important fishes and shellfishes using latest techniques
- Microsatellite based identification of commercial fishes
- Karyotaxonomy of commercially important fishes and shellfishes
- Ecopath modelling for minor reservoir, small waterbody
- Conservation biology and marine pollution
- Coral reef reproduction, assessment, monitoring and management
- Assessment of Coral reef associated fauna and flora biodiversity
- Remote sensing and geospatial analysis of coral reef ecosystem.
- Spawning grounds characterisation
- Estimation of MSY in various marine ecosystems
- Stock assessment and biology of Indigenous and endemic fisheries resources
- Multispecies fish stock assessment
- Fish stock assessment in various freshwater, brackishwater and marine ecosystems using FiSAT
- Mapping of coral resources and conservation strategies
- Mapping of seaweed resources
- Up gradation and Molecular characterization of various seaweed species available in the marine ecosystem
- Spawning biomass estimation
- Estimation of Taxonomic distinctness for major finfish and shellfish resources using molecular tools

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Aquatic Environment Management

Preamble

(Aquatic Environnent Management)

The objective of this course is to develop specialised human resources equipped with the latest knowledge related to changes in Aquatic Environment Management strategy in light of changing ecological condition, climatic variability and their impact on fish and fisheries.

The course provides advance skills and exposure in the wide range of topics necessary for the aquatic environment management at the post-graduate and doctoral levels.

Emphasis is given both on developing expertise in the techniques, understanding future environmental challenges and different gametes of aquatic environmental management including coastal zone management.

The new and innovative courses included for M.F.Sc. are Climate Change: Impact and Management, Inland Aquatic Resource Management and Utilization and Management of Aquatic Algal Resources and for Ph.D. Water Issues Challenges and governance and Aquatic Plant Resource and its Management. Practical credits have been enhanced and more emphasis is given towards field exposure and case studies based learning. These courses may help in understanding the policy issues related to Aquatic Environment Management.

Course Title with Credit Load
M.F.Sc. in Aquatic Environnent Management

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
AEM 501	Inland Aquatic Resource Management	2+1
AEM 502	Chemical Interactions in Aquatic Environment	2+1
AEM 503	Analytical Techniques in Environnemental Sciences	1+2
AEM 504	Climate Change: Impact and Management	1+0
AEM 505	Aquatic Pollution and Management	2+1
AEM 506	Eco-toxicology	1+1
AEM 507	Coastal Ecology and Coastal management	2+1
AEM 508	Aquatic Microbiology	1+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
AEM 509	Aquatic Environment and Biodiversity	1+1
AEM 510	Plankton Ecology and Trophic Dynamics	1+1
AEM 511	Environmental Biotechnology	1+1
AEM 512	Fisheries Oceanography	1+1
AEM 513	Utilization and Management of Aquatic Algal Resources	2+1
AEM 514	Restoration Ecology	1+1
	Supporting courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 Credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
AEM 591	Master's Seminar I	0+1
	Masters' Thesis Research	**30 Credits**
AEM 599	Master's Research (Semester III)	0+15
AEM 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Aquatic Environnent Management

I. Course Title : Inland Aquatic Resource Management

II. Course Code : AEM 501

III. Credit Hours : 2+1

IV. Aim of the course

- To educate the students on ecology of wetlands and its importance
- Manipulation and mapping of wetlands for sustainable management of these ecosystems.

V. Theory

Unit I

Types of inland aquatic resources: Concept of watershed; Lacustrine, Riverine, Wetland~~s~~, Floodplain~~s~~, Swamp~~s~~ and Pond~~s~~, Habitat characteristics, Flora and Fauna, Economic importance; Relationship between productivity (primary and secondary) and fish yield.

Unit II

Wetlands: Trophic classifications, Functions, Degradation of wetlands (causes consequences; Constructed wetlands; Restoration, Conservation and management of wetlands, Ecological services and livelihood from wetland.

Unit III

Ecological engineering: Concept, Application and restoration; Resource enhancement; Biomanipulation - Top-down and bottom-up methods; Integrated Environment Management (IEM) Programme, Ramsar convention.

Unit IV

River continuum concept and new paradigm shift, River linking; Mapping of aquatic resources using remote sensing and GIS.

Unit V

Water budget and Environmental flow, Its significance in water conservation and ecology, Environmental Economics and auditing, Ecosystem approach to resource management.

Unit VI

Wasted and degraded resources, Coastal and inland saline areas, Adaptations of organisms, restoration/remediation strategies, Prospects of gainful use of available technologies.

VI. Practical

Collection, preservation and analysis of flora and fauna (plankton, macrophytes and benthos) of wetland/degraded aquatic ecosystem. Calculation of shoreline development index and morphometry. Calculation of Morpho-edaphic index. Field visits to select~~ed~~ lakes/wetlands/degraded/restored ecosystem.

VII. Suggested Reading

- Andy D Ward, Stanley W Trimble, Suzette R Burckhard, John G Lyon. 2015. *Environmental Hydrology*, CRC press.
- Dodds WK. 2002. *Freshwater Ecology: Concepts and Environmental Applications*. Academic Press, New York.
- Jan Vymazal. 2010. *Water and Nutrient management in Natural and constructed wetlands*, Springer.
- Mitsch WJ and Jorgensen SE. 2003. *Ecological Engineering and Ecosystem Restoration*. 2nd revised edition, John Wiley and Sons, New York, 424 pp.
- Mitsch WJ. 2009. *Wetland Ecosystems*. John Wiley and Sons. 295 pp.
- Nath S. (Ed). 2008. *Recent Advances in Fish Ecology Limnology and Eco Conservation* Vol 7. Narendra Publishing House, New Delhi.

I. Course Title : Chemical Interactions in the Aquatic Environment

II. Course Code : AEM 502

III. Credit Hours : 2+1

IV. Aim of the course

- To acquaint the students with basic principle of chemistry with special reference to soil chemistry
- To study physical, chemical, biological and geological interactions in the aquatic environment.
- To study the nutrient dynamics and fate of contaminates in the aquatic environment.

V. Theory

Unit I

Basic principles: Chemical kinetics, Chemical equilibrium and Redox chemistry, Solubility concept, Dissolution kinetics.

Unit II

Sediment properties: Weathering of rocks; Soil formation, Soil profile, Mineral weathering; transformation, weathering products, Structure of oxide and silicate minerals, Sources of charge, adsorption on to clay minerals of major cations and anions, Double layer, Ion exchange - concept and source of cation exchange capacity (CEC), Sediment texture.

Unit III

Nutrient dynamics: Nutrient holding capacity of sediments and fixation, Processes controlling elemental cycling.

Unit IV

Transport of nutrients: Availability of Nutrients and productivity inaquatic ecosystem

Unit V

Processes in the degradation and conversion of organic matter, Humus and biogeochemical substances.

Unit VI

Fate of Contaminants: Degradable and non-degradable contaminants, Speciation and transport of contaminants, Bio-availability; Bio-accumulation and Biomagnification.

VI. Practical

Sample collection techniques

Determination of physicochemical parameters of sediment – pH, electrical conductivity, redox potential, soil texture, bulk density, particle density, porosity, total and organic carbon, total and available nitrogen, phosphorus, potassium and micronutrients; C: N: P ratio, CEC

VII. Suggested Reading

- Claude E Boyd. 1995. *Bottom Soils, Sediment, and Pond Aquaculture*, Chapman and Hill
- Essington ME. 2003. *Soil and Water Chemistry: An Integrated Approach*, CRC Press.
- Evangelou VP. 1998. *Environmental Soil and Water Chemistry: Principle and Application*, Wiley-Interscience.
- Lindsay WL. 1979. *Chemical Equilibria in Soils*. John Wiley and Sons, New York.
- Stumm W and Morgan JJ. 1996. *Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters*. John Wiley and Sons, New York.
- Tan KH. 1998. *Principles of Soil Chemistry*. CRC Press Inc., Boca Raton
- TD Biswas and SK Mukharjee. 2000. *Textbook of Soil Science*. Tata McGrow-Hill Publishing Company Limited, ND.

I. Course Title : Analytical Techniques in Environmental Sciences

II. Course Code : AEM 503

III. Credit Hours : 1+2

IV. Aim of the course

- To teach the student advance analytical techniques employed in environmental studies
- To acquaint the student to the advanced instrumentation employed in environmental studies

V. Theory

Unit I

Qualitative and quantitative analytical techniques including Gravimetric and volumetric analyses used in environmental science, Sampling techniques and procedures, Factors affecting the choice of analytical techniques, Interferences and their minimization, Laboratory safety measures.

Unit II

Photometric techniques: Theory, instrumentation and application of spectrophotometry and spectroscopy, AAS, FT-IR, ICP-MS, XRD, XPS, Biosensor, Microscopic Techniques etc. Theory and applications of electrophoresis, Principles and uses of ultra-centrifugation, Tracer Techniques, Isotopes in environmental analysis.

Unit III

Separation techniques: Chromatography – theory, instrumentation and applications of thin layer, paper, ion-exchange, size exclusion, high performance liquid and gas, Methods of preparing biological samples for chromatographic analysis, GC-MS.

Unit IV

Bioanalysis techniques: Immunoassay – Principle, methods and applications and Biosensors – components, characteristics, applications, impacts and challenges. **Nanotechnology:** Preparation of nanoparticles, characterization and applications

VI. Practical

Estimation of environmental parameters by UV-Visible spectrophotometer, Estimation by AAS, Estimation of environmental parameters using HPLC, Estimation of environmental parameters using GC/GC-MS, Estimation of environmental parameters by CHNS analyser, etc.

VII. Suggested Reading

- APHA, AWWA and WEF. 2009. *Standard Methods for the Examination of Water and Wastewater* (Eaton AD, Clesceri LS, Rice EW, Greenberg AE), 21st edition. American Public Health Association, Washington DC.
- Bryan M Ham and Aihui MaHam. 2016. *Analytical Chemistry: A Chemist and Laboratory Technician's Toolkit*, Wiley.
- Fishbein L. 1973. *Chromatography of Environmental Hazards: Metals, Gaseous and Industrial Pollutants*. Elsevier Publications, Amsterdam.
- GR Chatwal and Sham Anand. 2011. *Instrumental Methods Of Chemical Analysis*, Himalaya Publishing House.
- Jeffery GH, Basset J, Mendham J and Denney RC. (Eds.). 1989. *Vogel's Textbook of Quantitative Chemical Analysis*. Longman Publishers, Singapore.
- Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnston CT and Sumner ME. (Eds.). 1996. *Methods of Soil Analysis:* Part 3 - Chemical Methods. SSSA-ASA, Madison.

I. Course Title : Climate Change: Impact and Management

II. Course Code : AEM 504

III. Credit Hours : 1+0

IV. Aim of the course

- To understand global warming, its impact on the aquatic environment and fisheries
- To know about the different legislation across the country to combat climate change

V. Theory

Unit I

Weather and climate, Greenhouse effect, Radiative balance, Climatic migration, Impact on women; Carbon Sequestration and trading, Projected trends of climate change and disasters.

Unit II

Climate change, Its impacts, Aquatic ecosystem, Capture and culture fisheries, Carbon footprint in fisheries and aquaculture.

Unit III

Ocean acidification, Global ocean circulation, El Nino and Southern Oscillation, IPCC and its reports, UNFCCC, Kyoto Protocol, Politics of climate change.

Unit IV

Climate change adaptation and mitigation, Vulnerability assessment, Mitigation and Adaptation measures, Climate-resilient aquaculture, Climate smart villages-NICRA.

VI. Suggested Reading

- Hulme M. 2009. *Why we disagree about climate change: Understanding controversy, inaction and opportunity*. Cambridge University Press.
- Murphy RP and Boomer D. 2008. *An Appeal to Reason: A Cool Look at Global Warming*, By Nigel Lawson-super-1. Economic Affairs, 28(4), pp.80-81.
- Pecl GT, Araújo MB, Bell JD, Blanchard J, Bonebrake TC, Chen IC, Clark TD, Colwell RK, Danielsen F, Evengård B and Falconi L. 2017. *Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science,* 355(6332), p.eaai9214.
- Schmutter K, Nash M and Dovey L. 2017. Ocean acidification: assessing the vulnerability of socioeconomic systems in Small Island Developing States. Regional environmental change, 17(4), pp.973-987.

I. Course Title : Aquatic Pollution and Management

II. Course Code : AEM 505

III. Credit Hours : 2+1

IV. Aim of the course

- To impart fundamental and advanced knowledge on different aspects of aquatic pollution
- To impart fundamental and advanced knowledge on management of different aquatic resources

V. Theory

Unit I

Aquatic pollution: Sources, types and impacts, Pollution problems of groundwater resources (arsenic, fluoride, nitrate, pesticides), Sources of contamination and management issues.

Unit II

Pollutants: Sewage, pesticides, hydrocarbons, nutrients, Metals, Radioactive wastes, Biomedical wastes, hazardous chemicals, Microplastics, Nanoparticles; Dispersal and fate of pollutants.

Unit III

Air and soil pollution: Smoke, Smog, Photochemical smog and SPM, Impact of air and soil pollution on the aquatic environment.

Unit IV

Methods of waste disposal, water quality criteria: National and International standards; ISO-14000(EMS), EIA, Management strategies, Emerging issues in aquatic environment.

Unit V

Waste waters: Their nutrient potentials, Scope and limitations, Treatment methods; Recovery of nutrients from liquid and solid wastes, Ecological sanitation, closing the loop.

Unit VI

Integrated water management: Water conservation measures, Water use and reuse in aquaculture, Water use efficiency, Restoration ecology and rehabilitation

VI. Practical

Determination of total dissolved and suspended solids, Determination of BOD, Determination of COD, Determination of NH_3–N, Determination of Nitrate/Nitrite-N, Determination of Phosphate-P, Determination of metals and pesticides, Visit to a sewage treatment plant/fish processing unit/industries.

VII. Suggested Reading

- APHA (American Public Health Association). 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd Edition. American Public Health Association, Washington, D.C.
- Baird DJ, Beveridge MCM, Kelly LA and Muir JF. 1996. *Aquaculture and Water Resources Management*. Blackwell Science Ltd., Oxford.
- Clark RB. 2001. *Marine Pollution*.Oxford University Press.
- Czernuszenko W and Rowinski P. 2005. *Water quality hazards and dispersion of pollutants*. Springer Science and Business Media.
- Gray NF. 2004. *Biology of Wastewater Treatment*. Oxford University Press, London.
- Mason C. 2002. *Biology of Freshwater Pollution*. 4th edition, Benjamin Cummings, 400 pp.
- Trivedy RK. 1998. *Advances in Wastewater Treatment Technologies*. Global Science, Aligarh.

I. Course Title : Eco-toxicology

II. Course Code : AEM 506

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on toxicological aspects of various pollutants

- To impart the knowledge on emergent toxicants, their fate in aquatic environment and risk assessment
- To impart knowledge on the effects of toxic chemicals on populations, communities and aquatic ecosystems

V. Theory

Unit I

Toxicity: Factors influencing toxicity, Environmental, genetic and nutritional, Ecological effects of toxicants, Genotoxicity, Neurotoxicity, Toxicology of emerging contaminants, PBDE, New generation pesticides and antibiotics, Antibiotic resistance.

Unit II

Toxicity evaluation: Toxicity Testing, Microcosm and mesocosm Tests, Dose-Response Relationships, Bioassay, Physiological and molecular evaluation

Unit III

Metabolism: Metabolism of toxic substances by aquatic microbes and other organisms consequences, synergistic and antagonistic effects, Acute poisons and accumulative poisons, Biomonitoring and biosensors.

Unit IV

Bioaccumulation, Bioconcentration and Biomagnification, Systemic effects of toxic metals, Pesticides and Herbicides; Effect of select toxicants on aquatic life and detoxification mechanisms, Interrelationship of xenobiotics with other environmental variables, biofilter organisms.

VI. Practical

Toxicity evaluation of heavy metals on selected organisms by bioassay techniques, Toxicity testing methods, Toxicity assessment of pesticides and other contaminants on selected organisms.

VII. Suggested Reading

- Calow PP. 2009. *Handbook of Ecotoxicology*. Blackwell Science, 871 pp.
- Gasol JM, Kirchman DL. 2014. *Microbial Ecology of the Ocean*. 3rd Edition, Wiley Blackwell, 507 pp.
- Hoffman DJ. 1995. *Handbook of Ecotoxicology*. Lewis Publication, Boca Raton.
- Jorgensen SE. 2010. *Ecotoxicology*. Academic Press. 389 pp.
- Kumar A. (Ed). 2008. *Aquatic Environment and Toxicology,* Daya Publishing House, New Delhi.
- Mayer H. 1977. *Aquatic Toxicology and Hazards Evaluation.* ASTM Publication, Philippines.
- Newman MC. Clements, W.H. 2008. Ecotoxicology: A comprehensive treatment. CRC press. 852 pp.
- Rand GM and Petrocelli SR. 1994. *Fundamentals of Aquatic Toxicology*. Hemisphere Publishing Corporation, Washington.
- Raymond JM, Neisink RJM, de Vries J and Hollinger MA. 1996. *Toxicology: Principles and Applications*. CRC Press, New York.
- Ware GW. 2002. *Review of Environmental Contamination and Toxicology*. Springer –Verlag, New York.
- Walker CH, Hopkin SP, Sibly KM, Peakall DB. 2014. *Principles of Ecotoxicology*, 2nd Edition. Taylor and Francis, 308 pp.

I. Course Title : Coastal Ecology and Management

II. Course Code : AEM 507

III. Credit Hours : 2+1

IV. Aim of the course

- To impart theoretical and practical knowledge about fundamental and advanced aspects of marine ecology.
- To acquaint the students with the recent approaches for coastal resources management.

V. Theory

Unit I

Coastal resources: Characteristics of coastal ecosystems (flora and fauna, trophic relationship, nutrient production, cycle and transport).

Unit II

Mangrove ecosystem: Species diversity, distribution and importance; Other inter-tidal systems - Seagrass, Sandy beach, Lagoon and estuary.

Unit III

Developmental activities and biodiversity loss: Human settlements, Industries, Shore protection works, Ports, transport systems and Waste disposal.

Unit IV

Ecological issues, Impacts of environment changes, Threats to biodiversity, Habitat destruction; Depletion of fisheries resources.

Unit V

Coastal Zone Management: Integrated Coastal Zone Management (ICZM) - its benefits, Principles, Goals and objectives, scope, zonation.

Unit VI

National and international policies and planning for coastal resource management: Natural hazards and disasters -protection and management; Socioeconomic impacts and its assessment.

VI. Practical

- Analysis of soil and water characteristics of coastal areas and determination of different factors.
- Collection, preservation and identification of coastal biological communities
- Survey of different coastal zones.

VII. Suggested Reading

- Cairns J Jr. 1994. *Implementing Integrated Environmental Management* Virginia Tech University.
- Clark JR. 1992. *Integrated Management of Coastal Zones*. FAO Fisheries Technical Paper No. 327, Rome.
- *Coastal Area Management and Development* 1982. U.N. Department of International Economic and Social Affairs, New York.
- David S and Jeremy P. 2001. *Inshore Fisheries Management. Methods and Technologies in Fish Biology and Fisheries* (vol. 2). Kluwer Academic publishers, London.
- Khanna BK. 2000. *All You Wanted to Know About Disasters*. New India Publishing Agency.
- Ramkumar M, James A, Menier D, Kumarswamy K. 2018. *Coastal Zone Management: Global Perspective*, Regional Processes, Local Issue. Elsevier.

I. Course Title : Aquatic Microbiology

II. Course Code : AEM 508

III. Credit Hours : 1 +1

IV. Aim of the course

- To impart knowledge on aquatic microorganisms with reference to their role in the aquatic environment and bioprospecting.
- To impart knowledge and skill on culture and culture independent techniques for microbial studies.

V. Theory

Unit I

Distribution and classification: Microbial community in freshwater; Estuarine and marine environment (types and abundance); Factors affecting microbial growth and abundance; Extremophiles and their significance.

Unit II

Microbial interaction: interrelationships, Microbial degradation of persistent organic pollutants (POPs); Microorganisms and public health: Water-borne pathogens of public health importance - Protozoans, bacteria, enteroviruses; Microbial toxins; Algal toxins; Disinfection methods; Microbial standards for different water uses.

Unit III

Principles and applications of bioprocesses: Bioremediation, Biofertilization, Biofilms, Biofloc, Probiotics, Bio-leaching, Bio-corrosion, Bio-fouling; Microorganisms as Bioindicators and Biosensors.

Unit IV

Methods of assessing microbial biomass production; Bioprospecting: Current practices in bioprospecting and biopiracy; Microbial metabolites and its industrial application.

VI. Practical

- Isolation, identification and enumeration of algae and bacteria from polluted aquatic habitats
- Maintenance of algal and bacterial cultures
- Microbial sensitivity testing
- Bio-activity testing
- Disinfection methods

VII. Suggested Reading

- Dhevendaran K. 2008. *Aquatic Microbiology*, Daya Publishing House, New Delhi.
- Droop MR, Jannasch HW. 2012. *Advances in Aquatic Microbiology*. Volume One. Academic Press, 388 pp.
- Frobisher M, Hinsdill RD, Crabtree KT and Goodheart CR. 1974. *Fundamentals of Microbiology*. WB Saunders Company, Philadelphia.
- Maier RM, Pepper IL, Gerba CP. 2009. *Environmental Microbiology,* 2nd Edition, Academic Press, 624 pp.
- Pepper IL, Gerba CP, Gentry TJ and Maier RM. (Eds.) 2009. *Environmental Microbiology*, 2nd Edition, Academic Press, 624 pp.
- Rheinheimer G. 1992. *Aquatic Microbiology*. John Wiley and Sons, Sigee, D.C. 2005. Freshwater microbiology, Wiley Publisher, 517pp.
- Singh J, Sharma D, Kumar G, Sharma NR. 2018. *Microbial Bioprospecting for Sustainable Development*. Springer publisher, 396 pp.
- Stanier R, Ingraham JL and Adelberg EA. 1976. *General Microbiology*. MacMillan Publishers, London.
- Vernam AH and Evans M. 2000. *Environmental Microbiology*. Blackwell Publishing, U. K.

I .Course Title : Aquatic Environment and Biodiversity

II. Course Code : AEM 509

III. Credit Hours : 1+1

IV. Aim of the course

- To acquaint the students with the theoretical and practical aspects of the aquatic environment and biodiversity concept.
- To impart knowledge on biodiversity conservation and ecosystem approach to resource management.

V. Theory

Unit I

Basic ecological concepts - Habitat ecology, systems ecology, Synecology, Autecology; Characteristic features of different biomes; Concept of community, Continuum, Community attributes, Community development, Ecological succession, Changes in ecosystem production, Concept of climax.

Unit II

Biodiversity – Definition and concept; Categories of biodiversity - Species diversity, Genetic Diversity; Habitat Diversity; Ecosystem services and Economic appraisal of biodiversity

Unit III

Biodiversity indices and their significance; Concepts of Index of Biotic Integrity (IBI).

Unit IV

Biodiversity Conservation - Global diversity patterns and loss of biodiversity; Conservation measures; Biodiversity hotspots, Biosphere reserves; National parks, sanctuaries; Marine protected areas; Convention on Biological Diversity; IUCN; CITES; WWF; Ramsar Convention; Man and Biosphere Programme; Indian legislations to biodiversity conservation, Ecological Sensitive Areas (ESAs)

VI. Practical

- Collection and identification of flora and fauna from different ecosystems.
- Calculation of biodiversity indices – Shannon-Wiener index; Simpson index, Hill index etc.
- Visit to biodiversity hotspots and ESAs.

VII. Suggested Reading

- Barnes RSK and Mann KH. eds. 2009. *Fundamentals of aquatic ecology*. John Wiley and Sons.
- Carter RWG. 1998. *Coastal Environments: An Introduction to the Physical, Ecological and Cultural Systems of Coastlines*. Academic Press, London.
- Dodds W and Whiles M. 2010. *Freshwater Ecology*, 2nd Edition, Concepts and Environmental Application of Limnology. Academic Press, London.
- Kormondy EJ. 1986. *Concepts of Ecology*, Prentice-Hall, New Delhi.
- Okuda N, Watanabe K, Fukumori K, Nakano SI and Nakazawa T. 2014. *Biodiversity in aquatic systems and environments*: Lake Biwa. Springer Japan.
- Park CC. 1980. *Ecology and Environmental Management.* Butterworths, London.

I. Course Title : Plankton Ecology and Trophic Dynamics

II. Course Code : AEM 510

III. Credit Hours : 1+1

IV. Aim of the course

- To impart theoretical knowledge about the ecology of plankton in diverse aquatic environment with a reference to their ecological role in trophic dynamics.
- To improve the technical skills for sampling, identification and effects of different ecological conditions on plankters.

V. Theory

Unit I

Plankton diversity and productivity: Definition, Classifications and functions in aquatic ecosystem; Primary and secondary production - Production - Biomass (P/B ratio), factors affecting production.

Unit II

Sampling and preservation techniques- Plankton nets and recorders, Cryopreservation methods and their significance, Indices of diversity.

Unit III

Ecology of phytoplankton: Freshwater and marine, Spatial and temporal variations, succession; Contribution of nanoplankton to primary production; Algal blooms and algal toxins; Nutrient manipulation for algal growth and control; Biological control of algal blooms; Mass culture of phytoplankton as ~~a~~ live-feed; Role of microalgae in carbon sequestration.

Unit IV

Ecology of zooplankton: Freshwater and marine –Feeding behavior, Reproduction of important zooplankters; Swarms; Indicator species; Predator-prey relationship; Impact of grazing on the aquatic ecosystem; Vertical migration of zooplankton in relation to fish catch; Importance of zooplankton in the larval rearing of fish; Environmental manipulation for live-feed production; Mass culture of zooplankton as ~~a~~ live-feed.

VI. Practical

- Collection, preservation and estimation of phytoplankton and zooplankton
- Periphyton estimation.
- Identification and classification of various phytoplankton and zooplankton.
- Mass culture of Phytoplankton and zooplankton.
- Preparation of permanent slide and sectioning.

VII. Suggested Reading

- Castellani C and Edwards M. eds. 2017. *Marine Plankton: A Practical Guide to Ecology, Methodology, and Taxonomy*. Oxford University Press.
- Fasset NG. 1997. *A Manual of Aquatic Plants*. Allied Scientific Publishers, Bikaner.
- Kiørboe T. 2008. *A mechanistic approach to plankton ecology*. Princeton University Press.
- Lund HC and Lund JWG. 1995. *Freshwater Algae*. Biopress Ltd., Bristol.
- Mitra A. 2006. *Introduction to Marine Phytoplankton*, Narendra Publishers, New Delhi.
- Sournia A. 1978. *Phytoplankton Manual*. UNESCO Publication, Paris.
- Sardet C. 2015. *Plankton: wonders of the drifting world*. University of Chicago Press.
- Tomas CR. 1997. *Identifying Marine Phytoplankton*. Academic Press, San Diego.
- Harris RP, Wiebe PH, Lenz J, Skjoldal HR and Huntley M. (eds). 2000. *ICES Zooplankton Methodology Manual*. Academic Press.

I. Course Title : Environmental Biotechnology

II. Course Code : AEM 511

III. Credit Hours : 1+1

IV. Aim of the course

- To impart basic knowledge on biological methods for environmental management
- To impart basic knowledge on isolation of bacteria implicated in bioremediation and demonstration of their potential for environmental management
- To impart basic knowledge on Application of Molecular techniques in environmental management

V. Theory

Unit I

Fundamentals of environmental biotechnology: Environmental biotechnology-Concepts and Scope; Conventional and Modern approaches; IPR issues related to environmental biotechnology.

Unit II

Environmental monitoring: Cellular and molecular markers of environmental pollution monitoring; Bioindicators; Biosensors and nano-sensors.

Unit III

Remediation: Bioremediation; Genetically-improved/engineered organisms - Basic concepts; Applications in remediation of metals, Pesticides and hydrocarbons.

Unit IV

Consortia of microbes for environmental protection – Concept, Scope and Feasibility, Recombinant DNA technology, Culture intendent nucleic acid-based techniques.

VI. Practical

- Genomic, Metagenomic and plasmid DNA isolation.
- Case studies on wastewater treatment using biotechnological tools.
- PCR amplification of 16S rRNA gene as a tool for biomonitoring.
- PCR application of functional gene implicated in bioremediation.
- Screening of microbes for biodegradation properties.

VII. Suggested Reading

- Buck RP, Hatfield WE, Umana M and Bowden E F. 1990. *Biosensor Technology - Fundamentals and Applications*. Marcel Dekker, New York.
- Evans GG and Furlong J. 2011. *Environmental Biotechnology: Theory and Application*. John Wiley and Sons.
- Fujita M and Ike M. 1994. *Wastewater Treatment Using Genetically Engineered Microorganisms*. Technomic Publishing Co. Inc., Lancaster.
- Kingsman SM and Kingsman AJ. 1988. *Genetic Engineering: An Introduction to Gene Analysis and Exploitation in Eukaryotes*. Blackwell Scientific, Oxford.
- Sambrook J and Russel DW. 2001. *Molecular Cloning: A Laboratory Manual*. CSHL Press, New York.
- Sangeetha J, Thangadurai D, David M and Abdullah MA. eds. 2016. *Environmental Biotechnology: Biodegradation, Bioremediation, and Bioconversion of Xenobiotics for Sustainable Development*. CRC Press.
- Sayler GS, Sanseverino J and Kimberely DL. 1997. *Biotechnology in Sustainable Environment*. Plenum Press, New York.

I. Course Title : Fisheries Oceanography

II. Course Code : AEM 512

III. Credit Hours : 1+1

IV. Aim of the course

- To educate the students on the oceanographic concepts related to fisheries and impart skill to operate oceanographic equipment.
- To understand the role of different oceanographic parameters on fisheries production.

V. Theory

Unit I

Oceanographic factors in fisheries: Effects of physio-chemical and biological oceanographic factors on adaptation, Behaviour, Abundance and distribution of aquatic organisms; Primary and secondary productivity in ocean, Productivity changes in the ocean.

Unit II

Synoptic oceanographic analysis: El Nino and Southern Oscillation; Stratification; Mud banks, Upwelling and circulation patterns.

Unit III

Forecasting systems: Fisheries forecasts – Interpretation and use of ocean thermal structure; Fisheries forecasting system in India and other countries – Remote sensing; GIS, Application in fisheries; Application of echo-sounders and SONAR; Potential fishing zones.

Unit IV

Factors affecting marine fisheries: Environmental factors influencing the seasonal variations in fish catch in the Arabian Sea and the Bay of Bengal.

VI. Practical

- Use of tide tables.
- Oceanographic data analysis – water temperature, salinity, pH, nutrients, benthos and sediment characteristics.
- Fisheries forecasting systems.
- Oceanographic equipment and fish finding devices.

VII. Suggested Reading

- Grasshoff K, Ehrhardt M and Kremling V. 1983. *Methods of Seawater Analysis*. Verlag Chemie, Weinheim.
- Kennish MJ. 1989. *Practical Handbook of Marine Science*. CRC Press, New York.
- Laevastu T and Hayes ML. 1981. *Fisheries Oceanography and Ecology*. Fishing News Books, Farnham, U.K.
- Lalli CM and Parsons TR. 1993. *Biological Oceanography: An Introduction*. Elsevier Science Ltd., Oxford.
- Miller CB. 2004. *Biological Oceanography*. Blackwell Publications, Oxford.
- Pond S and Pickard GL. 2013. *Introductory Dynamical Oceanography*. Elsevier.
- Reddy MPM. 2007. *Ocean Environment and Fisheries,* Science Publishers, USA.
- Tomczak M and Godfrey JS. 2013. *Regional Oceanography: An Introduction*. Elsevier.

I. Course Title : Utilization and Management of Aquatic Algal Resources

II. Course Code : AEM 513

III. Credit Hours : 2+1

IV. Aim of the course

- To provide a holistic knowledge about the aquatic algal resources and their utilization for alternate livelihood
- To convey the information about the strategies and protocols for the management of aquatic algal resources

V. Theory

Unit I

Role of algae in fisheries and aquaculture, Batch and mass cultivation, Selection of culture medium, Isolation and maintenance of algal cultures; Water quality for algal culture, Algal culture as a livelihood option

Unit II

Bio-prospecting of algal resources for value-added compounds/products-pigments, Agar agar, Carrageenan, Single cell protein, Nutraceuticals and pharmaceuticals

Unit III

Production of nanoparticles; Biofuels, Food and Feed, Algal compounds in cosmetics and Natural colourants, Polar algal resources and their applications.

Unit IV

Value addition through food chain; Enhancement of productivity of phytoplankton - Use of thermal energy, Artificial upwelling, Wastewater utilization for algal cultivation.

Unit V

Role of algae in global warming mitigation; Nutrient supplementation of sea for productivity enhancement, Exotic algal species source and Preventive measures.

Unit VI

International regulations for discharge of ballast water, Algal blooms and control measures.

VI. Practical

- Techniques for algal cultivation
- Maintenance of pure cultures
- *Spirulina* and *Chlorella* cultivation – indoor and outdoor
- Extraction of pigments from algae (Carotenoids and Phycocyanin)

VII. Suggested Reading

- Borowitzka MA. 1988. *Micro-algal Biotechnology*, Cambridge University Press, U.K.
- Edmondson WT. 2003. *Freshwater Biology*. Textbook Publishers, 1248 pp.
- Graham LE, Graham JM and Wilcox LW. 2009. *Algae*, Pearson Benjamin Cummings, San Francisco.
- Kumar HD and Singh HN. 1990. *A Textbook on Algae*, Affiliated East-West Press Private Ltd., New Delhi.
- Lavens P and Sorgeloos P. (eds.). 1996. *Manual on the production and use of live food for aquaculture*. FAO Fisheries Technical Paper. No. 361. Rome, FAO, 295pp.
- Mamta Rawat, SumitDookia. 2012. *Biodiversity of Aquatic Resources* , Daya Publishing House, New Delhi.
- Sournia A. 1978. *Phytoplankton Manual*, UNESCO publication, Paris.
- Stein JR. 1973. *Handbook of Phycological Methods*, Cambridge University Press, London.
- Vonshak A. 1997 *Spirulina platensis* (*Arthrospira*): *Physiology, Cell-biology and Biotechnology*, Taylor and Francis, London.

I. Course Title : Restoration Ecology

II. Course Code : AEM 514

III. Credit Hours : 1+1

IV. Aim of the course

- To update and widen the knowledge about basic principles and recent concepts in ecology.
- To equip the students with an updated theoretical and practical knowledge and skills about restoration of aquatic ecosystems.

V. Theory

Unit I

Ecological restoration; Ecological processes and structures, Regional and Historical contexts, and sustainable culture practices; Ecosystem integrity; Community ecological principles; Disturbance, Succession, Fragmentation; Ecosystem function and Services.

Unit II

Emerging concepts-Assembly, Stable states; Environmental flows and cultural interactions; Application of theory-Invasion, Competitive dominance and resource use.

Unit III

Restoration planning; Wetland Assessment, Delineation, and Regulation; Recovery process, Mitigation, Rehabilitation, and Reclamation; Ecological Engineering – Ecosystem approach for restoration; Dynamics and restoration of degraded wetlands; Removal of threats to the health and integrity of the restored ecosystem, Use of constructed wetlands to eco-restoration.

Unit IV

Ecosystem modeling; Ecosystem auditing; Socioeconomics of recovery process; Ecosystem Health Cards

VI. Practical

- Collection and segregation of native and non-native species from a degraded environment
- Making list of historical and cultural interactions, status of assemblages
- Calculation of Index of Biotic Integrity
- Listing of the threats to the integrity of the ecosystem
- Organizing different participatory programs
- Designing a sustainable ecosystem

VII. Suggested Reading

- Cooke GD, Welch EB, Peterson S and Nichols SA. 2016. *Restoration and management of lakes and reservoirs*. CRC press.
- Gupta T, Agarwal AK, Agarwal RA, Labhasetwar NK. (Eds.). 2018. *Environmental Contaminants Measurement, Modelling and Control*, springer.
- Jørgensen SE, Xu L and Costanza R. eds. 2016. *Handbook of ecological indicators for assessment of ecosystem health*. CRC press.
- Keith W Little. 2017. *Environmental Fate and Transport Analysis with Compartment Modeling*, CRC press.
- Laevastu T, Clancy M and Stroud A. 1974. *Computation of Tides, Currents and Dispersal of Pollutants in Lower Bay and Approaches to New York with Fine Medium Grid Size Hydrodynamical-Numerical Models*. Part 3. National Technical Information Service Springfield, Virginia.
- Roy MH. (Ed). 1982. *Pollution: Causes, Effects and Control*. The Royal Society of Chemistry, England.
- Wlodzimierz C and Pawel R. 2005. *Water Quality Hazards and Dispersion of Pollutants,* Springer, USA.

Course Title with Credit Load
Ph.D. in Aquatic Environment Management

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
AEM 601	Techniques in Aquatic Environmental Studies	0+2
AEM 602	Dispersal and Fate of Pollutants	1+1
AEM 603	Water Issues: Challenges and governance	1+0
AEM 604	Management and Utilization of Waste and Waste Water	2+1
AEM 605	Environmental Impact Assessment	1+1
AEM 606	Ecology of Plankton and Benthos	1+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
AEM 607	Estuarine and Coastal Oceanography	1+1
AEM 608	Biotechnology in Aquatic Environment Management	1+2
AEM 609	Aquatic Plant Resource and its Management	1+1
AEM 610	Application of Remote Sensing and GIS in Fisheries	1+1
	Supporting courses	**5 credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Credits	**23 credits**
	Doctoral Seminar	**2 credits**
AEM 691	Doctoral Seminar-I	0+1
AEM 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 credits**
AEM 699	Doctoral Research (Semester II)	0+15
AEM 699	Doctoral Research (Semester III)	0+15
AEM 699	Doctoral Research (Semester IV)	0+15
AEM 699	Doctoral Research (Semester V)	0+15
AEM 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 credits**

Course Contents
Ph.D. in Aquatic Environment Management

I. Course Title : Techniques in Aquatic Environmental Studies
II. Course Code : AEM 601
III. Credit Hours : 0+2

IV. Aim of the course

To impart skill on various techniques in aquatic environment studies

V. Practical

- Analysis of ions
- Calculation of shoreline development index and other indices of lake productivity
- Eutrophication studies in natural waters-tanks and ponds
- Estimation of bio-indicator organisms in polluted waters
- Bioremediation experiments using different bio-agents
- Use of MS-GC in analysis of pesticide and other volatile and semi volatile organic substances
- Water quality improvement evaluation trials
- Field visits
- Visits to different institutes to learn the other techniques

VI. Suggested Reading

- APHA (American Public Health Association). 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd Edition Edition. American Public Health Association, Washington, D.C.
- Cheremisinoff NP. 2002. *Handbook of Water and Waste Water Treatment Technologies*. Butterworth – Heinemann, Woburn.
- Cairns JE. 2017. *Biological Monitoring in Water Pollution*. Elsevier.
- Sakhare VB. (Ed.). 2007. Advances in Aquatic Ecology Vol. 1. Daya Publishing House, New Delhi.

I. Course Title : Dispersal and Fate of Pollutants
II. Course Code : AEM 602
III. Credit Hours : 1+1

IV. Aim of the course

- To impart knowledge on dispersal of pollutants.
- To impart knowledge on fate of pollutants.

V. Theory

Unit I

Common transport processes of pollutants, Influence of winds, tides, waves and currents on the dispersal of pollutants.

Unit II

Pollutant dispersion in rivers, Coastal waters, estuaries and near outfall sites;

Pollutant dispersal, Dye diffusion studies.

Unit III

Mobility and speciation of pollutants; Nano particles; Recent advances in study of pollutants and their monitoring

Unit IV

Lifecycle analysis; Bio-concentration, Bioaccumulation and Bio-magnification

VI. Practical

- Techniques of computation of dispersion coefficients
- Calculation of Richardson number
- Numerical analysis of estuarine dispersion
- Simple plume experiments – designs of waste discharge and thermal systems

VII. Suggested Reading

- Ciambrone DF. 2018. *Environmental life cycle analysis*. CRC Press.
- John J, William R and Feiss GP. 1998. *People and the Earth: Basic Issues in the Sustainability of Resources*, Cambridge University Press.
- Laevastu T, Clancy M and Stroud A. 1974. *Computation of Tides, Currents and Dispersal of Pollutants in Lower Bay and Approaches to New York with Fine Medium Grid Size Hydrodynamical-Numerical Models*. Part 3. National Technical Information Service Springfield, Virginia.
- Roy MH. (Ed). 1982. *Pollution: Causes, Effects and Control*. The Royal Society of Chemistry, England.
- Rieuwerts J. 2017. *The elements of environmental pollution*. Routledge.
- Wlodzimierz C and Pawel R. 2005. *Water Quality Hazards and Dispersion of Pollutants*, Springer, USA.

I. Course Title : Water Issues: Challenges and Governance
II. Course Code : AEM 603
III. Credit Hours : 1+0

IV. Aim of the course

- To understand the current scenario and future challenges regarding water use.
- To understand different management measures for sustainable use of water.

I. Theory

Unit I

3R concept in water resource management, Best utilisation of water resources, Water as a global issue, Key challenges and needs, Policy option for water conservation and Sustainable use.

Unit II

Water availability in different regions of world, Factors affecting it and conservation; Role of society, Ancient wisdom.

Unit III

Conflicts in water resources utilisation and management, Social and religious importance of water resources.

Unit IV

National and international regulations for management and utilisation of water resources, Current scenario and future challenges of water resource management at National and International level.

II. Suggested Reading

- Cao G and Orrù R. eds. 2014. *Current environmental issues and challenges* (Vol. 31). New York: Springer.
- Costa-Pierce BA. 2002. *Ecological aquaculture*. Oxford, UK.: Blackwell Science.
- Giupponi C, Jakeman AJ, Karssenberg D and Hare MP. 2006. *Sustainable management of water resources*. Edward Elgar Publishing.
- Singh A, Saha D and Tyagi AC. eds. 2019. *Water Governance: Challenges and Prospects*. Springer.

I. Course Title : Management and Utilization of Waste And Wastewater
II. Course Code : AEM 604
III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge on management and utilization of waste and wastewater.

V. Theory

Unit I

Industrial and domestic wastewater characteristic; Conventional and advanced treatment methods for wastewater, Use of Nanotechnology in treatment; Nano-structured material.

Unit II

Waste recycling and utilisation (including solid waste) in aquaculture, Plant assisted bioremediation.

Unit III

Urban Drainage Sewage System; Theoretical principles and design - Screens, Equalization basin, Grit chamber, Primary and secondary settling tanks, Advanced Wastewater Treatment – Need and technologies used, Nitrification and Denitrification Processes, Phosphorous removal, Wastewater disinfection, The management of residuals from water and wastewater treatment.

Unit IV

Hazardous waste disposal (by incineration), Required minimum incineration temperature, The thermal treatment of halogenated waste, Present-day waste incinerators, Waste minimization, Role of human behavior in waste managment

Unit V

Production of Biogas and bio-fuel from waste; Wastewater-fed aquaculture, Integrated wastewater management, Green water technology, IMTA.

Unit VI

Wastewater disposal criteria - National and international standards; Monitoring-Role of Central and state pollution control boards and other agencies.

VI. Practical

- Estimation of physicochemical characteristics of wastewater (BOD, COD).

- Estimation of nutrients and contaminant of wastewaters.
- Analysis of living communities associated with treatment processes.
- Demonstration of liquid waste treatments (ozonization, chlorination, aeration, precipitation, coagulation etc.).
- Synthesis of nanostructured materials for wastewater treatment.

VII. Suggested Reading

- Baird DJ, Beveridge MCM, Kelly LA and Muir JF. 1996. *Aquaculture and Water Resources Management*. Blackwell Science Ltd., Oxford.
- Cheremisinoff NP. 2002. *Handbook of Water and Waste Water Treatment Technologies*. Butterworth – Heinemann, Woburn.
- Cairns JE. 2017. *Biological Monitoring in Water Pollution*. Elsevier.
- Eckenfelder, W. W. 2000. *Industrial Water Pollution Control*. McGraw Hill, New York.
- Gray NF. 2004. *Biology of Wastewater Treatment*. Oxford University Press, London.
- Letcher TM and Vallero DA. eds., 2019. *Waste: A handbook for management*. Academic Press.
- Rhyner CR, Schwartz LJ, Wenger RB. and Kohrell MG. 2017. *Waste management and resource recovery*. CRC Press.
- Trivedy RK. 1998. *Advances in Wastewater Treatment Technologies*. Global Science, Aligarh.
- Liu SX. 2014. *Food and Agricultural Wastewater Utilization and Treatment*. 2nd Edition, Wiley-Blackwell, New York, 260 pp.

I. Course Title : Environmental Impact Assessment

II. Course Code : AEM 605

III. Credit Hours : 1+1

IV. Aim of the course

- To impart theoretical and practical knowledge of environment impact assessment for sustainable development.
- To give exposure of Environment Impact Assessment report preparation.

V. Theory

Unit I

Environmental legislations; Concepts and approaches to Environmental Impact Assessment (EIA), EIA with reference to aquaculture projects, Coastal industries and Other developmental activities.

Unit II

Social Impact Assessment (SIA), Process, Scope and Significance, Social auditing.

Unit III

Ecosystem services; Environmental economics; Analysis and computation, Environmental auditing, Importance in planning.

Unit IV

International and national environmental protection standards; Environmental quality monitoring; ISO-14000.

VI. Practical

- Field visits for EIA and SIA of certain aquacultural projects.
- Case study and EIA report preparation.
- Setting of the environmental audit programme.

VII. Suggested Reading

- Canter LW. 1994. Environmental Impact Assessment. Mc-Graw Hill, New York.
- Fortlage CA. 2017. *Environmental assessment: a practical guide*. Routledge.
- Grilbert M and Gould R. 1998. *Achieving Environmental Standards*. Pitman Publishing, London.
- Keith L. 2017. *Environmental sampling and analysis: a practical guide*. Routledge.
- UNEP. 2002. *Environmental Impact Assessment Training Resource Manual*, 2nd Edition, UNEP, 573 pp.
- Wathern P. (Ed.). 1988. *Environmental Impact Assessment: Theory and Practice*. World Research Institute, Routledge, London.

I. Course Title : Ecology of Plankton and Benthos
II. Course Code : AEM 606
III. Credit Hours : 1+1

IV. Aim of the course

- To impart and enrich the theoretical and practical knowledge of the students about ecology of plankton and benthos.
- To develop the competence for analysis of plankton diversity.

V. Theory

Unit I

Plankton- Predator-Prey relationship; Role of plankters in food chain, Trophic level and food-webs; Factors affecting plankton distribution.

Unit II

Characterization of benthic habitats; Benthic resources; Role of benthos in bio-turbation and reclamation, Detrital food chain; Factors affecting benthos distribution.

Unit III

Spatial and temporal variation of plankton and benthos; Assessment methods for plankton and benthos, Modern tools.

Unit IV

Plankters and Benthos as pollution indicators; Biofilters and Bio-monitors.

VI. Practical

- Collection and analysis of soil and water in relation to plankton and benthic ecology.
- Collectionand preservation of plankton and benthos; Identification of plankters, benthos.
- Experiment to explore the role of benthos in nutrient transformation.

VII. Suggested Reading

- APHA (American Public Health Association). 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd Edition. American Public Health Association, Washington, D.C.
- Bellinger EG and Sigee DC. 2015. *Freshwater algae: identification and use as bioindicators*. John Wiley and Sons.
- Cole GA. 1988. *Textbook of Limnology*. 3rd Edition. Waveland Press, Prospect Heights, Illinois.
- Cuffney TF, Gurtz ME and Meador MR. 1993. *Methods for Collecting Benthic Invertebrate Samples as Part of the National Water-Quality Assessment Programme*. U.S. Geological Survey Open-File Report 93-406. U.S.G.S., Raleigh, North Carolina.

- Dawson CL and Hellenthal RA. 1986. *A Computerized System for the Evaluation of Aquatic Habitats Based on Environmental Requirements and Pollution Tolerance Associations of Resident Organisms*. EPA/600/S3-86/019. Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, Oregon.
- Downing JA and Rigler FH. (Eds.). 1984. *A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters*. 2nd Edition. IBP Handbook 17. Blackwell Scientific Publications, Oxford, England.
- Haskins J. 2017. *Standards for Water, Wastewater updated in book:* New edition brings water safety to forefront for public health.
- Whitton BA. (Ed.). 1975. *River Ecology*. University of California Press, Berkeley, California.

I. Course Title : Estuarine and Coastal Oceanography

II. Course Code : AEM 607

III. Credit Hours : 1+1

IV. Aim of the course

- To strengthen the knowledge base of the students about the characteristics of estuarine ecosystems.
- To enhance the practical skills for the study of estuarine and coastal oceanography.

V. Theory

Unit I

Estuary; significance, Zonation, characteristics; Buoyancy input as freshwater; Biodiversity, Mangroves.

Unit II

Esturine and Coastal dynamics, Flow and circulation; productivity, Fish and fisheries of estuaries, World famous estuaries and their ecological significance

Unit III

Salinity distribution; Freshwater fraction; Flushing time of an estuary and methods of determination; Sediment transport in estuarine ecosystem

Unit IV

Waves in shallow waters, Transformation, Refraction and reflection; Mass transport, Return flow, Momentum balance

VI. Practical

- Analysis of tidal heights – Net flow and residence time computations
- Computation of salt and nutrient flux
- Construction of wave refraction diagrams
- Visit to coastal and mangrove areas
- Study of coastal profiles

VII. Suggested Reading

- Beer T. 2017. *Environmental oceanography*. CRC Press
- Carter RWG. 1998. *Coastal Environments: An Introduction to the Physical, Ecological and Cultural Systems of Coastlines*. Academic Press, London.
- Clark JR. 1992. *Integrated Management of Coastal Zones*. FAO Fisheries Technical, Paper No. 327, Rome.
- Eden C and Iske A. eds., 2019. *Energy Transfers in Atmosphere and Ocean*. Springer. •
Kormondy EJ. 1986. *Concepts of Ecology*. Prentice-Hall, New Delhi.
- Park CC. 1980. *Ecology and Environmental Management*. Butterworths, London.

- Vallega A. 1999. *Fundamentals of Integrated Coastal management,* Kluwer Academic Publishers
- Vallega A. 1992. *Sea Management A Theoretical Approach*. Elsevier Science Publishers Ltd.

I. Course Title : Biotechnology in Aquatic Environment Management

II. Course Code : AEM 608

III. Credit Hours : 1+2

IV. Aim of the course

- To educate about the application of biotechnology in aquatic environment management.
- To impart practical knowledge about various biotechnological tools used in aquatic environment management.

V. Theory

Unit I

Bioremediation: Microbial and Phyto-remediation of contaminated water and pollutants, Biotechnological approaches for bio-energy

Unit II

Biosensor, Bioreactor, Bioreactor for single cell protein, Microbial enzymes and bio-molecules, Industrial application.

Unit III

Molecular tools for biotechnological applications-it's use toxic studies- Pollution bio-indicators and biomarkers; Culture-independent techniques.

Unit IV

Application of biotechnology in aquaculture; Aquatic organisms in industrial/medical biotechnology.

VI. Practical

- Isolation of prospective bacteria as bio-remediators
- Isolation of prospective bacteria as bio-fertilizers
- Enzyme assays
- Mass culture of bacteria
- Gel electrophoresis
- DNA isolation and amplification
- RFLP analysis
- Meta-genomics
- Genomic libraries

VII. Suggested Reading

- Arora S, Singh AK and Singh YP. eds., 2017. *Bioremediation of salt affected soils: an Indian perspective*. Springer.
- Buck RP, Hatfield WE, Umana M and Bowden EF. 1990. *Biosensor Technology - Fundamentals and Applications*. Marcel Dekker, New York.
- Crespi RS. 1991. *Biotechnology and Intellectual Property*, Part 1 and 2. TIBTECH, 9
- Fingerman M. ed., 2016. *Bioremediation of aquatic and terrestrial ecosystems*. CRC Press.
- Moo-Young M, Anderson WA and Chakrabarty AM. 2006. *Environmental Biotechnology: Principle and Applications*. Kluwer Academic Press.

- Sambrook J and Russel DW. 2001. *Molecular Cloning: A Laboratory Manual*. CSHL Press, New York.
- Sayler GS, Sanseverino J and Kimberely DL. 1997. *Biotechnology in Sustainable Environment*. Plenum Press, New York.
- Yoxen, E. 1988. *The Gene Business: Who should Control Biotechnology*. Oxford University Press.

I. Course Title : Aquatic Plant Resources and its Management

II. Course Code : AEM 609

III. Credit Hours : 1+1

IV. Aim of the course

- To broaden the knowledge base of the students about aquatic plant resources and their significance.
- To improve the capacity of the students for better management of ecosystem.

V. Theory

Unit I

Aquatic plant resources- Definition and concept; Species diversity of aquatic plants in diverse habitats, Bio-prospecting- definition and concept, Bio-prospecting of aquatic plants.

Unit II

Economic importance of aquatic plants in fisheries and aquaculture, Environmental factors affecting aquatic plant resources, Role of aquatic plants as bio-filter in decontamination and Management of wastewater.

Unit III

Management of aquatic plant resources, Methods for increasing productivity of water bodies through thermal energy and Artificial upwelling, Artificial sea ranching, Plants as FAD's.

Unit IV

Utilization of aquatic plants for environmental management, Algae and angiosperms as bio-indicators, Global warming mitigation through algal biomass and biofuel production; Cultivation of economically important aquatic vegetation *viz.* Trapa and makhana.

VI. Practical

- Documentation of economically important plants from freshwater and marine habitats.
- Techniques for algal cultivation and maintenance of pure cultures, Spirulina and Chlorella cultivation – indoor and outdoor.
- Extraction and analysis of pigments from algae (Carotenoids and Phycocyanin)
- Heavy metal and dye removal by algae and macrophytes.

VII. Suggested Reading

- Borowitzka MA. 1988. *Micro-algal Biotechnology*, Cambridge University Press, U.K.
- Cooke D and Welch EB. 2005. *Restoration and Management of Lakes and Reservoirs*, CRC Press, USA.
- Gautam A. 1998. *Conservation and Management of Aquatic Resources*, Daya Publishing House, New Delhi.

- Gopal B. 1990. *Ecology and Management of Aquatic Vegetation in Indian Sub-continent,* Kluwer, Academic Publishers.
- Gangstad EO. 2018. *Weed Control Methods for River Basin Management: 0.* Crc Press.
- Lucas JS, Southgate PC and Tucker CS. eds. 2019. *Aquaculture: Farming aquatic animals and plants*. Wiley-Blackwell.
- Pullin RSV, Bartley DM and Kooiman J. 1999. *Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources*, International Centre for living aquatic resources management, Rome, Italy.
- Sahoo S. 2002. *Plant Resource Utilization*, Allied Publishers Pvt. Ltd., New Delhi.

I. Course Title : Application of Remote Sensing and GIS in Aquatic Environmental Studies

II. Course Code : AEM 610

III. Credit Hours : 1+1

IV. Aim of the course

- To impart knowledge and skill on application of Remote sensing and GIS in Oceanographic studies and aquatic environment management planning.
- To impart knowledge on use of modern RS tools in ecosystem management.

V. Theory

Unit I

General consideration, Survey planning, Position fixing; Sampling frequency and duration, Data storage and transmission, Sensors for temperature and salinity (*via* conductivity); Measurement of depth (via pressure); CTD units for estuarine and open ocean work; Sensor calibration techniques; Sensors for measuring flow; Tracking of drogue buoys, Acoustic Doppler current measurements.

Unit II

In situ determination of pigment concentration; Remote sensing optical methods; Satellite measurements of temperature (*via* thermal IR), Interpretation of Microwave (geotropic currents, waves, surface winds), Optical measurements; transmittance and subsurface reflectance.

Unit III

Geographical Information System (GIS): Definition, Concepts, Spatial data management, Database management system, Data Capture, Digitization, Data integration, Projection and Registration, Data Structure, Data Modeling, Visual Image Interpretation; Applications of GIS in Aquatic Environment Management; Digital Image Processing (DIP), Different Methods and Approaches.

Unit IV

Recent advances in RS technologies and its applications in different studies, use of Artificial Intelligence, etc.

VI. Practical

- Position fixing techniques
- Various types of current meters and measurement of currents
- Wave recorders and measurements
- Determination of pigment concentrations
- Remote sensors – interpretation of data

- Practical on visual interpretation of data from map
- Digital Image Processing (DIP)
- Field practical on the Application of GPS
- Mapping of aquatic environment resources through GIS softwares (ARCVIEW, MAPINFO etc.)

VII. Suggested Reading

- Elangovan K. 2005. *GIS: Fundamentals, Applications and Implementations*. New India Publishing Agency.
- ESRI. 2007. *Understanding GIS, The ARC/INFO Method*. Environmental System Research Organization, Inc., USA.
- Lillesand TM, Kiefer RW, Chipman JW. 2004. *Remote Sensing and Image Interpretation.* John Wiley and Sons (Asia) Pvt. Ltd., Singapore.
- Meaden GJ and Do Chi, T. 1996. *Geographical Information System: Applications to Marine Fisheries*. FAO Technical Paper No. 356, Rome.
- Meaden GJ and Kapetsky JM. 1991. *Geographical Information System and Remote Sensing in Inland Fisheries and Aquaculture*. FAO Technical Paper No. 318, Rome.
- Quattrochi DA, Wentz E, Lam NSN and Emerson CW. eds., 2017. *Integrating Scale in Remote Sensing and GIS*. CRC Press.

List of Suggested Journals

- *ActaOecologica – International Journal of Ecology*
- *Agriculture, Ecosystem and Management*
- *AnalyticaChemica*
- *Applied Environmental Microbiology*
- *Applied Microbiology and Biotechnology*
- *Applied Soil Ecology*
- *Aquaculture*
- *Aquaculture Engineering*
- *Aquatic Microbial Ecology*
- *Australian Journal of Ecology*
- *Australian Journal of Soil Research*
- *Biology and Fertility of Soils*
- *Bioresource Technology*
- *Bulletin of Environmental Contamination and Toxicology*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *Coastal Aquaculture*
- *Communication in Soil and Water analysis*
- *Current Opinion in Biotechnology*
- *Ecological Restoration- Journal published by the University of Wisconsin Press*
- *Ecological Engineering*
- *Ecotoxicology and Environmental Safety*
- *Environment and Ecology*
- *Environmental Pollution*
- *Environmental Science*
- *Environmental Studies*
- *Environmental Technology*
- *Environmental Toxicology*
- *Estuarine, Coastal and Shelf Science*
- *FEBS Letters*
- *FEMS Microbiology Ecology*
- *FEMS Microbiology Letters*
- *FEMS Microbiology Reviews*
- *Fisheries Oceanography*

- *Fisheries Science*
- *Functional Ecology*
- *Geo-Marine Letters*
- *Hydrobiologia*
- *Indian Journal of Environment and Toxicology*
- *Indian Journal of Marine Sciences*
- *International Journal of Ecology and Environmental Sciences*
- *Journal of Aquatic Botany*
- *Journal of Chromatography*
- *Journal of Ecotoxicology*
- *Journal of EnvironmentalQuality*
- *Journal of Marine Research USA*
- *Journal of Phycology*
- *Journal of Plankton Research*
- *Journal of Sustainable Agriculture*
- *Limnology and Oceanography*
- *Marine Biology*
- *Marine Ecology*
- *Marine Pollution Bulletin*
- *Oceans*
- *Restoration Ecology*
- *Science of the Total Environment*
- *Seaweed Research and Utilization*
- *Society for Ecological Restoration International*
- *Soil Science Society of America Journal*
- *Spill Science and Technology Bulletin*
- *Systematic and Applied Microbiology*
- *Toxicon*
- *Trends in Biotechnology*
- *Water Research*
- *World Journal of Microbiology and Biotechnology*

List of Suggested e-Resources

- https://www.neonscience.org/
- https://www.nationalgeographic.com/environment/freshwater/aquatic- ecosystems/
- https://www.environment.gov.au/
- https://www.oecd.org
- https://www.epa.gov/
- https://www.kmae-journal.org/
- http://www.mbgnet.net
- https://gisgeography.com/
- https://interact-gis.org
- http://www.remss.com
- https://www.geospatialworld.net/
- https://www.nrdc.org
- http://npic.orst.edu/factsheets/ecotox.html
- https://cfpub.epa.gov/ecotox/
- https://www.ipcc.ch
- https://climate.nasa.gov
- http://www.coastalwiki.org
- http://www.fao.org/inland-fisheries/en/
- https://www.jcomm.info
- https://www.niwa.co.nz/education-and-training/schools/students/estuaries
- https://www.nationalgeographic.org/encyclopedia/estuary/
- https://www.nationalgeographic.org/encyclopedia/wetland/

- https://www.worldwildlife.org
- https://www.usgs.gov/science/science-explorer?term=816

Suggested Broad Areas for Master's and Doctoral Research

- Prospecting algae as source of biofuel
- Isolation and characterization of microbes
- Interactive effect of warming and eutrophication on microbial CH_4 and N_2O conversions
- Utilization of agricultural waste in aquaculture as nutrient input
- Interventions for productivity enhancement in aquatic ecosystems
- Utilization of wastewater for mass cultivation of algae
- Bioactive compounds from aquatic organisms
- Ecotoxicity studies of industrial pollutants
- Role of aquatic macrophytes in biological treatment of wastewater
- Genetic improvement of microbes for pollution management
- Soil – water – nutrient interaction
- Nutrients in fish productivity
- Pollutant cycling in aquatic environment
- Coastal pollution assessment
- Conservation of ecologically important species
- Impact of coastal zone regulations and policies on coastal zone
- Resource assessment through remote sensing and GIS
- Bioaccumulation of toxicant
- Effects of toxicant on aquatic biota
- Development of methods for efficient and rapid analysis
- Comparison of different analytical techniques
- Documentation of plankton in diverse aquatic habitats
- Diversity analysis and algal indices of pollution load
- Evaluation of plankton for fish food
- Marine pollution and fisheries production
- Seasonality of fish catch and meteorological factors
- Application of GPS and remote sensing in marine fisheries
- Microbial pollution indicators
- Biomonitoring of aquatic environment
- Microbial indicators of pollution
- Use of microbes for improving soil fertility
- Factors affecting benthic population
- Abundance and distribution of benthic communities
- Benthic organisms as pollution indicators and biomonitors
- Measurement of tidal currents in estuaries
- Dynamics of estuarine circulation
- Measurement of rates of production from changes in phytoplankton biomass
- Application of remote sensing in studies on chlorophyll and other pigments
- Principles and practices of EIA
- Preparation of environmental audit
- Removal of nitrogen and phosphorus from wastewater
- Effect of selected toxicants on aquatic life and detoxification mechanism
- Toxicity assessment of pesticides and oil on selected organisms
- Applications of GIS in aquatic resource identification
- Application of remote sensing and GIS in oceanographic studies
- Computation of dispersion coefficients
- Analysis of estuarine dispersion
- Design of marine waste disposal systems
- Dynamics and restoration of degraded wetlands
- Removal of threats to the health and integrity of the restored ecosystem
- Environmental modeling

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Genetics and Breeding

Preamble
(Fish Genetics and Breeding)

In India, there was tremendous growth in fish production post-independence era. In 1950–51, fish production in India was 0.752 million tonnes, which comprised 0.534 million tonnes and 0.218 million tonnes from marine and inland sectors, respectively. In 2018–19, the provisional fish production in India was 13.421 million tonnes, which comprised 3.712 million tonnes and 9.709 million tonnes from marine and inland sectors, respectively. India has achieved a 17-fold increase in fish production in just six decades (indiastat.com). Currently, the country aims for the Blue Revolution and is investing massively in the fisheries sector through PMMSSY Scheme. However, an essential part of increasing the future aquaculture production is to improve the biological productivity of farmed species of fish, shellfish (crustacean and mollusks), and seaweeds.

Animal genetics and breeding have played an essential role in increasing the production efficiency of animals in a cumulative way. Similarly, the applications of the principles of animal genetics and breeding in aquaculture species, viz., salmon, tilapia, rohu, vannamei, and other species have helped improve the overall performance of these species. An increase in the global demand for food of animal origin is expected. Aquaculture production, however, faces many challenges, including the impact of climate change on fish and agricultural production systems and the impact of aquaculture on the environment and climate. There are further challenges concerned with the increasing scarcity of natural resources and feed, or concerns about animal welfare, anti-microbial resistance, and genetic diversity. The role of genetics is immense in this regard. Genetic technologies can be utilized in aquaculture for a variety of reasons. The primary use is to improve production, develop disease resistance, alter body shape, color, and conserve natural resources.

Investments in well planned and managed breeding programs are unique because genetic gains obtained in such programs are eternal and cumulative. They are never 'used up' and never 'wear out.' Genetic improvement programs can be used to provide short-term or long-term gains. Linking the use of genetic technologies in fishing and aquaculture will increase the efficiency and efficacy of the technologies. However, it should be noted that many of these technologies require specialized equipment and highly skilled staff. In this background, it is essential to develop well trained human resources to apply principles of genetics and breeding in boosting aquaculture production. The postgraduate and doctoral courses offered in Fish Genetics and Breeding are meticulously designed and meet the international standards. The students passing these courses will be well trained human resources for hatcheries, national and international breeding companies, data analysts, scientists, breeders, and entrepreneurs. They shall play a significant role and bring a paradigm shift in aquaculture production based on genetically improved stocks.

The salient features of revised syllabi indicating major changes made including new courses/topics/aspects added

Revising the syllabus is an exercise towards developing a human resource to meet society's demand for the 21st century. Determining what these needs are, how to address them, and how to revise the established curriculum is a challenging job. In the present exercise, the syllabus of the Masters' and Doctoral program of Fish Genetics and Breeding program was revised to meet the challenges of the sector and bring it to an international standard. To change and develop a new syllabus, the approved syllabus of the ICAR-Central Institute of Fisheries Education, Mumbai was taken as the base. Further, this syllabus was compared with the courses offered at Six European universities and with the ICAR approved Animal Genetics and Breeding syllabus. Discussion with the FGB Master's and Doctoral scholars was held, and also the feedback was obtained from the former Students. The revised syllabus was sent to Faculty, Scientist, s and present and past students, Fish, Plant, and Animal Geneticists in India and abroad. We received the suggestions/comments from 13 eminent geneticists.

Based on the suggestions and comments, the following exercise was carried.

- One New Course Microbial Genetics FGB511 (1+1) was added to MFSc Syllabus. Microbial genetics is the fundamental requirement in the biotechnology and fermentation industry. Moreover, this course is an independent course, and students from various disciplines like biotechnology, aquatic animal health, post-harvest technology, fish physiology, and biochemistry course can opt for this.
- The nanotechnology course was dropped as it was found not directly related to the Fish Genetics and Breeding program but was more appropriate to be taught to the Biotechnology students.
- In the recent past, the Cytogenetic has moved from the traditional banding and karyotyping to the molecular aspects. Hence, there is a need to add new developments in molecular elements into the existing syllabus of the cytogenetic course. It was also essential to avoid duplicity in the earlier courses of cytogenetic ad molecular genetic. Hence, by merging the relevant syllabus from both these courses, a new course, Molecular and Cytogenetic, with 2+1 credit was formed. The course also includes recent developments in both cyto and molecular genetics. This further helps the students more opportunity to choose the courses and also reduce the burden of the exams.
- The shellfish and ornamental fish culture are gaining more popularity and are contributing to aquaculture production. The selective breeding of these species is in progress in many countries. However, it is not so in India. To meet the demand of the industry, and develop new strains, attention to developing the breeding programs of these species is essential. They need to be studied separately as their breeding, and the inheritance of economic traits is different. To meet the above-mentioned requirements, the course Fish breeding Plan was modified, and from 1+1 credit, it was made into 2+1 course by incorporating the breeding plans for shellfish and ornamental fish.
- Major changes were made to course, FGB 505, FGB 507, and FGB 509. Conservation of aquatic biodiversity is essential. Similarly, the preservation of genetic variation in the hatchery population is equally important. The changes made to the syllabus of Conservation Of Fish Genetic Resources FGB 505 will help students gain in-depth knowledge about genetic resource conservation. The advent of genotyping of the individuals has opened up new tools for genetic selection. The use of molecular markers in genetic selection is the latest trend, and to impart this knowledge, the course on Molecular breeding was revised by adding topics related to QTL and MAS, molecular pedigree assigning GWAS.
- A new course, Fish Genome and Genomic Selection (2+1), was added to the Ph.D.

syllabus. This course is in tune with the developments in whole genome sequencing and incorporating the related technologies into genetic selection programs.

- Based on the feedback from the students and others and a detailed comparative study, it was observed that the syllabus of Genetics in commercial aquaculture, Advances in Cytogenetic, and Transgenic production and GMOs is not much different from the similar courses offered in the Masters' program. Further, their use in the field is minimal hence, these courses were dropped. However, the care was taken to add the relevant topics from these courses to the syllabus of other proposed courses.
- Courses merged: The courses 'Linear models (1+1) and Experimental designs in fish genetics (1+1)' were merged in to 'Linear models and experimental designs in fish genetics' (1+2).
- Significant changes were made to courses, FGB 601 and FGB 602, by adding the new developments in fish genetic selection and breeding, emphasizing case studies, and solving the industry problems.
- The advisory committee should decide the minor courses and optional courses considering the students' research topics.

Course Title with Credit Load
M.F.Sc. in Fish Genetics and Breeding

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FGB 501*	Principles of Genetics and Breeding*	2+1
FGB 502*	Population and Quantitative Genetics*	2+2
FGB 503*	Principles of Selection and Selection Methods*	2+1
FGB 504*	Fish Breeding Plans*	2+1
FGB 505	Conservation of Fish Genetic Resources	2+1
FGB 506	Bioinformatics and Computer Applications in Fish Genetics	0+2
FGB 507	Molecular and Cytogenetics@	2+1
FGB 508	Cell and Tissue Culture#@	1+1
FGB 509	Molecular Breeding	1+1
FGB 510	Microbial Genetics#@	2+0
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
FBT 501	Fundamentals of Molecular Biology	2+1
AQC 504	Aquaculture Policy and Planning	1+1
AQC 512	Commercial Ornamental Fish Breeding and Culture	1+1
FBT 509	Molecular Markers	2+1
FGB 510	Microbial Genetics#@	2+0
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
FBT 501	Fundamentals of Molecular Biology	2+1
AQC 504	Aquaculture Policy and Planning	1+1
AQC 512	Commercial Ornamental Fish Breeding and Culture	1+1
FBT 509	Molecular Markers	2+1
	Supporting Courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	

Course Code	Course Title	Credit Hours
	Common Courses	**5 credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	**1 Credit**
FGB 591	Master's Seminar	0+1
	Masters' Thesis Research	**30 Credits**
FGB 599	Master's Research (Semester III)	0+15
FGB 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

*Major compulsory courses

Course Contents
M.F.Sc. in Fish Genetics and Breeding

I. Course Title : Principles of Genetics and Breeding
II. Course Code : FGB 501
III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic principles of genetics and breeding and their application to fisheries management and aquaculture

V. Theory

Unit I

Historical development of genetics and breeding; Aim and scope of genetics and breeding; Domestication; Society and Genetics-Ethical issues; Basic statistical parameters-Probability concepts; Mean, Variance, Coefficient of variation, Correlation, Regression and Analysis of Variance.

Unit II

Cell structure, cell division and physical basis of heredity; Mendel's Principles: Scope, Limitation; Modifications to Mendel's ratios: Multiple alleles, Epistasis; Chromosomal theory of inheritance; Genetic variation: Causes and measurement; Linkage and crossing over, Recombination, Interference, Linkage disequilibrium.

Unit III

Modern concept of gene; DNA as genetic material, Replication of DNA; Genetic code and protein synthesis, Transfer and regulation of genetic information; Introduction to bioinformatics in fish genetics and breeding; Fish Genome: Zebrafish genome, Fish as genetic model.

Unit IV

Cytogenetics; Cytogenetics and evolution; Karyotyping and chromosome banding; Genetic basis of sex determination; Sex-linked, Sex-limited, and Sex-influenced traits, Y-linked inheritance; Chromosome manipulation: Ploidy induction, Sex reversal, Gynogenesis and Androgenesis; Chromosomal aberrations; Mutations-Natural and Induced, Mutagens.

Unit V

Basic concepts of Population Genetics: Individual vs population; Gene and Genotype frequency; Hardy-Weinberg Principles and factors affecting them; Mutation; Fate of mutant allele in the population; Genetic drift; Concept of inbreeding and its management; Application of population genetics in fish resource conservation, preservation of gametes.

Unit VI

Basic Concepts of Quantitative Genetics; Polygenic inheritance; Basis of genetic selection; Qualitative vs Quantitative traits; Pleiotropy; Penetrance; Natural Vs

Artificial Selection, Aim of genetic selection and breeding, Present status of selective breeding in aquaculture; Economic traits of fishPedigree and its importance in fish breeding; Methods and aid to genetic selectionApplication of selection for performance improvement Cross breeding and Hybridization.

VI. Practical

- Probability in genetics
- Exercises on Mendel's principles, Multiple alleles, Epistasis, Linkage and crossing over
- Exercises on Hardy-Weinberg principles Estimation of gene and genotype frequencies
- Karyotyping; Nucleic Acid isolation
- Quantification of Inbreeding; Estimation of kinship coefficient
- Record keeping in fish breeding
- Estimation of genetic parameters

VII. Suggested Reading

- Gjedrem Trygve *et al*. 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Kirpichnikov VS. 1981. *Genetic Basis of Fish Selection*. Springer-Verlag
- KorOldenbroek en Liesbeth van der Waaij. 2014. *Textbook Animal Breeding and Genetics*. Wageningen University and Research Centre, the Netherlands
- Lakra WS, Abidi SAH, Mukherjee SC and Ayyappan S. 2004. *Fisheries Biotechnology*. Narendra Publ. House.
- Lutz CG. 2003. *Practical Genetics for Aquaculture*. Wiley-Blackwell.
- Lynch M and Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland.
- Purdom CE. 1993. *Genetics and Fish Breeding*. Chapman and Hall.
- Snustad DP and Simmons MJ. 1999. *Principles of Genetics*. 2nd Ed. JohnWiley and Sons.
- Stansfield WD. 1991. *Theory and Problems of Genetics*. McGraw-Hill.
- Tave D. 1993. *Genetics for Fish Hatchery Managers*. 2nd Ed. Chapman and Hall.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20 and%20Genetics-v17-20151122_1057.pdf

I. Course Title : Population and Quantitative Genetics

II. Course Code : FGB 502

III. Credit Hours : 2+2

IV. Aim of the course

Understanding the concepts of genetic structure of the population and inheritance of quantitative traits

V. Theory

Unit I

Historical developments; Review of basic concepts of genetics and statistics; Scope and applications Biometrical techniques: Introduction to matrix algebra, Determinants, ANOVA, Regression and Correlations Basic concepts of General Linear Mixed Models (GLMM)

Unit II

Definition of population, Individual vs. population, quantitative vs. qualitative characters Genetic structure of random mating populations. Polygenic inheritance: Limitation of single gene model; Polygenes and major genes; Polygenic model-importance and limitations; Polygenic segregation and linkage

Unit III

Hardy -Weinberg principles; Test, application and properties of equilibrium populations –Systematic and dispersive forces changing gene and genotype frequencies, Concept of Mutation, Balance between mutation and selection Genetic bottleneck; Genetic drift, Drift equilibrium, Effect on population structure –Intensity of selection, Fisher's theorem of natural selection; Wahlund effect

Unit IV

Coefficient of genetic differentiation – F_{ST}, R_{ST}, Q_{ST}, G_{ST} - their relative merits and demerits, Genetic similarity, distance and population divergence, Null alleles – Path coefficient; theory, analysis and applications –Basis of relationships; Independent and correlated causes –Idealized population and its properties, Effective population size. Concept of inbreeding- Calculating coefficient of kinship, Relationship, Inbreeding and Population size; Types and Methods of estimation and consequences-Change of mean and variance –Mechanisms of evolution and speciation; Delineation of species and/or stocks.

Unit V

Quantitative variation: Gene effects; Mode of inheritance and continuous variation; Population mean; Components of phenotypic value, Genotypic value, Average effect of gene and Gene substitution Estimation, tools for population genetic parameters – Variance component estimation with complex pedigree –Genetic parameters; heritability- Concept of heritability, Effective heritability, Different methods of estimation, Variance of heritability, Properties and applications of heritability; Repeatability, Maternal effects; Correlation between traits- Composition of genetic and Phenotypic covariance genetic, Phenotypic and Environment correlations and their standard errors, Concept of co-heritability

Unit VI

Breeding value: Biometrical relationship among relatives; Estimating fixed factors and Predicting random effects-BLUE and BLUP; Models for EBV –Selection: Aids and methods; genetic gain and correlated response; Recurrent and reciprocal recurrent selection Heterosis; Theories and estimation, Combining ability-GCA, SCA; Utilization of non-additive genetic variance –Genomics and Phenomics

VI. Practical

- Exercise on various statistical procedures and matrix algebra- Components of Variance, Covariance, Correlation and Regression, ANOVA in genetic parameter estimation
- Estimation of gene and genotype frequencies and factors affecting them, Equilibrium in sex linked genes
- Genetic stock structure analysis with dominant and co-dominant markers- Type I and Type II markers; Pedigree construction through Molecular marker information
- Path coefficient
- Estimation of effective population size, Rate of inbreeding, in breeding co-efficient,
- Estimation of Heritability and Repeatability and their accuracies;
- Building of pedigree files and construction of relationship matrix and its inverse;
- Estimation of breeding values-EBV, BLUE and BLUP
- Genetic gain

VII. Suggested Reading

- Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag.
- Falconer DS and Markay TFC. 1996. *An Introduction to QuantitativeGenetics*. 4th Ed. Addison Wesley Longman.
- Hartl D. 1988. *A Primer in Population Genetics*. Sunderland
- Hartl D and Clarke AG. 2007. *Principles of Population Genetics*. 4th Ed. Sunderland
- Li CC. 1955. *Population Genetics*. University of Chicago Press.
- Lynch M and Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland.
- Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press.
- Turner HN and Young SSY. 1969. *Quantitative Genetics in Sheep Breeding*. Cornell University Press.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding %20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

I. Course Title : Principles of Selection and Selection Methods

II. Course Code : FGB 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn the application of genetic tools for genetic improvement of aquatic species

V. Theory

Unit I

Genetic Selection and Breeding: Scope, Application, Role of genetics in fish selection and breeding National and International scenario of selective breeding programmes in aquaculture.

Unit II

Selection: Basis of selectionIntroduction to variance components –Estimation of selection differential, intensity of selection, response to selection –Identification of animals with high genetic merit –Estimation of breeding values- variance and accuracy of predicted breeding value; Various sources of information- Individual, information from relatives; Least squares and BLUP methods; Accuracy of selection

Unit III

Combined selection: Combined selection –Selection index-selection Objective and criterion, selection criterion coefficients –Methods of selection –Realized heritability, Repeatability, Genetic, Phenotypic and Environmental correlations.

Unit IV

Factors affecting rate of genetic improvement –Short term response to selection-Variance in response-Bidirectional selection, Selection limits Renewed selection gain –Threshold characters- Heritability of threshold traits, genetic correlation among threshold traits, selection for threshold traits –Scale effects

Unit V

Formulation of breeding plans: Stock improvement plans for different population sizes and environments, Control population and experimental design –Development of new strains/synthetic population; Crossbreeding and hybridization. Domestication and inadvertent selection –Selection and mating designs for select traits: Mating systems and genetic consequences; Small stock and inbreeding effects, Inbreeding Depression; causes and methods to overcome; Out breeding; Crossbreeding, Utilization of heterotic effects, Selection and mating designs for growth, Disease resistance, color enhancement, Genotype×Environment interaction and its role in fish/shellfish breeding.

Unit VI

Major genes and QTLs- Major and minor genes, Tests for detecting major genes, Application of markers in selection programmes, Status and their relevance; QTL and its application in selection, Marker Assisted Selection in Fisheries; Genomic selection.

VI. Practical

- Estimation of genetic parameters: heritability, repeatability and genetic correlation; Estimation of phenotypic and environmental correlations Estimation of Breeding Values from various sources of information and their accuracies
- Construction of selection indices
- Designing and conducting challenge test for disease resistance
- Selection: basis of selection, genetic gain
- Response to selection and factors affecting response
- Aids to selection; Methods of selection
- QTL and MAS

VII. Suggested Reading

- Cameron ND. 1997. *Selection Indices and Prediction of Genetic Merit in Animal Breeding*. CABI.
- Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag.
- Falconer DS and Mackay TFC. 1996. *An Introduction to Quantitative Genetics*. 4th Ed. Addison Wesley Longman.
- Gjedrem, Trygve *et al*., 2005. *Selection and Breeding Programs in Aquaculture* Springer
- KorOldenbroek en Liesbeth van der Waaij. 2014. *Textbook Animal Breeding and Genetics*. Wageningen University and Research Centre, the Netherlands
- Lynch M and Walsh B. 1997 *Genetics and Analysis of Quantitative Traits*. Sinauer, underland.
- Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press.
- Turner HN and Young SSY. 1969. *Quantitative Genetics in Sheep Breeding*. Cornell university Press.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Fish Breeding Plans

II. Course Code : FGB 504

III. Credit Hours : 2+1

IV. Aim of the course

To learn the applications of genetic techniques for stock improvement

V. Theory

Unit I

Historical development of fish breeding and domestication, Current status of aquaculture in world and India Maintaining pedigree, Physical and molecular tagging and maintaining breeding records

Unit II

Economic traits in cultured species-Performance- Growth, Disease resistance, productive and reproductive traits, Recapture frequency, Behavior, Quality traits and their inheritance, Recording economic traits, Study of growth curves and their components, Influence of non-genetic factors on economic traits

Unit III

Formation of base population, Designing mating plans, Effect of breeding programme on genetic diversity of farmed animals, Present status of breeding, Cross breeding in aquaculture; Broodstock management –Inbreeding depression and heterosisin various economic characters –Role of Breeders' associations in national breeding programmes Fish breeding guidelines, Policies, Programs and economic analyses of breeding programmes, Their present status in India and World, Prospectus and challenges.

Unit IV

Reproductive cycle, Factors affecting sexual maturation, Adapatability and reproduction, Age at maturity, Gonadal development stages in fin/shellfish and levels of hormonal intervention; Sex determination, Cryopreservation of gametes, Live feed development for larvae, Larval feeding and maintenance, Packaging and transport of fish; Nursery systems and their operation; Biosecurity.

Unit V

Application of recent technologies in stock improvement –Biosafety issues involved with genetically modified organisms, Release and registration of new varieties, Quality seed; Classes, production practices and maintenance of pure seed, Seed purity standards; Seed quality and fish seed certification.

Unit VI

Shellfish breeding: Reproductive cycle of the shellfish; controlled mating of the shellfish; Economic traits and their recording. Ornamental fish breeding: Introduction to ornamentation and their inheritance Selection and mating systems, Inbred strains, transgenic strains, Production of gene knock-out fish, Genetic control and monitoring, Record keeping and ethics.

VI. Practical

- Tagging methods
- Construction of growth curves

- Record keeping of stock; Standardization of the performance records for genetic parameters estimations
- Breeding plan and design of breeding programme from successful case studies
- Morphometric analysis- Truss analysis
- Practical on synchronization of spawning, Closed lifecycle and controlled mating- Hormone induced ovulation; Collection of fish gametes, Assessing gamete quality
- Cryopreservation

VII. Suggested Reading

- Chattopadhyay NR. 2016. *Induced fish breeding: A practical guide for hatcheries*. Academic Press.
- Gjedrem, Trygve *et al*. 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Hoar WS and Randall DJ.1988. *Fish Physiology*. Academic Press.
- Kinghorn BP. 1981. *Quantitative Genetics in Fish Breeding*. University of Edinburgh.
- Lee CS and Donaldson EM. eds. 2012. *Reproductive biotechnology in finfish aquaculture*. Elsevier.
- Purdom CE. 1993. *Genetics and Fish Breeding*. Chapman and Hall.
- Rath RK. 2018. *Freshwater aquaculture*. Scientific Publishers.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- Weatherely AH and Gill HS. 1988. *The Biology of Fish Growth*. Blackwell Synergy.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture,*
- *Aquaculture Reports,*
- *Aquaculture Research,*
- *Genetics,*
- *Indian Journal of Fisheries,*
- *Journal of Fish Biology,*
- *The Journal of heredity*

I. Course Title : Conservation of Fish Genetic Resources

II. Course Code : FGB 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on application of genetic principles in conservation and management of aquatic resources.

V. Theory

Unit I

Fish genetic resources; Sample survey and distribution, Threatened aquatic species of India and world, Assessing threats to species and populations, Conflicts between nature conservation and other goals of the society.

Unit II

Evolutionary Genetics- Genetic diversity, Importance, Influencing factors, Characterizing Genetic diversity, Evolution in large and small population, Maintenance of genetic diversity, Conservation and preservation of aquatic species;

Effect of population size, Loss of genetic diversity in small population, Inbreeding, Population fragmentation, Issues and strategies, Risk status/population viability analysis and classification, Breeding strategies of threatened species for restocking and live gene bank.

Unit III

Importance of mutation, Migration and their interaction with selection in conservation Application of molecular genetic tools for management of small population for conservation.

Unit IV

Gene bank: Concepts, Objectives, Resources, Uses Institutes and Societies associated with conservation, Impact of inbreeding on genetic diversity and conservation; Evolutionary potential and heritability; Genetics and management of wild and captive populations, Introduction, domestication and acclimatization, Genetic management for reintroduction; *In situ* and *ex-situ* conservation; Gene pool concept - Primary, Secondary and Tertiary gene pool, and Gene introgression, Cryopreservation of sperm, Eggs and embryos.

Unit V

Effective population size and population structure; Factors threatening indigenous species; IPR issues of genetic resources; Regulations regarding introduction of exotic germplasm; Export import rules and regulations on conservation of aquatic genetic resources; Fish quarantine – status, procedures, scope and significance – Convention on Biodiversity and National Biodiversity Authority of India

Unit VI

Taxonomy and related issues, DNA barcoding, Characterization and identification of stock; Identification of farm escapees, Interaction between farmed and wild population Application of nanobiosensor for tracking of fish –Genomics in Conservation: Effect of climatic change on biodiversity.

VI. Practical

- Tagging methods for population
- Estimation of gene and genotypic frequencies
- Estimation of genetic diversity and relatedness using morphometric and molecular information
- Application of molecular genetic markers for estimation of effective population size, rate of inbreeding and genetic bottleneck Analysis of genetic variance in population
- Morphometric analysis of stocks Visit to Gene Bank/National/Regional Research Centres
- Studies on Domestic and international quarantine process; its weaknesses and measures for its strengthening
- Case studies on rescue and release of animals

VII. Suggested Reading

- Allendorf FW. 2007. *Conservation and the Genetics of Populations*. Blackwell. \
- Bruce Walsh and Michael Lynch, 2018. *Evolution and Selection of Quantitative Traits*. Oxford University Press in the UK
- Cloud JG and Thorgaard GH. 1993. *Genetic Conservation of Salmonid Fishes*. NATO ASI Series, Life Sciences, Springer.

- Frankham R, Ballou JD and Briscoe DA. 2004. *A Primer of Conservation Genetics*. Cambridge University Press.
- Frankham R. 1995. *Introduction to Conservation Genetics*. Annual Reviews of Genetics.
- Hartl D. 1988. *A Primer in Population Genetics*. Sunderland.
- Roff, Derek A. 2012. *Evolutionary quantitative genetics*. Springer Science and Business Media.
- http://agtr.ilri.cgiar.org/overview
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf

Suggested Journals

- *Aquaculture,*
- *Aquaculture Reports,*
- *Aquaculture Research,*
- *Genetics,*
- *Indian Journal of Fisheries,*
- *Journal of Fish Biology,*
- *The Journal of heredity*

I. Course Title : Bioinformatics and Computer Applications in Fish Genetics

II. Course Code : FGB 506

III. Credit Hours : 0+2

IV. Aim of the course

To learn the application of information technology and software packages for the Fish Genetics and Breeding studies

V. Practical

Unit I

File Transfer Protocols; Work stations Application of spreadsheets in maintaining fish breeding records and breeding data management –Fish breeding data bases – Data input, Import, export, Modification; Data cleaning, manipulation and transformations; Data normalization, Graphical analysis and representation of breeding data.

Unit II

Introduction to basic matrix algebra, Definition, Addition, Multiplication, Determinants, Inverse of matrix.

Unit III

Usage of various computer packages for genetic analyses: SAS, R, AsReml and others, Analysis of variance, Variance component estimations, Estimation of genetic parameters; Inbreeding estimation.

Unit IV

Software for molecular genetics data analysis (SAS Genetics, SAS Genomics, R), Estimation of population parameters, Estimation of 'F' Statistics.

Unit V

Introduction to Bioinformatics and various operating systems employed, Exposure to various open source online bioinformatics tools and applications, Use of Perl and R-Bio conductor packages, Introduction to Bioinformatics databases, Information retrieval from various sequence and structure databases and mock sequence submission, Database searching, Sequence formats and alignments; BLAST, Conversion and handling of various sequence formats, Usage of online sequence alignment tools.

Unit VI

Sequence analysis; Annotation, Sequence conversion and translation, Sequence comparison, Phylogenetic analysis, Protein structure analysis and its analysis; analysis of amino acids sequence, NGS data formats and data cleaning, Use of bioinformatics tools for identifying QTL and selection of elite germplasm.

VI. Suggested Reading

- Attwood TK and Smith DJP. 1999. *Introduction to Bioinformatics*. Addison Wesley Longman.
- Brown SM. 2000. *Bioinformatics: A Biologist's Guide to Biocomputing and the Internet*. Eaton Publ.
- Cody RP and Smith JF. 1997. *Applied Statistics and SAS Programming Language*. Elsevier.
- Lesk AM. 2008. *Introduction to Bioinformatics*. Oxford University Press.
- Isik, Fikret, James Holland, and Christian Maltecca. 2017. *Genetic data analysis for plant and animal breeding*. New York: Springer.
- Littell RC, Milliken GA, Stroup WW and Wolfinger RD. 1996. *SAS System for Mixed Models*. SAS Institute.
- Mount DW. 2001. *Bioinformatics: Sequence and Genome Analysis*. ColdSpring Harbor Press.
- Rashidi HH and Buehler LK. 2005. *Bioinformatics Basics: Applications in Biological Sciences and Medicine*. CRC Press.
- Saxton AM. 2004. *Genetic Analysis of Complex Traits Using SAS*. SAS Publ.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of Heredity*

I. Course Title : Molecular And Cytogenetics

II. Course Code : FGB 507

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on different tools of molecular and cytogenetic

V. Theory

Unit I

Introduction, Historical background, Importance, Chromosome theory of inheritance; Chromosomal models and their ultra-structure, Chromosomal movements and position effect –Cytogenetic and evolution.

Unit II

DNA and RNA as genetic material; Chemistry and structure of DNA, Fine structure of gene, Split genes, Pseudogenes, Overlapping genes and Multigene families, Mechanisms of DNA replication, Extra Chromosomal Inheritance / Cytoplasmic Inheritance; Mitochondrial DNA.

Unit III

Biochemical markers: Allozyme polymorphism and its application in estimating population genetic parameters, Genetic basis of immunity.

Unit IV

Molecular markers; RAPD, RFLP, AFLP, EST, SNP, Minisatellites and Microsatellites and application in population genetic analysis and gene mapping, FISH–principle and application, Maternally and paternally inherited genetic markers, Molecular pedigree, Major genes, Poly genes and QTLS, Application of molecular markers in genetic selection, QTL and MAS, Association studies, Genomic selection.

Unit V

Genetics of Sex determination and differentiation; Genotypic sex determination (GSD); Environmental Sex determination (ESD); Sex manipulation, Production of monosex population, Sex chromatin and Lyon's hypothesis; Chromosome numbers in fish and karyotyping, Chromosome banding techniques Molecular Cytogenetics; Fluroscence *In Situ* Hybridisation (FISH) –Application of nanotechnology in chromosome and genome mapping, Mitochondria and Y chromosome.

Unit VI

Genotoxicity and mutagenicity –Chromosomal aberrations; Single cell gel electrophoresis, MNT, SCE; Genetic and evolutionary implications.

VI. Practical

- Biochemical markers and Molecular markers
- DNA sequence polymorphism and related software for alignment and analysis
- Genomic DNA isolation from prokaryotes and eukaryotes
- Interpretation of gels and data analysis using various software
- Isolation of RNA and RT-PCR, Agarose gel electrophoresis of DNA and RNAPCR, primer designing, PCR-RFLP, extraction of DNA from agarose gels
- Preparation of chromosome spreads; Karyotyping; Banding techniques; MNT, SCE, Comet Assay.

VII. Suggested Reading

- Lakra WS, Abidi SAH, Mukherjee SC and Ayyappan S. 2004. *Fisheries Biotechnology*. Narendra Publ. House.
- Pasteur N, Pasteur G, Bonhomme F, Catalan J and Britton-Davidian J. 1988. *Practical Isozyme Genetics*. Ellis Horwood.
- Pisano E. 2007. *Fish Cytogenetics*. Science Publ.
- Reddy PVGK, Ayyappan S, Thampy DM and Krishna G. 2005. *FishGenetics and Biotechnology*. ICAR. 4. Caetano-Anolles G and Gresshoff PM. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH.
- Sambrook J and Russel WD. 1989. *Molecular Cloning: A Laboratory Manual*. Vols. I-III. Cold Spring Harbor Laboratory Press

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*

- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Cell and Tissue Culture

II. Course Code : FGB 508

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on cell and tissue culture techniques and their application in gene banking, genetic characterization and health management.

V. Theory

Unit I

Introduction: Structure and Organization of animal cell; Equipment and materials for animal cell culture technology, Cell lines and media; Primary and established cell line cultures; Media supplements, their metabolic functions; serum and protein free defined media and their application.

Unit II

Cell culture: Basic techniques of cell culture *in vitro*; Development of primary cultures, Cell separation, Maintenance of cell lines; Biology of cultured cells, Transformation and differentiation of cell cultures, Characterization of cell lines; Measurement of viability and cytotoxicity assays; Measuring parameters of growth; Karyotyping, Isozyme assays, Cryopreservation, Assessment of contaminants.

Unit III

Cell cloning: Micromanipulation, cell transformation, application of fish cell culture, 3D cell culture, Scaling-up of cell culture, Cell hybridization; Somatic cell fusion, hybridoma technology, Production and Application of monoclonal antibodies.

Unit IV

Stem cell culture and its application, Bio-products from cell culture, Cryopreservation of embryos and cells.

VI. Practical

- Principles of sterile techniques and cell propagation
- Preparation of different cell culture media
- Primary cell culture techniques; Establishing cell lines: isolation, characterization identification of cell lines
- Pure culture techniques; Maintenance and preservation of cell lines
- Propagation of cells in suspension cultures
- Hybridoma technology: strategy and techniques
- Production of monoclonal antibodies
- Cryopreservation of cell lines

VII. Suggested Reading

- Barnes D and Mathur PJ. 1998. *Methods in Cell Biology*. Vol. 57. *Animal Cell Culture Methods*. Academic Press.
- Basega R. (Ed.). 1989. *Cell Growth and Division: A Practical Approach*.IRL Press.

- Butler M and Dawson M. (Ed.). 1992. *Cell Culture*. Bios Scientific Publ. 4. Clynes M. 1998. *Animal Cell Culture Techniques*. Springer.
- Freshney I. 1994. *Culture of Animal Cells: A Manual of Basic Techniques*. 4th Ed. Wiley-Liss.
- Harrison AM, Rae FI and Harris A. 1997. *General Techniques of Cell Culture*. Cambridge University Press.
- Lan FR. 1994. *Culture of Animal Cells*. 3rd Ed. Wiley-Liss.
- Masters RW. 2000. *Animal Cell Culture-Practical Approach*. Oxford University Press

I. Course Title : Molecular Breeding

II. Course Code : FGB 509

III. Credit Hours : 1+1

IV. Aim of the course

To apply basic concepts of molecular genetics in fish breeding

V. Theory

Unit I

Introduction to Molecular Breeding; Molecular mechanism of genetic recombination, Molecular taxonomy and its application in Fisheries; Phylogenetics and its application –Genetics of Sex determination; Genotypic sex determination (GSD); Environmental Sex determination (ESD); Sex manipulation, production of monosex population.

Unit II

Single genes in fish breeding; Mapping and Identifying single genes; Types of DNA sequence responsible for alterations to create single gene effect –QTL and MAS identification; Marker assisted selection with markers in linkage disequilibrium with QTL –Molecular pedigree Assigning.

Unit III

Major genes, Poly genes and QTLS, Tests for detecting major genes, Complex segregation analysis, Genetic maps and candidate genes, Genome-wide association studies (GWAS) in pedigreed population, Methods and tools for GWAS.

Unit IV

Introduction to genomic selection; Methodologies for genomic selection; Estimation of Genomic breeding value, Factors affecting the accuracy of genomic selection, Genomic selection with low marker density; Genomic selection across populations and strains, Re-estimation of the chromosome segments, Designing breeding programs with genomic information.

VI. Practical

- LD Analysis
- Molecular pedigree construction
- Power of association studies; Building the IDB matrix from linkage disequilibrium information; marker assisted selection with linkage disequilibrium
- Genomic Relationships and GBLUP
- Realized Genomic Relationships; Calculation of G Matrices; Genomic BLUP; Genomic selection using BLUP; Genomic selection using a Bayesian approach; Bayesian Approach using a prior for chromosome segment variances with a large weight at zero (Bayesian)

VII. Suggested Reading

- Caetano-Anolles G. and Gresshoff, P.M. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH.
- Lehninger LA, Nelson DL and Cox MM. 2008. *Principles of Biochemistry*. 4th Ed. WH Freeman.
- Lewin B. 2004. *Genes VII*. International Ed. John Wiley and Sons.
- Pasteur N, Pasteur G, Bonhomne F, Catalan J and Britton–Davidian J. 1988. *Practical Isozyme Genetics*. Ellis Horwood.
- Sambrook J and Russel WD. 1989. *Molecular Cloning: A LaboratoryManual*. Vols. I-III. Cold Spring Harbor.
- Stryer L, Berg JM and Tymocz KJL. 2004. *Biochemistry*. 5th Ed. WH Freeman.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook% 20 Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture,*
- *Aquaculture Reports,*
- *Aquaculture Research,*
- *Genetics,*
- *Indian Journal of Fisheries,*
- *Journal of Fish Biology,*
- *The Journal of heredity*

I. Course Title : Microbial Genetics

II. Course Code : FGB 510

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of genetics applicable to microbes

V. Theory

Unit I

Basic of microbial existence: Why study the prokaryotic genetics History of Microbiology –Bacterial genetics, Conjugation, Sex factors; High frequency recombination; Transduction (generalized and specialized), Bacterial transformation; Mutation types, Repair mechanism, Selection of mutants, Genetics of Bacteriophage-Bacteriophage classification, Types, PhageT4-Structure, Gene expression and genome organization, Lamda phage replication, Lytic and lysogeneic cycles, Mechanisms of repressor synthesis and its control, Auto regulation, One step growth curve; Importance of bacteriophages, Coalescent of bacterial population, Population reproduction models, Time and effective population size, Demography – Recombination and gene conversion.

Unit II

Linkage, Selection and the clonal complex- Recombination, Linkage and substructure, Neutrality versus Selection, Clustering Techniques; Sequence based population structure analysis.

Unit III

Population Genetics-Natural Selection, Methods for detecting presence of natural selection, Measure of genetic diversity, The concept of Effective population size, Population sub division, Population Genomics, Population structure and genetic evolution, Similarities and differences, Bacterial Population genomics, MLVA and SNP for analysis in population genetic study, Phylogenetic resolution, Phylogeographic resolution.

Unit IV

Gene Maps, Tools and protocols World Wide Web Databases, Genetically modified organisms (GMOs) Technological advances Controls and cautions.

Unit V

Transposable Elements: IS elements, Tn3 family and medical significance, The Genetic and evolutionary significance of transposable elements; Use in genetic analysis and evolutionary issues.

Unit VI

Microbial strain improvement techniques; Identification of ideal microorganisms for bioprocess, Microbial strain improvement, Genetic engineering and evolutionary engineering, Bioprocess optimization and applications in industry, Agriculture and health.

VI. Suggested Reading

- Maloy SR, Cronan JE and Freifelder D. 2009. "*Microbial Genetics*", Narosa Book Distributors, 2nd edition.
- Pelczar MJ, Chan ECS and Kreig NR. 2001. "*Microbiology*", McGraw Hill Publishers, 5th edition.

Course Title with Credit Load
Ph.D. in Fish Genetics and Breeding

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FGB 601	Design of Breeding Programs	2+1
FGB 602	Genetic Selection of Complex Traits	2+1
FGB 603	Fish Genome and Genomic Selection	2+1
FGB 604	Linear Models and Experimental Designs in Fish Genetics	1+2
	Minor Courses	**6 Credits**
	(From the subjects closely related to a student's major subject)	
	Supporting courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
FGB 691	Doctoral Seminar	0+1
FGB 691	Doctoral Seminar	0+1
	Doctoral Research	**75 Credits**
FGB 699	Doctoral Research (Semester II)	0+15
FGB 699	Doctoral Research (Semester III)	0+15
FGB 699	Doctoral Research (Semester IV)	0+15
FGB 699	Doctoral Research (Semester V)	0+15
FGB 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fish Genetics and Breeding

I. Course Title : Design of Breeding Programs

II. Course Code : FGB 601

III. Credit Hours : 2+1

IV. Aim of the course

To learn the recent advances and development of breeding plans

V. Theory

Unit I

Genetics in Broodstock management of commercially important fish and shellfish, Assembling base population, Choosing selection objectives and criterion, Pedigree identification, Physical and molecular tagging; Maintaining breeding records.

Unit II

Genetic parameters, Heritability, Repeatability, Genetic, Phenotypic and Environmental correlations Factors influencing genetic progress, Comparison of Selection Systems, Criteria and procedure for comparison, Long term program, Short term program, Single population program; Open Nucleus Breeding System (ONBS), Case study of national and international genetic improvement programs viz., Jayanti Rohu, *Clarias magur*, GIFT Tilapia, Norwegian Salmon, Pacific White Shrimp *L.vannamei* and others.

Unit III

Important reproductive tools for implementation of breeding plan; Captive maturation, Synchronization of spawning Cryopreservation of gametes Application of Hybridization, Ploidy manipulation, Monosex culture, Genetic engineering, Transgenesis for commercial purpose.

Unit IV

Designing mating plans Inbreeding, Types of inbreeding, Genetic and Phenotypic effect of Inbreeding; Consequences of inbreeding and management of genetic variation in fish breeding program Genetic selection and its impact on natural stock Outbreeding, Forms of outbreeding, Effects of Outbreeding, Breeding plans to exploit additive and non-additive genetic variation, Maternal influence and its estimation, Genetic mechanisms in adaptation, measurement and adaptability indices, G x E interaction.

Unit V

Breeding plans for shellfish improvement, Controlled mating in shellfish Developing new ornamental strains of fishes: Inheritance of ornamentation traits; Sex linked inheritance of ornamentation; Recording ornamentation traits; Molecular genetics of body pigmentation.

Unit VI

Genetics of developing SPR strain; Immune system in fish and shell fish and genetics of immune system Genetics of disease susceptibility; application of genetic tools to predict disease susceptibility; Developing plans for genetic selection of threshold traits Fish genetics and welfare; A continued need for genetic selection scientific, regulatory and public acceptance issues Ethical, moral and fish welfare issues Ownership of genetically improved strain through public sector funding.

VI. Practical

- Developing Growth curves and their components
- Estimation of Genetic Parameters; Selection and genetic gains
- Path coefficient and calculation of inbreeding coefficient and relationship
- Designing breeding programs for threshold traits, Estimation of heritability of threshold traits
- Preservation of gametes; Synchronization of spawning
- Developing the protocols for evaluating the various genetic improvement programs and their impacts
- Survey on impact of the program on farmers and consumers
- Impact of climate change on fish germplasm
- The focus will be on critical review of contemporary applied breeding programs and journal articles - students are also expected to prepare a term paper for submission at the end of the semester

VII. Suggested Reading

- Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag.
- Falconer DS and Markay TFC. 1996. *An Introduction to Quantitative Genetics*. 4th Ed. Addison Wesley Longman.
- Gjedrem, Trygve et al., 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Genetic Selection Of Complex Traits

II. Course Code : FGB 602

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the efficiency of different selection methods

V. Theory

Unit I

Introduction: Past and present status of fish breeding, Complex traits and their inheritance, Recording complex traits.

Unit II

Strain comparison, Factors affecting the rate of genetic improvement, Performance testing; Estimation of genetic gain under different selection program.

Unit III

Influence of non-genetic factors on growth, Factors influencing production and reproductive traits, Correction and standardization of animal breeding data, Simultaneous prediction of breeding values for several traits, Recurrent and Reciprocal Recurrent Selection –Crossbreeding and hybridization.

Unit IV

QTL and MAS; Breeding values for binary traits, Threshold characters and their selection procedure, Selection and breeding for disease resistance and survival analysis –Diallel analysis; Selection for single trait and multiple traits.

Unit V

Organizing breeding programs, Structure of breeding programs, Breeding for optimum production, Economic value of each animal, Cost of broodstock production, Organizing field trial –Farmers cooperatives, breeding companies, National or local breeding programs

Unit VI

Dissemination procedures and issues, Breeding nucleus, Multiplier centers –Socio-economic impact, Technological adoption, Increased production –Economic Evaluation of Genetic Breeding Programs, Criteria for Economic Evaluation; Profit Horizon, Interest Rate, and Return on Investment, Environmental impact of improved varieties/strains.

VI. Practical

- Application of various computer software for genetic analyses: SAS, R, AsReml etc.
- Application of Mixed models for estimation of genetic parameters-Heritability, Correlations;
- Construction of selection index
- Diallele crossing
- Developing and evaluating the dissemination programs of genetically improved strain
- Estimation of breeding values EBV, BLUE, BLUP
- QTL parameter estimation; Analysis of QTL as random effect

VII. Suggested Reading

- Cameron ND. 1997. *Selection Indices and Prediction of Genetic Merit in Animal Breeding*. CABI.
- Falconer DS and Markay TFC. 1996. *An Introduction to Quantitative Genetics*. 4th Ed. Addison Wesley Longman.
- Gjedrem, Trygve *et al*. 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Isik, Fikret, James Holland, and Christian Maltecca. 2017. *Genetic Data Analysis for Plant*

and Animal Breeding. New York: Springer.
- Joel Ira Weller. 2016. *Genomic Selection in Animals*. John Wiley and Sons, Inc., New Jersey. • Morde
- Lynch M and Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Fish Genome and Genomic Selection

II. Course Code : FGB 603

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on understanding genomes, application of genomic tools and strategies for enhancing production performances and conservation of fish genetic resources

V. Theory

Unit I

Organisation of genomes: Genome, Genomics, Transcriptomics, and Proteomics, Genome size estimation, Genome size in model organisms, C-value paradox, Genome diversity, Taxonomy and significance of genomes, Classification of genomics, Vertebrate genome evolution –Establishing phylogeny on the basis of genomics, Comparative genomics, Population genomics, Limitation and application of genomics, Structural genomics; Linkage maps and QTL, Haplotype structure of genome; Genetic, physical and transcription maps, Fluorescent *in situ* hybridisation, Radiation hybrid mapping, Sequence tagged site mapping, Restriction mapping.

Unit II

Functional genomics: NGS data analysis, Sequence assembly, Gene identification, Gene prediction rules, Gene annotation and pathway analysis genome databases and browsers, Gene ontology assignment, Mining of transcriptome data for protein coding genes, Differentially expressed genes, Short and long non coding RNA and their target genes –Next generation sequencing; Second and third generation sequencing platforms, NGS platforms such as Illumina, Roche 454, SOLiD, Ion torrent, PacBio, Oxford, Nanopore Technologies, Principles, Applications and Limitations.

Unit III

Genome projects: The human genome project, HapMap project, The 100 genome project, Encode project, Ethical, legal and social issues of human genome project, Fish genome projects: Fugu, Tetraodon, Elephant shark, Atlantic salmon, Zebra fish, Common carp, Rainbow trout, Channel catfish, Fishes in Genome 10 K project, Status of fish genomics research in India, IPR issues; Patent at one place and not in another, Access to fish genetic resources.

Unit IV

Genomic tools: Genome wide association studies, Custom microarray technologies, DNA microarray, SNP array, Subtractive hybridization, Comparative genomic hybridization.

Unit V

Application of markers in fish breeding, Genomic resources: ESTs, RFLPs, Microsatellite markers, SNPs, BAC library, Molecular pedigree assigning, Molecular, kinship estimation, Experimental designs to detect QTL, Generation of linkage disequilibrium –Limits to response via MAS; Implementing MAS in breeding programs.

Unit VI

Genomic Selection- Overview of Implementation and Benefits of Genomic Selection Genomic Best Linear Unbiased Prediction (GBLUP); Two Equivalent Mixed Models for GBLUP of Breeding Values; GBLUP for Individuals without Phenotypic Observations, Genomic Estimation of Variance Components; Genomic Estimation of Heritabilities; Genomic Relationship and Correlation.

VI. Practical

- Tools for NGS data analysis
- QTL Analysis, Hapalotype based QTL analysis
- Genomic approaches to selection for disease resistance
- Genomic tools: Genome wide association studies, custom microarray technologies, DNA microarray, SNP array, Subtractive hybridization comparative genomic hybridization
- Estimation of GBLUP; Genomic Estimation of Variance Components; Genomic Estimation of Heritabilities; Genomic Relationship and Correlation

VII. Suggested Reading

- Brown TA. 2017. Genomes 4 (4th edition). Garland Science, US, 544 pp.
- David Siegmund and Benjamin Yakir. 2007. The statistics of Gene Mapping. Springer, USA.
- Dunham I. 2003. Genome mapping and sequencing, Panima Publishing Corporation-New Delhi, 470 pp.
- Hartwell LH, Hood HL, Goldberg ML, Reynolds AE, Silve LM and Veres RG. 2004. Genetics: From Genes to Genomes McGraw-Hill Education.
- Isik Fikret, James Holland and Christian Maltecca. 2017. Genetic data analysis for plant and animal breeding. New York: Springer.
- Joel Ira Weller. 2016. Genomic Selection in Animals. John Wiley and Sons, Inc., New Jersey
- Primrose SB and Twyman RM. 2006. Principles of Gene Manipulation and Genomics (7th edition). Blackwell Publishing, Oxford UK., 672 pp.
- Primrose SB and Twyman RM. 2006. Principles of gene manipulation and genomics.
- Sahai S. 2002. Genomics and Proteomics, Functional and Computational Aspects, Kluwer Academic Publishers, New York.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Linear Models and Experimental Designs in Fish Genetics

II. Course Code : FGB 604

III. Credit Hours : 1+2

IV. Aim of the course

To learn the application of different statistical models in breeding data.

V. Theory

Unit I

The Binomial, Poisson, Normal models; ANOVA, Multiple regression and correlation Testing of genetic hypothesis, Test of hypothesis, Hierarchical classification, Variance Components, Linear Mixed Models (LMMs) an overview, Clustered data, Repeated measures, Longitudinal data; Levels of Data; Types of factors and their related effects in LMM, Fixed effects, Random effects.

Unit II

Matrix operations: Determinants, Inverse of matrix, Linear equations, the matrix algebra of regression analysis.

Unit III

Specification of LMM: General specification for an individual observation General matrix specification-Covariance structure for the D and R matrix, Mixed models: Predicting Random effects, Best Linear Unbiased Predictors (BLUP), their application in estimation of genetic variance components and parameters, BLUP Under the Animal Model; BLUP with Repeated Records; Analysis of non-orthogonal and multivariate data.

Unit IV

Maximum likelihood (ML) estimation of variance-covariance components, Structure of Variance, Covariance Matrix as a Function of Partial Derivatives, ML Estimation of Variance, Covariance Components, Restricted maximum likelihood estimation (REML) of Variance-covariance components, General REML Equations; REML Using the CE and the MME methods of BLUP.

Unit V

ANOVA –Challenge Test-Designing the challenge tests, Data collection protocols

Unit VI

Model building and simulations; Simulation of phenotypes; Simulation of fish breeding in different conditions

VI. Practical

- Matrix operation, matrix inversion, matrix algebra of regression analysis
- Least Squares analysis in one way classification
- Use of various statistical packages for genetic parameter estimations: SAS, R, AsReml, PEST, SelAction
- One way classification with regression and covariance
- Two way classification with and without interactions
- Multiple and nested classification
- Predicting Random effects- Best Linear Unbiased Predictors (BLUP)
- Maximum likelihood estimation of genetic parameters, Analysis of non-orthogonal and multivariate data
- Genomic Best Linear Unbiased Prediction (GBLUP)
- Genomic Estimation of Variance Components
- Genomic Estimation of Heritability
- Survival analysis- commonly used survival functions, Kaplan-Meier estimate of survival function, Cox regression method, Hazard ratio and survival

VII. Suggested Reading

- Dutkowski G and Gilmour A. 2005. *AsReml Cook Book*. Statistical Software Package.
- Isik, Fikret, James Holland, and Christian Maltecca.2017. Genetic data analysis for plant and animal breeding. New York: Springer.
- Kruschke J.K. 2015. Doing bayesian data analysis. Second Edition. Academic Press
- Littell RC, Milliken GA, Stroup WW and Wolfinger RD**.** 1996. *SAS Systemfor Mixed Models*. SAS Institute.
- Lynch M and Walsh B. 1997. Genetics and Analysis of Quantitative Traits. Sinauer, Sunderland.
- Saxton AM. 2004. *Genetic Analysis of Complex Traits Using SAS*. SAS Publ.
- West B.T. Welch, K.B. and Gatecki, A.T. 2015. Linear Mixed Models. CRC press
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20 Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

List of Suggested Journals

- *Acta Cytologica*
- *Advances in Genetics Incorporating Molecular Genetic Medicine*
- *Animal Genetic Resource Information*
- *Animal Genetics*
- *Annual Review of Genetics*
- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Bioinformatics*
- *Biological Conservation*
- *BMC Bioinformatics*
- *BMC Molecular Biology*
- *Breeding Science*
- *Briefings in Bioinformatics*
- *Briefings in Functional Genomics and Proteomics*
- *Cancer Genetics and Cytogenetics*
- *Conservation Biology*
- *Conservation Genetics*
- *Cytogenetics*
- *Genetics*

- *In Silico Biology*
- *Indian Journal of Agricultural Statistics*
- *Indian Journal of Cytology and Genetics*
- *Indian Journal of Fisheries*
- *Indian Journal of Genetics and Plant Breeding*
- *Indian Journal of Statistics*
- *Journal of Animal Breed and Genetics*
- *Journal of Animal Science*
- *Journal of Applied Statistics*
- *Journal of Bio-Chemistry and Molecular Biology*
- *Journal of Computational and Graphical Statistics*
- *Journal of Fish Biology*
- *Journal of Genetics*
- *Journal of Heredity*
- *Journal of Molecular Biology*
- *Journal of Official Statistics*
- *Journal of Statistical Software*
- *Journal of Statistics Education*
- *Journal of Tissue Culture Methods*
- *Molecular and Cellular Biology*
- *Molecular Cytogenetics*
- *The Journal of heredity*

List of Suggested e-Resources

- http://www.ncbi.nlm.nih.gov/
- http://www.genome.gov
- http://www.hgsc.bcm.tmc.edu/projects/bovine
- http://www.animalgenome.org
- http://www.blackwell-synergy.com
- http://www.genomics.liv.ac.uk
- http://www.biomedcentral.com
- http://www.genomealliance.org.au
- http://www.csiro.au
- http://www.isag.org.uk
- http://www.ebi.ac.uk/imgt/
- http://www.csrees.usda.gov

Suggested Broad Areas for Master's and Doctoral Research

- Cryopreservation of gametes of species of commercial importance
- Estimation of gene and genotype frequencies using various population genetic tools (markers)
- Estimation of effective population size, inbreeding accumulation rate in a breeding population
- Genetic stock structure analysis; genetic variability studies of species o commercial importance
- Estimation of genetic parameters in species of commercial importance
- Developing breeding plans for different commercial fish and prawn species
- Estimation of genetic parameters in species of commercial importance
- Estimation of heterosis and Inbreeding depression in breeding population
- Construction of growth curves for different commercial fish and prawn species Developing breeding plans for different commercial fish and prawn species
- Cryopreservation of gametes of species of commercial importance
- Application of molecular genetic markers for estimation of effective population size, rate of inbreeding
- Estimation of genetic diversity and relatedness using molecular information
- Morphometric analysis of stocks

- Milt quality analysis and cryopreservation of milt
- Estimation of linkage disequilibrium using molecular genetic data
- Application of molecular genetic markers for estimation of effective population size, rate of inbreeding
- Estimation of genetic diversity and relatedness using molecular information
- QTL Analysis and application in selective breeding
- Estimation of linkage disequilibrium using molecular genetic data
- Application of molecular genetic markers for estimation of effective population
- size, rate of inbreeding
- Estimation of genetic diversity and relatedness using molecular information
- QTL Analysis and application in selective breeding
- Chromosome mapping for different commercial fish and prawn species
- Karyotyping and chromosome spread preparation for different commercial fish and prawn species
- Estimation of genetic parameters using various statistical packages like SAS, AsREML, PEST
- Molecular data analysis using softwares like GENEPOP
- Establishing cell lines
- Construction of growth curves for different commercial fish and prawn species
- Estimation of genetic and non-genetic parameters
- Developing breeding plans for different commercial fish and prawn species
- Cryopreservation of gametes of species of commercial importance
- Developing breeding plans for different commercial fish and prawn species
- Estimation of genetic parameters in species of commercial importance
- Estimation of genotype-environment Interaction
- Estimation of heterosis and Inbreeding depression in breeding population
- Socio-economic impact studies for genetically improved varieties
- Evaluation of International genetic improvement programmes
- Chromosome mapping for different commercial fish and prawn species
- Karyotyping and chromosome spread preparation for different commercial fish and prawn species
- Pedigree assigning using molecular data
- Estimation of genetic parameters using molecular data
- Estimation of genetic and non-genetic parameters using various statistical packageslike SAS, AsREML, PEST

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Nutrition and Feed Technology

Preamble

(Fish Nutrition And Feed Technology)

Over the last decade, spectacular growth has taken place in aqua farming with deployment of formulated feeds. The bulk of high-value freshwater and marine carnivorous finfish/ shellfish is produced by intensive farming systems using high-cost nutrient inputs in the form of "nutritionally-complete formulated diets".

Thus, nutrition and feeding will continue to play an essential role in the sustained development of aquaculture which however, must take into account and ensure that the needs of competing users are met, and that environmental integrity is protected by formulating eco-friendly feeds

Growth, health and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrient, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Supply of inputs (feeds, fertilizers etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved.

Thus, good nutrition is of paramount importance for economic production of healthy and high quality product. In fish farming, nutrition of fish is critical because feed represents 40-50% of the production costs. Fish nutrition research has advanced in recent years with the development of commercial diets that promote fish growth and health. Development of species-specific feed formulations support the aquaculture (fish farming) industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products.

Culturing fish in captivity, nothing is more important than sound nutrition and adequate feeding. Hence growth is affected either due to less intake of feed or under utilization of feeds. An under nourished animal cannot maintain its health and be productive, regardless of the quality of its environment.

Thus, the production of nutritionally balanced feed for fish requires efforts in research, quality control, and biological evaluation. Faulty nutrition obviously impairs fish productivity and result in a deterioration of health until recognizable diseases ensues. The borderlines between reduced growth and diminished health, on the one hand, and the apparent disease, on the other, are very difficult to define. However, the problem of recognizing a deterioration of performance in its initial stages and taking corrective action will remain an essential part of the skill of fish culturist.

Like any other terrestrial animal, fish also needs the same type of nutrients for their growth. However, the amount of these nutrients varies due to variation of metabolic rate. Hence, supply of these nutrients is warranted in fish feed. Unlike animals, the availability of these nutrients to fish is different due to their surrounding environment. Some nutrients are available form water, which needs to be considered critically while formulating feed for fish.

Finfish require around 40 nutrients for optimal growth and wellbeing. The proteins, lipids/fats and carbohydrates are considered as "macro nutrients", while vitamins and minerals put together constitute "micronutrients" required for the healthy growth in fish.

Thus, careful attention has to be paid in understanding the nutritional requirements and formulating a nutritionally balanced feed.

Fish feed technology is one of the developing sectors of aquaculture, particularly in the third world countries. Commercial formulations of feeds are generally proprietary secrets, and the ingredients used are often too expensive to be used in fish farming. The need for developing suitable feeds based on locally available inexpensive ingredients has therefore, been widely recognized.

The technology of feed processing has undergone substantial improvement in recent years. It was only sixty years ago that feeds stuffs were mixed on the warehouse floor by the use of a shovel. Feed processing has progressed from the simple mixing of several ingredients by hand to mechanical mixing, to continuous mixing, and now to computer controlled mixing and pelleting. However, the basic concept of mixing ingredients together to result in a nutritionally balanced feed has remained unchanged.

To accomplish the mixing of different ingredients, grinding these ingredients to similar particle sizes, and then putting them together in a single unit, requires a considerable amount of specialized equipment and technical expertise. Some feed plants are versatile and designed for multitasking of producing different feeds for several animals such as poultry feeds, canine feeds etc. including fish feeds.

Whatever good quality feed may be produced but the manner in which it is offered to fish becomes prime important. Considerable innovations have been made the world over in production of feed broadcasting equipment to manage feeding and feeding schedules to prevent overfeeding or underfeeding to maximise growth.

The intensive aqua farming practices to raise high production per unit area has resulted in emergence several of the diseases driving the farmer to economic losses. Thus, the farming industry has focused its attention in enhancing immunity of aquatic animals through functional feeds. Though lot of research was generated on the use of probiotics and prebiotics, but yet find their place as commercially viable technologies.

It is with this background that the members of the BSMA committee and the invited experts from farm and feed industry reviewed the existing PG and Ph.D. course syllabus critically several times, incorporated the recent content learning both in theory and practical to bring it in this elevated format to groom the fish nutrition and feed technology specialists and professionals to the industry, R and D and academics. The committee took note of several considerations like relevance of course title, objectives and unit contents, merging of units to bring uniformity in avoiding content repetition in units while ensuring uniform distribution of units as far as possible to 6-7 units in 2+1 course and minimum 3-4 units in 1+1 courses.

Under M.F.Sc. program major changes in title and contents of as many as 6 courses has been made with minor changes in other 6 courses. In Ph.D. program, only one course was subjected to major changes and upgraded to include feed mill management as new content of learning for feed industry needs while in other 7 courses only minor modifications were made. A new course "Introduction to Biomolecules" has been introduced in Ph.D. program to expose the students to an emerging science on feed biomolecules in fish biosystem.

Course Title with Credit Load
M.F.Sc. in Fish Nutrition and Feed Technology

Course Code	Course Title	Credit Hours
	Major courses	**20 Credits**
FNT 501	Principles of Fish Nutrition	2+1
FNT 502	Nutrient Digestion and Growth	2+1
FNT 503	Feeds and Feed Technology	2+1
FNT 504	Nutritional Energetics	2+1
FNT 505	Nutritional Requirement and Feeding Management	2+1
FNT 506	Feed Ingredients and Additives	2+1
FNT 512	Nutraceuticals	1+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a student's major subject)	
FNT 507	Shellfish Nutrition and Feeding	2+1
FNT 508	Protein Nutrition	1+1
FNT 509	Lipid Nutrition	1+1
FNT 510	Carbohydrate Nutrition	1+1
FNT 511	Vitamins and Minerals Nutrition	1+1
	Supporting courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 credits**
	(The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 3. Intellectual Property and its management in Agriculture 4. Basic concepts in Laboratory Techniques 5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FNT 591	Master's Seminar I	0+1
	Masters' Thesis Research	**30 Credits**
FNT 599	Master's Research (Semester III)	0+15
FNT 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fish Nutrition and Feed Technology

I. Course Title : Principles of Fish Nutrition
II. Course Code : FNT 501
III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic principles of fish nutrition and the role of different nutrients.

V. Theory

Unit I

Protein nutrition: Protein and amino acids, Their specific functions, Classification and evaluation criteria of dietary protein (nutrient gain, nutrient efficiency, TGC, PER, NPU, BV, EAAI, chemical score), Protein deficiency symptoms.

Unit II

Lipid nutrition: Lipids and fatty acids, Their specific functions, Classification and evaluation of lipid quality, Lipid deficiency symptoms.

Unit III

Carbohydrate nutrition: Carbohydrates, Functions, Classification and Utilization of carbohydrate in fish diets.

Unit IV

Vitamin and mineral nutrition: Specific functions, Classification, Sources of vitamins and minerals and their deficiency symptoms.

Unit V

Nutritional energetics: Definition, Different forms of energy and energy value of feed (gross energy, digestible energy, metabolizable energy, net energy), Importance of protein-energy ratio in fish diets.

Unit VI

Larval and Brood stock nutrition: Larval gut morphology, importance of live feed and formulated feeds in larval nutrition, Nutrients required for egg and sperm quality and reproductive efficiency.

VI. Practical

Proximate analysis: Moisture, Crude protein, Crude lipid, Gross energy, ash, acid insoluble ash, crude fibre, nitrogen free extract of feed and fish tissue, analysis of fatty acids and amino acids, calcium, phosphorus, vitamin C content of feed.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome.
- De Silva, S. S. and Anderson, T. A. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.

- FAO *training manual related to feed analysis*.
- Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. *Nutrition and Feeding of Fish and Crustaceans,* Springer Praxis Publishing, Chichester, U.K.
- Halver J. E. 1989. *Fish Nutrition*, Academic Press, San Diego, Califonia.
- Halver, J. E. and Tiews, K. T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver, J. E. and Hardy, R. W. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher, B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell, R. T. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Paulraj, R., 1993. Aquaculture Feed. CMFRI publication, 84 pp.

I. Course Title : Nutrient Digestion and Growth

II. Course Code : FNT 502

III. Credit Hours : 2+1

IV. Aim of the course

To understand digestion, absorption and transportation of nutrients and nutrient induced growth in fish and shell fish

V. Theory

Unit I

Digestive system of fish: Digestive organs and their roles, Anatomy and histology, Feed ingestion, Feeding mechanism, Gastro-intestinal motility.

Unit II

Digestive system of shellfish: Digestive organs and their roles, Anatomy and histology, Feed ingestion, Feeding mechanism, Gastro-intestinal motility.

Unit III

Digestion: Digestion of proteins, Lipids and carbohydrates, Methods of determining digestibility; Direct and indirect methods, Advantages and disadvantages of methods, Digestibility value of feed ingredients and Factors affecting digestibility, Role of gut micro flora in digestion.

Unit IV

Absorption and Transportation: Active, passive and facilitated absorption of nutrients, Transport of nutrients and cellular uptake.

Unit V

Regulation of digestion: Appetite and satiation, Factors influencing appetite and satiation, Hormonal regulation and Factors affecting digestion.

Unit VI

Growth: Concept of growth, Growth curve, Biotic and abiotic factors affecting growth, Correlation of growth with body weight and length.

VI. Practical

Dissection and examination of digestive organs; Histological preparation of digestive organs; Assays of enzyme activity of amylase, proteases and lipases; *In vivo - in vitro* digestibility studies.

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in*

Aquaculture Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*, Springer Praxis Publishing, Chichester, U.K.
- Halver JE. 1989. *Fish Nutrition*, Academic Press, San Diego, Califonia.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.

I. Course Title : Feeds and Feed Technology

II. Course Code : FNT 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn basic concept of feed formulation and different feed processing techniques

V. Theory

Unit I

Feed formulation: General principles and criterions, Different methods of feed formulation; Pearson's square method and least cost formulation (quadratic equation, solver function, Graphic solution, Linear programming and software assisted formulations), Limitations of formulation methods.

Unit II

Types of feed: Wet, Moist and Dry (pellets – steam compressed, extruded and crumbled, flakes, powdered/ mash, micro-encapsulated, micro-bound and micro-coated diets). Farm made feeds, Experimental diets; Reference diet, purified and semi-purified diet, Compact pellet, Floating and slow sinking pellet feeds; Starter, grower, Finisher and broodstock feeds, High energy eco-friendly and medicated feed.

Unit III

Feed processing technology: Receiving of raw materials, Equipments used in feed manufacture and processing; Grinder/pulverizer, Mixer, Pelletizer/extruder, Crumbler, Drier, Vacuum coater/ fat sprayer, automatic bagging and sealing, Role of pre-conditioning in feed preparation, Effects of processing on the nutritional value and availability of nutrients.

Unit IV

Feed storage: Hydro-stability of feed and their storage; Prevention of spoilage from rancidity, Fungus and associated toxins; Vectors of fish disease in feed and quality control; Nutritional value in relation to feed storage.

Unit V

Feed additives and supplements: Binders, carotenoids, Attractants, Antioxidants, Probiotics, Prebiotics, Synbiotics, Immunostimulants, Nutraceuticals, Acidifiers and Preservatives, Bile acids, Herbal additives and Vitamins, minerals, Limiting amino acids, Essential fatty acids, Phospholipids, and Cholesterol.

Unit VI

Quality control in fish feed manufacturing: Quality control procedures, Raw materials, Finished products; Safety of farm fish products, Harmful residues (pesticides, antibiotics, and pollutants).; Geometrical, and physical feature; Mechanical characteristics in air, Behavioural characteristics in water, Feed economics and evaluation.

VI. Practical

Feed formulation, Preparation of mineral and vitamin premix, Feed additives, binders, water stability test, and available lysine, Determination of feed particle size, Development of feed dispensers both for laboratory and pond feeding as part of project assignment, Visit to feed processing industries.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology,* ADCP/REP/80/11.F.A.O., Rome.
- D' Abramo, L.R., Conklin, D.E. and Akiyama, D.M. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva, S.S. and Anderson, T.A. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, UK.
- Halver, J.E. and Tiews, K.T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver, J.E. 2002. *Fish Nutrition*. Academic Press, San Deigo, C.A.
- ICAR-IRRI Outreach programme
- Lovell, R.T. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers
- Muir, J.F., and Robert, D. (Eds.). 1998. *Recent Advances in Aquaculture* Vol.II., Blackwell Science
- New, M.B. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O. Rome.

I. Course Title : Nutritional Energetics

II. Course Code : FNT 504

III. Credit Hours : 2+1

IV. Aim of the course

Nutritional energetics of different macromolecules and energy producing pathways.

V. Theory

Unit I

Concepts of nutritional energetics: Energy budget equation; Energetic efficiencies and energy flow/partitioning in biological systems; Gross energy, Digestible energy, Metabolizable energy, Net energy, Heat increment of feeding (specific dynamic action, SDA); Factors influencing energy metabolism.

Unit II

Energy requirement: Energy requirement of fish and shellfish, Factors influencing energy requirements; Energetics of maintenance and methodology of estimating the maintenance requirement.

Unit III

Energy estimation: Direct and indirect methods of estimation of energy of feed and feed components based on chemical compositions.

Unit IV

Energetics of growth: Relationship between feeding and growth; Energy exchange in biological systems; Growth and maturation

Unit V

Energetics of reproduction: Gonadal maturation and reproduction in relation to feeding

Unit VI

Energetics of intermediary metabolic pathways: Aerobic and anaerobic glycolysis, TCA cycle, Glycogenolysis, Beta oxidation, Electron transport chain, Effect of biotic and Abiotic factors on energy metabolism.

VI. Practical

Estimation of gross and digestive energy of feed and feed ingredients; Estimation of digestibility of nutrients, Bomb- calorimetry; Energy budget equation based on experimental data; Determination of standard metabolism in fish; Assay of metabolic enzymes.

VII. Suggested Reading

- Berg JM, Tymoczko JL and Stryer L. 2002. *Biochemistry*. W.H. Freeman and Company.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*.Chapman and Hall Aquaculture Series, London.
- Devlin TM. 1997. *Textbook of Biochemistry with Clinical Correlations*. Wiley-Liss, Inc.
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes*. CRC Press.
- Florkin M and Mason HS. 1963. *Comparative Biochemistry*. Academic Press, New York.
- Halver J and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell Science Ltd., London.
- Jobling M. 1994. *Fish Bioenergetics*. Chapman and Hall, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Murray RK, Granner DK, Mayes PA and Rodwell VW. 2000. *Harper's Biochemistry*. Appleton and Lange.
- Nelson DL and Cox MM. 2005. *Lehninger Principles of Biochemistry*. W.H. Freeman and company.
- Voet D, Voet JG and Pratt CW. 2006. *Fundamentals of Biochemistry*. John Wiley and sons, Inc.

I. Course Title : Nutritional Requirement and Feeding Management

II. Course Code : FNT 505

III. Credit Hours : 2+1

IV. Aim of the course

To learn nutritional requirements, feeding methods and feed management of commercially important fish and shellfish.

V. Theory

Unit I

Nutritional requirements of finfish and shell fish: Nutritional requirements of larvae, growout and broodstock of commercially important finfish and shellfish. Methods of studying nutritional requirements; Qualitative and quantitative methods; Nutrients deficiency symptoms.

Unit II

Nutritive value of live food: Algae, Artemia, Cladocerans, Ostracods, Rotifers and copepods, Bio enrichment of artemia and zooplankton, Experimental diets; Reference diet, Purified and Semi-purified diet.

Unit III

Response indices for nutrient requirement studies: Weight gain, Specific growth rate (SGR)/ daily growth coefficient (DGC), Thermal growth coefficient (TGC) and, feed conversion ratio (FCR), Protein efficiency ratio (PER), Net protein utilization (NPU), Physiometabolic parameters, Dose response curves, Gonadosomatic index (GSI)

Unit IV

Body composition of fish and shellfish: Influence of nutrients on body composition and flesh quality; Effect of rations on fecundity and egg quality.

Unit V

Feeding methods and devices: Broadcasting, Bag feeding, Tray feeding, Raft feeding, demand feeder, Mechanical automatic feeder, Blower feeder. Check tray feed monitoring, Ration size/ feeding rate and feeding frequency, Restricted feeding and mixed feeding.

Unit VI

Feeding management: Application of research findings to farming situations, Record keeping, Growth prediction and Feeding management.

VI. Practical

Determination of feed intake in fry and fingerlings; Determination of nutrient requirements of fish/prawn using purified diet; Analysis of experimental data from growth study; Measures of protein quality (PER, NPU, BV); Exercise on feeding.

VII. Suggested Reading

- Cho CH and Kaushik SJ. 1990. *Nutritional Energetics in Fish: Energy and Protein Utilization in Rainbow Trout*. World Review on Nutrition and Dietetics.61: 132-172.
- D' Abramo LR, Conklin DE and Akiama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II, Heenemann, Berlin.
- Halver JE. 1989. *Fish Nutrition*. Academic Press, San Diego, CA.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell Science Ltd., London.
- Kaushik SJ. 1998. *Nutritional Bioenergetics and Estimation of Waste Production in Non-Salmonids*. *Aquat living resour* 11(4): 211-217
- New MB. 1987. *Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture*. ADCP/REP/87/26 F.A.O., Rome.
- NRC. 2011. *Nutrient Requirements of Fish and Shrimp*. National Academies Press, Washington D.C., USA

I. Course Title : Shellfish Nutrition and Feeding

II. Course Code : FNT 507

III. Credit Hours : 2+1

IV. Aim of the course

To study the nutritional requirements of shellfish, feed formulation and feeding strategy

V. Theory

Unit I

Nutritional requirements: Protein, carbohydrate, Lipid, Vitamin, Mineral, Essential amino acid, Fatty acid at various life stages, Methods for determining nutrient requirements, Factors affecting nutritional requirements.

Unit II

Energy requirements: Protein-energy ratio, Protein sparing and methods for determining energy requirement and factors affecting energy requirements.

Unit III

Food and feeding: Food and feeding habits, Natural food organisms, Micro-particulate diets (MBD, MCD, MED, MEM, PARA) for hatcheries; Grow-out and finisher feeds; Broodstock feeds for conditioning, Maturation and reproduction.

Unit IV

Digestion, absorption and metabolism: Feed ingestion and feeding mechanism, Digestion, Absorption and Assimilation of nutrients, Gastro-intestinal motility, Factors affecting digestibility; Importance of microbial digestion.

Unit V

Feeding management: Ration size/feeding rate and feeding frequency; Feed dispensing methods and devices.

Unit VI

Feed Additives and health: Role of feed additives in shellfish nutrition, Immunity and health, Nutrient deficiency diseases in shellfish.

VI.Practical

Study of digestive system of shrimps, prawns, lobsters, crabs; Formulation and preparation of diet with specific additives; nutrient requirement study in crustacean; water stability test

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26. F.A.O., Rome

- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and Crustaceans*. National Academy Press, Washington.
- Boyd CE. 2015. *Water quality: an Introduction*. Springer.

I. Course Title : Feed Ingredients and Additives

II. Course Code : FNT 506

III. Credit Hours : 2+1

IV. Aim of the course

To learn the requirement and availability of ingredients for aqua-feed and different types of additives used.

V. Theory

Unit I

National and international scenario: Present production trend and future requirements of feed ingredients, International coding of feed ingredients.

Unit II

Ingredient classification: Conventional and unconventional feed ingredients, Plant (protein and energy-carbohydrate and lipid) and Animal (protein and energy-lipid) sources.

Unit III

Quality evaluation of feed ingredients: Physical, Chemical (proximate composition, amino acids, EAAI, chemical score, fatty acids, vitamins and minerals profile and energy estimation, Anti- Nutritional Factors (ANFs) and other adventitious toxins) and Biological methods, Classification, Mode of action and Methods of detoxification of ANFs, Adulterants in feed ingredients.

Unit IV

Feed additives and supplements: Classification, Function; Gustatory stimulants and feed attractants; Nutraceuticals, Non-nutrient feed components.

Unit V

Feed raw material storage and spoilage: Grain storage, Liquid storage, Meal storage and Vitamin storage methods and practices, Prevention and management of raw material spoilage**,** Factors responsible for spoilage, Design criteria of storage shed, Silos, Bins, Roof ventilation and Aeration management etc., Temperature Monitoring, Silo Aeration system management and fumigation system to prevent spoilage.

Unit VI

Enhancing nutrient status of feed raw material: Application of genetic engineering and production of genetically modified plant ingredients. Amino acids deficient in plant ingredients. Manipulating biosynthesis pathways to enhance essential amino acids in plant ingredients.

VI. Practical

Identification of feed ingredients; Amino acid analysis of feed ingredients; Estimation of gross energy; Estimation of ANFs (Tannin, gossypol, phytate, protease inhibitors, cyanogens) and aflatoxin

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Joachim WH and Pascual FP. 2000. *Handbook on Ingredients for Aquaculture Feeds*. Kluwer Academic Publishers, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Rechcigl M. 1977. *CRC Handbook Series in Nutrition and Food*. CRC press.
- Rechcigl M. 1983. *Handbook of Nutritional Supplements*. CRC press.
- https://www.feedipedia.org
- http://www.iaffd.com

I. Course Title : Shellfish Nutrition and Feeding

II. Course Code : FNT 507

III. Credit Hours : 2+1

IV. Aim of the course

To study the nutritional requirements of shellfish, feed formulation and feeding strategy

V. Theory

Unit I

Nutritional requirements: Protein, Carbohydrate, Lipid, Vitamin, Mineral, Essential amino acid, Fatty acid at various life stages, Methods for determining nutrient requirements, Factors affecting nutritional requirements.

Unit II

Energy requirements: Protein-energy ratio, Protein sparing and Methods for determining energy requirement and Factors affecting energy requirements.

Unit III

Food and feeding: Food and feeding habits, Natural food organisms, Micro-particulate diets (MBD, MCD, MED, MEM, PARA) for hatcheries; Grow-out and finisher feeds; Broodstock feeds for conditioning, Maturation and reproduction.

Unit IV

Digestion, absorption and metabolism: Feed ingestion and feeding mechanism, Digestion, Absorption and Assimilation of nutrients, Gastro-intestinal motility, Factors affecting digestibility; Importance of microbial digestion.

Unit V

Feeding management: Ration size/feeding rate and feeding frequency; Feed dispensing methods and Devices.

Unit VI

Feed Additives and health: Role of feed additives in shellfish nutrition, Immunity and health, Nutrient deficiency diseases in shellfish.

VI. Practical

Study of digestive system of shrimps, prawns, lobsters, crabs; Formulation and preparation of diet with specific additives; nutrient requirement study in crustacean; water stability test.

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L.A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/ 26.F.A.O., Rome
- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and Crustaceans*. National Academy Press, Washington.
- Boyd CE. 2015. *Water quality: an Introduction*. Springer.

I. Course Title : Protein Nutrition

II. Course Code : FNT 508

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of protein in aquafeeds and relationship of protein with energy metabolism

V. Theory

Unit I

Protein requirement and their sources: Conventional and non-conventional, Plant and animal origin; Non-protein nitrogen; Protein requirement for maintenance, Growth and reproduction, Essential and non-essential amino acids, Amino acid antagonism, Protein and amino acid deficiency symptoms.

Unit II

Protein energy ratio: Factors affecting protein requirement, Importance of protein energy ratio (P/E Ratio).

Unit III

Digestion, absorption and metabolism: Digestion of protein, Absorption of amino acids and Their metabolism; Amino acid pool and Protein turnover.

Unit IV

Evaluation of protein quality: PER, NPU, BV, ANPU, Kjeldahl Nitrogen Conversion factors. Ideal protein concept.

VI. Practical

Extraction and purification of protein, Microkjeldahl method; Estimation of protein by methods of Biuret, Lowry and Bradford, total free amino acids; *In vivo* and *In* *vitro* protein digestibility.

VII. Suggested Reading

- Cho CY, Cowey CB, Watanabe T. 1985. *Finfish Nutrition in Asia: Methodological Approaches to Research and Development*. Ottawa, Ont.IDRC.155pp.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Wilson K and Walker J. 1995. *Principles and Techniques of Practical Biochemistry*. Cambridge University Press.

I. Course Title : Lipid Nutrition

II. Course Code : FNT 509

III. Credit Hours : 1+1

IV. Aim of the course

To understand the importance of lipids in aqua feeds and the relationship of dietary lipid and tissue lipid

V. Theory

Unit I

Requirement of lipid and their sources: Terrestrial and aquatic origin; Optimum dietary lipid level; Essential fatty acid requirements for growth, Reproduction and health importance of other fat soluble substances (vitamins, carotenoids etc.). Interspecies differences in lipid requirement.

Unit II

Lipid metabolism: Lipid digestion, Absorption, Transportation/mobilization, Metabolism and storage, Protein sparing effect of lipids.

Unit III

Lipids and their fatty acids: Role of lipids and essential fatty acids, Their qualitative and quantitative requirement.

Unit IV

Lipids quality: Oxidation of fats/lipids, Antioxidants and evaluation of lipid quality, Deficiency symptoms.

VI. Practical

Estimation of total lipids, phospholipids and free fatty acids, peroxide value, saponification number, iodine value Separation and quantification of individual fatty acids by GCMS.

VII. Suggested Reading

- Berg JM, Tymoczko JL and Stryer L. 2002. *Biochemistry*. W.H. Freeman and Company.
- Cho CY, Cowey CB, Watanabe T. 1985. *Finfish Nutrition in Asia: Methodological Approaches to Research and Development*. Ottawa, Ont.IDRC.155pp.
- Cowey CB and Sargent JR. 1972. *Fish Nutrition. In Advances in Marine Biology* (Vol. 10, pp. 383-494). Academic Press.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall

Aquaculture Series, London.
- Halver J and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Murray RK, Granner DK, Mayes PA and Rodwell VW. 2000. *Harper's Biochemistry*. Appleton and Lange.
- NRC (National Research Council). 2011. *Nutrient Requirements of Fish*. National Academy Press, Washington.
- Sargent JR. 1997. *Fish Oils and Human Diet. British Journal of Nutrition*, 78(1), pp.S5-S13.
- Sargent JR, Tocher DR and Bell JG. 2003. *The Lipids. In Fish Nutrition* (Third Edition) (pp. 181-257).
- Voet D, Voet JG and Pratt CW. 2006. *Fundamentals of Biochemistry*. John Wiley and Sons, Inc.

I. Course Title : Carbohydrate Nutrition

II. Course Code : FNT 510

III. Credit Hours : 1+1

IV. Aim of the course

To understand the importance of carbohydrate in aquafeed and their protein sparing effect

V. Theory

Unit I

Sources: Carbohydrate sources and digestible energy supply, Role of digestible and non-digestible carbohydrates; Dietary levels of carbohydrate for carps and catfishes.

Unit II

Digestibility and interactions with other nutrients: Carbohydrate digestibility, Factors affecting starch utilization, Carbohydrate and Interaction with other nutrients and protein sparing effect.

Unit III

Constraints and utilization: Constraints of carbohydrate utilization in fish, Non-starch polysaccharides, Strategy to enhance carbohydrate utilization; Gelatinization, Exogenous amylases, Glucose Intolerance; Carbohydrates and immunity.

Unit IV

Economic importance aquafeeds: Maximum and inclusion levels for different fish species, Uses of carbohydrates for low cost feed formulations.

VI. Practical

Estimation of starch gelatinization in different feed processing methods; Blood glucose estimation; Estimation of crude fibre and non-starch polysaccharides.

VII. Suggested Reading

- D' Abramo, LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L.A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, UK.

- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.
- NRC (National Research Council). 1993. *Nutrient Requirements of Fish*. National Academy Press, Washington.
- Kamalam BS, Medale F and Panserat S. 2017. *Utilisation of dietary carbohydrates in farmed fishes: New insights on influencing factors, biological limitations and future strategies.* Aquaculture, 467, pp.3-27.
- Kamalam, B.S., Medale, F., Larroquet, L., Corraze, G. and Panserat, S., 2013. *Metabolism and fatty acid profile in fat and lean rainbow trout lines fed with vegetable oil: effect of carbohydrates. PloS One*, 8(10), p.e76570.
- Hemre, G.I., Mommsen, T.P. and Krogdahl, Å., 2002. *Carbohydrates in fish nutrition: effects on growth, glucose metabolism and hepatic enzymes. Aquaculture Nutrition*, 8(3), pp.175-194.
- Kamalam, B.S. and Panserat, S., 2016. *Carbohydrates in Fish Nutrition*. International Aquafeed, pp.20-23.

I. Course Title : Vitamin and Mineral Nutrition

II. Course Code : FNT 511

III. Credit Hours : 1+1

IV. Aim of the course

To learn the importance of vitamins and minerals in fish and crustacean nutrition

V. Theory

Unit I

Vitamins: Classification and sources, properties and functions of water and fat soluble vitamins; Vitamin as co-enzymes and prosthetic groups of enzymes.

Unit II

Vitamin requirements and sources: Vitamin requirements of different species; dietary sources of vitamins; factors affecting vitamin requirements; Loss of vitamins during feed processing and storage.

Unit III

Vitamin deficiency: Manifestation of vitamin deficiency; Vitamin –mineral interactions. Hypo- and hyper-vitaminosis.

Unit IV

Minerals: Classification and sources, macro, micro minerals and heavy metals toxicity. Minerals requirements for different aquaculture species, dietary sources of minerals, factors affecting mineral requirement; nutrient-minerals interaction; Mineral-Mineral interactions; manifestation of mineral deficiency

VI. Practical

Estimation of zinc, phosphorus, magnesium, iron and vitamin A; preparation of vitamin and mineral premix; estimation of vitamin and mineral losses due to leaching

VII. Suggested Reading

- Antony JesuPrabhu P, Schrama JW and Kaushik SJ. 2016. *Mineral requirements of fish: a*

systematic review. *Reviews in Aquaculture*, 8(2), pp.172-219.
- Antony JesuPrabhu P, Schrama JW and Kaushik SJ. 2013. Quantifying dietary phosphorus requirement of fish–a meta analytic approach. *Aquaculture Nutrition*, 19(3), pp.233-249.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and Crustacea.* National Academy Press, Washington.
- Prabhu PAJ, Geurden I, Fontagné-Dicharry S, VeronV, Larroquet L, Mariojouls C, Schrama JW and Kaushik SJ. 2016. *Responses in micro-mineral metabolism in rainbow trout to change in dietary ingredient composition and inclusion of a micro-mineral premix. PloS One*, 11(2), p.e0149378.
- Woodward B. 1994. Aquaculture 124, 133-168.

I. Course Title : Nutraceuticals

II. Course Code : FNT 512

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutraceuticals in the physiological wellbeing of fish and shellfish

V. Theory

Unit I

Nutraceuticals/functional foods: Definition, Classification and scope in aquaculture

Unit II

Benefits and modes of action of nutraceuticals: Immunomodulatory proteins, Peptides, Polysaccharides, Oligosaccharides, Herbal extracts/phytochemicals, Carotenoids, Nucleotides, Bioactive compounds from seaweeds etc.

Unit III

Minerals as nutraceuticals: Zinc, Copper, Chromium, Manganese, and Selinium

Unit IV

Role of nutraceuticals: Stress mitigation and Growth enhancement, Immunomodulation and disease prevention

VI. Practical

Estimation of immunomodulatory parameters (lysozyme, NBT, MPO, antibody titre), estimation of antioxidant enzymes (SOD, catalase, GPx), extraction of bioactive compounds, *in vitro* antioxidant assay.

VII. Suggested Reading

- DeFelice SL. 1995. The nutraceutical revolution: its impact on food industry R and D. *Trends in Food Science and Technology*, 6(2), pp.59-61.
- Debnath D, Sahu NP, Pal AK, Baruah K, Yengkokpam S and Mukherjee SC. 2005. Present scenario and future prospects of phytase in aquafeed. *Asian-Aust. J. Anim. Sci,* 18(12), pp.1800-1812.
- Kalra EK. 2003. Nutraceutical-definition and introduction. *Aaps Pharmsci,* 5(3), pp.27-28.

- KartikBaruah, Asim K Pal, Narottam P Sahu, Kamal K Jain, Subhas C Mukherjee, Dipesh Debnath. 2005. *Dietary protein level, microbial phytase, citric acid and their interactions on bone mineralization of Labeo rohita* (Hamilton) juveniles, 36(8): 803-812.
- Luckstadt C. 2008. Utilization of acidifiers in nutrition and feeding of tropical fish–a mini-review. *Bulletin of Fish Biology* 10(1/2): pp.105-109.

Course Title with Credit Load
Ph.D. in Fish Nutrition and Feed Technology

Course Code	Course Title	Credit Hours
Major courses		**12 Credit**
FNT 601*	Feed Technology and Feed Mill Management	2+1
FNT 602*	Nutrigenomics	1+1
FNT 603*	Larval and Broodstock Nutrition	2+1
FNT 604*	Introduction to Biomolecules	2+1
FNT 607*	Nutraceuticals as Functional Foods	1+1
Minor Courses		**6 Credits**
	(From the subjects closely related to a student's major subject)	
FNT 605	Macro and Micronutrient Nutrition	2+1
FNT 606	Bioenergetics	2+1
FNT 608	Feed intake and feeding behaviour	1+2
FNT 609	Feed and environment	2+1
Supporting courses		**5 credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 credits**
Doctoral Seminar		**2 credits**
FNT 691	Doctoral Seminar-I	0+1
FNT 692	Doctoral Seminar-II	0+1
Doctoral Research		**75 credits**
FNT 699	Doctoral Research (Semester II)	0+15
FNT 699	Doctoral Research (Semester III)	0+15
FNT 699	Doctoral Research (Semester IV)	0+15
FNT 699	Doctoral Research (Semester V)	0+15
FNT 699	Doctoral Research (Semester VI)	0+15
	Total PhD Program Credit Hours	**100 Credits**

*Major compulsory subjects

Course Contents
Ph.D. in Fish Nutrition and Feed Technology

I. Course Title : Feed Technology and Feed Mill Mangement

II. Course Code : FNT 601

III. Credit Hours : 2+1

IV. Aim of the course

To study the feed formulation techniques; design of feed mill and feed manufacturing; feed quality assurance and regulations.

V. Theory

Unit I

National and global scenario of feed ingredients and feed industry: Availability demand and supply; Types of feeds, BIS and international standards for fish feed, Overview of feed mill business.

Unit II

Feed formulation: Different methods of feed formulation, Use of feed formulation softwares; Nutritional and physical quality of feed ingredients; Importance of additives formulation of nutritionally balanced diet (amino acid, micronutrients)

Unit III

Feed manufacturing process and control: Receiving of raw material, Grinding, Mixing, Conditioning, Pelleting /extrusion, Drying and cooling, Coating/top dressing, Packaging and labelling, Factors affecting feed manufacture and stability of nutrients, Effects of processing on the nutritional value of feeds, Processing methods for non-compacting feed; Economics of feed manufacturing.

Unit IV

Emerging new feed ingredients: Scope and exploration of new feed ingredients, Anti-nutritional factors and methods of detoxification (e-beam irradiation, solvent extractions, SSF, protein concentrates/isolates, genetic improvement of plants etc.).

Unit V

Storage and quality control: Ingredient quality assurance, Feed processing quality assurance and Processed feed quality assurance Miscellaneous adventitious toxins and Effect on feed safety; Storage of feed and quality deterioration, CGMPs and HACCP feed regulation, Feed transmitted bioterrorism and its implications.

Unit VI

Design of a feed mill unit: Layout, Feed mill design and safety of operation, Maintenance and record keeping.

VI. Practical

Analysis of anti-nutritional and toxic substances in feed ingredients and feed; Formulation of diets using software, Preparation of different types of feed and their quality evaluation; Effect of feed storage on nutritional value of feed, Preparation of farm made feeds.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome.
- D'Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Heijden PGM van der. 2016. *The aquaculture sector of Zambezi Valley, Mozambique: Description of the current situation and emerging opportunities*. Centre for advance Innovation.Wageningenuniversity.
- ICAR-IRRI Outreach programme reports.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*, Kluwer Academic Publishers.
- Muir JF and Robert D. (Eds.). 1968. *Recent Advances in Aquaculture* Vol.II. Blackwell Science.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.

I. Course Title : Nutrigenomics

II. Course Code : FNT 602

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutrients on gene expression

V. Theory

Unit I

Principles of nutrigenomics: Methodologies, Genomics, Transcriptomics, Proteomics, Metabolomics and Nutrigenomics, Gene structure and Regulation, Nutritionally Important genes, Nutrient-gene interaction and expression.

Unit II

m-RNA and cDNA: Extraction of m-RNA, reverse transcription and cDNA biosynthesis, Cloning techniques; Genomic and differential gene expression.

Unit III

Use of DNA probe: Blotting and hybridization, Microarray; Microarray nitrocellulose hybridization and labelling with P^{32} probes; Quantitative real time polymerase chain reaction (qRT PCR).

Unit IV

Bioinformatics: Gene expression software; BLASTIN, FASTA and PHYLIP etc.; Relative expression software tool (REST); Interpretation of microarray data; Cloning technique.

VI. Practical

Genomic DNA, plasmid DNA and RNA extraction and isolation, m-RNA purification; cDNA synthesis by reverse transcription from fish tissue; Elution of PCR product for gene sequencing; RT PCR, cloning, exploration of bioinformatics tools.

VII. Suggested Reading

- Afman L, Müller M. 2006. *Nutrigenomics: from molecular nutrition to prevention of disease*. J Am Diet Assoc 106: 569-576.
- Fenech M, El-Sohemy A, Cahill L, Ferguson LR, French TA *et al*. 2011. *Nutrigenetics and Nutrigenomics: Viewpoints on the Current Status and Applications in Nutrition Research and Practice*. J NutrigenetNutrigenomics 4: 69-89.
- Fingerman M, Nagabhushanam R and Thompson MF. 1997. *Recent Advances in Marine Biotechnology* (vol1-3). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Glick BR and Pasternak JJ. 1999. *Molecular Biotechnology: Principles and Applications of Recombinant DNA Technology*, ASM Press, Washington, D. C.
- Kaput J, Rodriguez RL. 2006. *Nutraceutical Genomics*. Wiley Interscience Hoboken, New Jersey.
- Lehninger AL. 1984. *Principles of Biochemistry*. CBS Publishing, New Delhi.
- Martin SAM, Król E. *Nutrigenomics and Immune Function in Fish: New Insights From Omics Technologies*. Dev Comp Immunol. 2017; 75(Suppl C): 86–98.
- Panserat S, Kaushik S. 2010. *Regulation of Gene Expression by Nutritional Factors in Fish*. Aquacult Res 41: 751–762.
- Panserat S, Kirchner S, Kaushik S. 2007. *Nutrigenomics*. In: Nakagawa H, Sato M, Gatlin D III (eds) Dietary supplements for the health and quality of cultured fish. CAB International North America, USA, pp 210–229
- Pedro M Rodrigues, Tomé S Silva, JorgeDias and FlemmingJessen. 2012. Proteomics *in Aquaculture: Applications and Trends. Journal of Proteomics*. 75: 4325-4345
- Primrose SB. 1989. *Modern Biotechnology*. Blackwell Scientific, Oxford.
- Rodney B. 1998. *Concepts in Biochemistry*. Cole Publishing Company London.

I. Course Title : Larval and Broodstock Nutrition

II. Course Code : FNT 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand the role of nutrition in reproductive performance and larval development of fish and shellfish

V. Theory

Unit I

Embryonic and larval development: Nutritional profile of egg yolk and mechanism of egg yolk utilization, Degradation of egg yolk platelets and granules, Utilization of egg protein, Amino acid and lipid, Influence of abiotic factors on yolk absorption; Criteria for evaluation of early larval development

Unit II

Larval digestive system: Ontogenesis of digestive systems, Digestion and absorption of protein and lipid, Mechanism of transition from endogenous to exogenous nutrition.

Unit III

Larval nutrition: Importance of live foods, Weaning diets and their importance in larval nutrition, Nutritional requirements and deficiency symptom, Nutritional status of larvae.

Unit IV

Broodstock nutrition: Effect of nutrition on fecundity, Fertilization, Embryonic development and larval quality.

Unit V

Improving brood-stock performance: Special ingredients and specific nutrients for improving gonadal development and reproductive performance; Effective feeding periods for optimum brood-stock performance.

Unit VI

Feeding strategies: Manual, Mechanical and automatic feeding; Feeding devices and strategies, Larval feeding behaviour and feed management.

VI. Practical

Preparation of larval feed, Nutritional profiling of egg yolk and larvae, Nutritional analysis of live food organisms, Estimation of proteases in larvae, Estimation of gonado-somatic index and fecundity.

VII. Suggested Reading

- CIFE, 1993. *Training Manual on Culture of Live Food Organisms for Aqua Hatcheries*. Central Institute of Fisheries Education, Versova, Mumbai.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer Academic Publishers, London.
- Holt JG. 2011. *Larval Nutrition*. John Wiley and Sons, Inc.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

I. Course Title : Introduction to Biomolecules

II. Course Code : FNT 604

III. Credit Hours : 2+1

IV. Aim of the course

To study the importance of different biomolecules and their biological functions in a biosystem.

V. Theory

Unit I

Definition, types, structure, properties of biomolecules: Protein, Lipids, Carbohydrates, Vitamins, Minerals, Nucleic acids and Water as biomolecules and its applications, Water: importance of water in biological systems with special reference to the maintenance of native structure of biological molecules, Water as a universal solvent, pH, buffers, buffer capacity and their importance in biological systems.

Unit II

Protein and amino acids: Protein and its classification, Structure of proteins, Primary, Secondary (helix and pleated sheet), Tertiary and Quaternary structures of protein and forces stabilizing it, Denaturation and renaturation of proteins, Ramachandran's plot, Amino acidsanditsstructural features, Stereoisomerism, R and S notations, Structure and classification of standard amino acids, pH titration curve, Isoelectric pH of amino acids and pKa value, Peptidesand structure of peptide bond.

Unit III

Lipids: Classification and their biological role, Fatty acids: nomenclature, structure and properties of saturated, Unsaturated, Essential fatty acids, Triacylglycerols; Nomenclature, Physical properties, Chemical properties (hydrolysis, esterification, Rancidity of fats, saponification value, iodine value, Acid value) and significance, Chemistry and biological function of eicosanoids, fats, waxes and phospholipids and cholesterol.

Unit IV

Carbohydrates: Classification and biological importance of carbohydrates, Structure of monosaccharides, stereochemistry, D and L, Epimers, Anomers, Diastereomers and Mutarotation, Disaccharide, Establishment of glycosidiclinkage in sucrose, Maltose, lactose, Deoxy ribose and ribose sugar, Polysaccharides: Types, partial structure, Occurrence and importance of starch, Glycogen, Insulin, Cellulose, Chitin, Pectin, Reactions of carbohydrates Molisch's, Benedicts / Fehlings, picric acid, Barford's, Bials, Seliwanoff's, Osazone test.

Unit V

Vitamins and minerals: Water soluble vitamins –B complex and Vitamin C: Structural formula, Co-enzyme forms, Biological role, Deficiency symptoms and dietary sources, Vitamin C as a redox reagent, Fat soluble vitamins**,** A, D, E, and K: structure, Dietary sources, Requirements, Deficiency symptoms and Biological role, Mineral macronutrients and micronutrients, Dietary sources, Physiological functions, Deficiency disorders, Absorption and excretion, Importance of selenium and fluorine, Metals in biological system: Fe, Co, Ca, Mb, Cu.

Unit VI

Nucleic acids and water: Nucleic acids, Nucleosides and Nucleotides; Structure and properties, Phosphodiester bonds, Chemical differences between DNA and RNA and its significance, Different class of RNAs - mRNA, rRNA, tRNA and snRNA. Primary, secondary and tertiary structure of tRNA, Determination of primary structure (sequencing) of DNA using Maxam-Gilbert method and Sangers method and limitations.

VI. Practical

Preparation of buffers, Qualitative estimation of carbohydrates, Quantitative estimation of glucose and maltose by DNS method and any other methods, Quantitative estimation of protein by Biuret and Folin Lowry's method, Estimation of lipid by Zak's method, Estimation of vitamin C.

VII. Suggested Reading

- *Biochemistry*, 4th Edition Donald Voet, Judith G. Voet.

- *Biochemistry*. Lubert Stryer. W.H. Freeman and company, New York.
- *Experimental biochemistry*. Beedu Sashidhar Rao and Vijay Deshpande. IK international Pvt Ltd.
- *Lab Manual in Biochemistry, Immunology and Biotechnology*. Arti Nigam and ArchanaAyyagari. Tata McGraw-Hill.
- Lehninger Principles of Biochemistry David L. Nelson and Michael M Cox. Publisher: W.H.Freeman and Co Ltd.
- *Principles of Biochemistry* (with special reference to fishes). Prof. Kasturi Samantaray. Narendra Publishing House.

I. Course Title : Macro and Micronutrient Nutrition

II. Course Code : FNT 605

III. Credit Hours : 2+1

IV. Aim of the course

To understand recent developments in macro and micro nutrient nutrition for fish and shellfish

V. Theory

Unit I

Protein and aminoacids: Requirements, Functional roles of aminoacids, Ideal protein concept, Nitrogen excretion, Amino acid antagonism, Improving nitrogen Retention, dietary supply of synthetic amino acids in different forms.

Unit II

Lipid and essential fatty acids: Functions and deficiencies, Fatty acid oxidation, antioxidants, Role of phospholipids and steroids.

Unit III

Optimization of carbohydrates in diets: Strategies for improving carbohydrate utilization; Potential of exogenous enzymes, solid state fermentation (SSF).

Unit IV

Micronutrients: Physiological roles and functions of vitamins and minerals; Forms of supply of minerals and vitamins, Deficiency symptoms.

Unit V

Recent developments in energy nutrition and feed additives: Recent advances in nutritional energetics and feed additives, Medicated feeds (farm-made and commercial), Regulations and certification of feed additives.

Unit VI

Designer fish production: Tailoring flesh quality, food safety, Roles of nutrients and additives (fatty acids, antioxidants, drugs etc.), Flesh quality evaluation (colour, texture and sensory), Estimation of fatty acids, Amino acids and minerals in ingredients, feeds and flesh of fish and shrimp; Dietary effects on nitrogen excretion.

VI. Practical

Protein quality estimation (PER, NPU). Digestibility studies. Estimation of fatty acids and amino acids.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed

Technology. ADCP/REP/80/11. F.A.O., Rome.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE. 1989. *Fish Nutrition*, Academic Press, San Diego, California.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

I. Course Title : Bioenergetics

II. Course Code : FNT 606

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles of energetics, nutrient energy and its metabolic scope in larval, growout and broodstock fish

V. Theory

Unit I

Energy requirements of fish: Principles and methods; Factors affecting energy requirement; Energy budgeting, Metabolic rate and Factors affecting it.

Unit II

Metabolic scope: It's variation in herbivores, Omnivores and Carnivores.

Unit III

Larval energetics: Growth, metabolism and energy budget, Energy relationship between egg and hatchlings, Energy flow during early ontogenesis.

Unit IV

Energetics of growout and brood stock: Energetics of feeding and digestion, Energy requirements for growth and reproduction, Energetics of gonadal maturation and gamete production, Bioenergetics of spawning, Relationship between feeding and maturation.

Unit V

Lipids: Lipids as energy source, Net energy supply from lipids, Fatty acid biosynthesis and degradation, Transport and deposition of lipids in finfish and shellfish, Fatty acid bioconversion (elongation and desaturation) in different species, Importance of phospholipids and cholesterol.

Unit VI

Carbohydrates: Carbohydrates as energy source; Net energy supply from carbohydrates; Biosynthesis, Storage and Degradation, Interaction of carbohydrate with lipid and protein.

VI. Practical

Estimation of oxygen consumption; Estimation of energy flow, Estimation of gross energy and digestible energy of feed; Study of energy requirements of, herbivorous omnivorous and carnivorous fish; Estimation of total and free cholesterol; Estimation of metabolic rates.

VII. Suggested Reading

- Cho CH and Kaushik SJ. 1990. *Nutritional Energetics in Fish: Energy and Protein Utilization in Rainbow Trout. World Review on Nutrition and Dietetics*. 61: 132-172.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes*. CRCPress.
- Halver JE and Hardy RW. 2002. *Fish Nutrition. Academic Press*, London.
- Houlihan D, Boujard T and Jobling M. eds. 2008. *Food Intake in Fish*. John Wiley and Sons.
- Jobling M. 1994. *Fish Bioenergetics*. Chapman and Hall, London
- Kaushik SJ. 1998. *Nutritional Bioenergetics and Estimation of Waste Production in Non-Salmonids. Aquat Living Resour* 11(4): 211-217.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Tyler P and P Calow. 1985. *Fish Energetics: New Perspectives*. Croom Helm Ltd. Provident House, Burrell Row, Beckenham, Kent, London.

I. Course Title : Nutraceuticals as Functional Foods

II. Course Code : FNT 607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutraceuticals in the physiological wellbeing of fish and shellfish.

V. Theory

Unit I

Functional foods v/s Nutrceuticals: Definitions, concepts and beneficial roles, Application of functional foods in immune modulation and disease prevention.

Unit II

Characteristics of nutraceuticals and delivery systems: Nanotechnology of drug delivery system such as biocompatible polymers, Stimuli responsive polymers

Unit III

Modes of action and benefits: Probiotics, Prebiotics, Stanols and Sterols, Their immunomodulatory effects.

Unit IV

Stress mitigation and growth enhancement: Inter-relationships of stress and growth in fish, Functional feed additives and role of functional foods in stress mitigation and growth enhancement.

VI. Practical

Estimation of immunomodulatory parameters (lysozyme, NBT, MPO, antibody titre), Estimation of antioxidant enzymes (SOD, catalase, GPx), Extraction of bioactive compounds, *in vitro* antioxidant assay, Pro PO.

VII. Suggested Reading

- Debnath D, Sahu NP, Pal AK, Baruah K, Yengkokpam S and Mukherjee SC. 2005. *Present scenario and future prospects of phytase in aquafeed. Asian-Aust. J. Anim. Sci*, 18(12), pp.1800-1812.

- DeFelice SL. 1995. *The nutraceutical revolution: its impact on food industry R and D. Trends in Food Science and Technology*, 6(2), pp.59-61.
- Kalra EK. 2003. *Nutraceutical-definition and introduction. AapsPharmsci*, 5(3), pp.27-28.
- Kartik Baruah, Asim K Pal, Narottam P Sahu, Kamal K Jain, Subhas C Mukherjee, DipeshDebnath. 2005. *Dietary protein level, microbial phytase, citric acid and their interactions on bone mineralization of Labeo rohita (Hamilton) juveniles*, 36(8): 803-812.
- Luckstadt C. 2008. *Utilization of acidifiers in nutrition and feeding of tropical fish–a mini-review. Bulletin of Fish Biology* 10(1/2), pp.105-109.

I. Course Title : Feed Intake and Feeding Behaviour

II. Course Code : FNT 608

III. Credit Hours : 1+2

IV. Aim of the course

To study the mechanism of feed intake and feeding behaviour.

V. Theory

Unit I

Gustation and feeding behaviour: Chemoreception, olfactory, Peripheral gustation sensation, Gustatory pathways in the Central Nervous System, Taste and feeding behavior.

Unit II

Feed intake: Techniques for the measurement of voluntary feed intake, Stomach content analysis, Chemical markers, Direct observation and video recording, Demand feeder, X-radiography, factors affecting voluntary feed intake, Effect of feeding time on feed intake and growth.

Unit III

Regulation of feed intake: Neuropeptides and hormones, Inhibitory peptides, Stimulatory peptides, Growth hormones, Nutrient receptors and transporters, Hormonal control of metabolism; Nutrients influencing feed intake gustatory feeding stimulants.

Unit IV

Physiological effects of feeding: Methods of feeding and short term effects of meal on post-prandial levels of nutrients; Tissue metabolic physiology; Feeding frequencies, Physiology of starvation and feed restriction.

VI. Practical

Measurement of feed intake by chemical marker, Feed intake measurement with respect to temperature, Experiment on feeding stimulant, Feed intake and blood glucose correlation, Comparative intake of natural vs artificial feed, Monitoring feeding behaviour in different species, Evaluation of fish response to feed in terms of feed detection and intake, Study of crustacean feeding behavior in different life stages, Study of digestive anatomy and morphology and their correlation with digestive physiology, Impact of feeding regimes on feed intake.

VII. Suggested Reading

- Balasubramaniam A, Rigel DF, Chance WT and Fischer JE. 1992. Central and peripheral effects of sculpin pancreatic polypeptide and anglerfish peptide Y in rats. *Pept. Res.* 5, 106–109.

- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell Science, France. • Lovell RT. 1998. *Nutrition and Feeding of Fishes*, Kluwer Academic Publishers.
- Volkoff H. 2016. The neuroendocrine regulation of food intake in fish: a review of current knowledge. *Front. Neurosci.* 10: 540.
- Volkoff H, Bjorklund JM and Peter RE. 1999. Stimulation of feeding behavior and food consumption in the goldfish, *Carassius auratus*, by orexin-A and orexin-B. *Brain Res.* 846, 204–209.

I. Course Title : Feed and Environment

II. Course Code : FNT 609

III. Credit Hours : 2+1

IV. Aim of the course

To understand the impact of nutrient utilization on environment

V. Theory

Unit I

Nutrient dynamics: Influence of nutrient cycles on food web/chain. Influence of detrital food web on nutrient distribution, Nutrient loading through feed and fertilizer.

Unit II

Stress and nutrition: Influence of stress on feed intake, Digestion and absorption, Stress indicator and nutritional strategies to mitigate stress.

Unit III

Eco-friendly feed: Use of high energy diets, Optimizing protein energy ratio, Ideal aminoacid profile, Improving nutrient utilization through exogenous phytase and acidifiers, Methods of enhancing feed digestibility, Biofloc and probiotics influences on nutrient utilization.

Unit IV

Impact of feed on environment: Judicious use of feed and nutrients; Nutrient build up on water quality; Nutrient management in different aquaculture systems (extensive, semi-intensive, intensive- recirculatory systems); Nutritional strategies to reduce the nutrient flow in aquaculture system, Contribution of feed waste to organic load of aquaculture production systems, Reducing environmental pollution (use of additives, weeds etc.).

Unit V

Productivity and fish production: Optimization of natural productivity for increasing fish production, Different food chains in aquatic ecosystem, Feeding behavior and feeding niche, Effect of environmental parameters on appetite of fish

Unit VI

Environmental impact assessment: Rules and Regulations on waste management in aquaculture (International and National)

VI. Practical

Assessment of water quality parameters (ammonia, nitrite, nitrate, chloride phosphate etc.) as affected by feeds; Levels of feeding and water quality; Stress enzymes (catalase, SOD, glutathione peroxidase), stress hormone (cortisol).

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980.
- Cho CY and Bureau DP. 1997. Reduction of waste output from salmonid aquaculture through feeds and feeding. *The Progressive Fish-Culturist*, *59*(2), pp.155-160.
- Cho CY and Bureau DP. 2001. A review of diet formulation strategies and feeding systems to reduce excretory and feed wastes in aquaculture. *Aquaculture research*, *32*, pp.349-360.
- Chua TE. 1992. Coastal aquaculture development and the environment: the role of coastal area management. *Marine Pollution Bulletin*, *25*(1-4), pp.98-103.
- Cripps SJ and Bergheim A. 2000. Solids management and removal for intensive land-based aquaculture production systems. *Aquacultural engineering*, *22*(1-2), pp.33-56.
- Folke C and Kautsky N. 1992. Aquaculture with its environment: prospects for sustainability. *Ocean and coastal management*, *17*(1), pp.5-24.
- Halver JE and Hardy RW. 2002. Fish Nutrition. Academic Press, London.
- Kaushik SJ. 1998. Nutritional bioenergetics and estimation of waste production in non-salmonids. *Aquatic Living Resources*, *11*(4), pp.211-217.
- Papatryphon E, Petit J, Van Der Werf HM, Sadasivam KJ and Claver K. 2005. Nutrient-balance modeling as a tool for environmental management in aquaculture: the case of trout farming in France. *Environmental Management*, *35*(2), pp.161-174.
- Tacon AG and De Silva SS. 1997. Feed preparation and feed management strategies within semi-intensive fish farming systems in the tropics. *Aquaculture*, *151*(1-4), pp.379-404.
- Talbot C and Hole R. 1994. Fish diets and the control of eutrophication resulting from aquaculture. *Journal of Applied Ichthyology*, *10*(4), pp.258-270.

List of suggested Journals

- *Animal (Reproduction, Nutrition, Development)*
- *Animal Nutrition and Feed Technology*
- *Aquaculture Nutrition*
- *Archives of Animal Nutrition*
- *Food and Nutrition Bulletin*
- *Indian Journal of Animal Nutrition*
- *International Journal for Vitamin and Nutrition Research*
- *International Journal of Food Sciences and Nutrition*
- *Journal of Animal Physiology and Animal Nutrition*
- *Journal of Nutritional Biochemistry (Nutrition Reports International)*
- *Journal of Nutritional Science and Vitaminology*
- *Fish Physiology and Biochemistry*
- *Aquaculture*
- *Aquaculture International*
- *Aquaculture Research*
- *Journal of Aquaculture*
- *Journal of the World Aquaculture Society*
- *North American Journal of Aquaculture*
- *Reviews in Fisheries Science and Aquaculture*
- *Ichthyological Research*
- *Journal of Applied Ichthyology*

- *Journal of Applied Physiology*
- *Journal of Aquaculture in the Tropics*
- *Animal Feed Science and Technology*
- *Journal of Animal Feed Science and Technology*
- *Journal of Animal and Feed Sciences*

List of suggested e-Resources

- http://www.aquafeed.com
- https://articles.extension.org/pages/58703/fish-nutrition
- https://www.liveaquaria.com/article/198/?aid=198
- https://onlinelibrary.wiley.com/journal/13652095
- https://www.usgs.gov/ecosystems/fisheries-program/science/fish-physiology-and-behavior?
- https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/HealthBenefits
- https://thefishsite.com/articles/
- https://www.ncbi.nlm.nih.gov/books/
- https://nutrigenomicsinstitute.com
- https://www.karger.com/
- https://www.nature.com/subjects/nutrigenomics
- https://www.dnafit.com/

Suggested Broad Areas for Master's and Doctoral Research

- Study on essential aminoacids and vitamins requirement of fishes
- Accurate quantitative requirements of essential fatty acids particularly larval development and maturing broodstock
- Nutrient and energy budget in fed fish culture
- Optimization of inclusion level of non-conventional feed resources in fish feed
- Nutrient gene interaction studies in fish
- Feed additive for promotion of productivity and growth in fishes
- Development of appropriate feed processing technology for improving the feed and nutrient use efficiency
- Microbial nutrition
- Nutraceuticals and functional food acids
- Quantitative estimation of feed intake: natural vs artificial feed
- Digestibility of natural and artificial feed
- Energetics of utilization of natural and artificial feed
- Energetics of utilization of animal vs plant ingredients
- Energetics of growth vs reproduction
- Feeding standards for cultivable species
- Feeding strategy to eliminate waste
- Utilization of refinery waste as single cell protein
- Farmer friendly methods for detoxification of anti-nutritional factors
- Immunostimulants and growth promoters
- Redefining protein-energy ratio in shrimp diet with respect to salinity
- Digestibility due to plant to animal ingredient ratio
- Enhancement of digestibility of plant feed ingredients
- Reduction of dietary protein content through amino acid balance
- Optimizing protein to lipid, protein to carbohydrate content in fish and shrimp diets
- Dietary lipid source and flesh lipid quality
- Optimizing PUFA and HUFA content in individual species
- Impact of lipid peroxidation on growth and flesh quality
- Starch utilization and immunity status
- Optimization of gelatinized to non-gelatinized starch content in feed
- Source of carbohydrate and their utilization
- Study the key enzymes for carbohydrate metabolism
- Development of species specific vitamin and mineral premix

- Energy utilization from carbohydrate sources
- Enzyme coating and feed additives in pelleted feed
- Low cost microencapsulated, micro coated and micro bound diets
- Fortification of larval and broodstock diets
- Utilization of unconventional ingredients
- Nutritional contribution of natural food for growth
- Nutritional comparison of natural and artificial feed
- Biochemical mechanism of endocrine function
- Hormonal regulation of calcium and phosphorous metabolism
- Immunostimulants/Immunomodulators
- Gene regulation by lipids and carbohydrates
- Fasting, feed intake and nutrient utilization.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Aquatic Animal Health Management

Preamble

(Aquatic Animal Health Management)

Aquatic animals play a significant role in our societies and ecosystems. Aquatic animals include not only fish but also a myriad of other animals, viz., amphibians, marine mammals, crustaceans, reptiles, molluscs, aquatic birds, aquatic insects, starfish and corals that live in water for most of their life. The global human population is increasing, so also the demand for aquatic food products. Aquaculture, the culture of aquatic animals for food, is one of the most lucrative economic activities and is considered as one of the means of assuring food and nutritional security for humans. It contributes about 50% of global fish food consumption and presents the fastest growing food-producing sector in the world. The annual growth rate for aquaculture is 8-10% compared to 3% for livestock and 1.6% for capture fisheries. Like humans and terrestrial animals, aquatic animals - both cultured and wild - can be affected by infectious pathogens such as viruses, bacteria, fungi, protozoa and parasites. The occurrence of disease in the aquatic animal was known before the 1900s but was of no practical significance. Over the years, this branch of science is developed separately from the health sciences of other animal groups. It also requires a much different approach than terrestrial animals. Infection and disease in aquatic animals are common but can become severe under certain conditions. It is particularly true in intensive aquaculture practices that tend to provide a platform for the emergence of pathogens. The risk of pathogen transfer is generally considered greater for movement of live aquatic animals. The global trade in aquatic animals and their products offer avenues for the trans-boundary spread of pathogens. Few diseases of aquatic animals are known to have implications for human health. Sustainable growth of aquaculture is threatened by both known diseases and new diseases, which may become pandemic. A disease outbreak can devastate farmed populations and severely impact the short-term profitability and even long-term viability of aquaculture businesses. Around the world, diseases caused serious economic losses to aquaculture. Globally, the economic loss due to diseases in aquaculture is estimated at US$ 1.05 - 9.58 billion/year. Aquatic animal health must, therefore, be managed effectively to protect the productivity of aquaculture industries, access to international markets and aquatic environments. Successful aquatic animal health management relies on the accurate and rapid diagnosis of various diseases. New assays from genetic engineering using nucleic acid probes, next-generation sequencing, etc. have come as a boon to the aquaculture industry. In all cases, a quick response is essential to enable correct diagnosis of the problem and to allow for appropriate measures to be taken.

Recent pandemics have shown that global production systems are epidemiologically connected and, consequently, aquatic animal diseases present a shared global threat that demands global solidarity. The world now depends on a sustainable future for aquaculture and improved aquatic animal health management is critical to its continued and growing contribution to global food security. The improved control of transboundary diseases requires the wider and more consistent implementation of OIE (Office International des Epizooties or World Organisation for Animal Health) standards, particularly on disease notification. For animal (including aquatic animal) health and zoonoses, the World Trade Organization (WTO) recognise the standards developed by the OIE as a reference within the Sanitary and

Phytosanitary Measures (SPS Agreement). The Aquatic Animal Health Code (AAHC) includes standard international trade in the welfare of cultured fish and utilisation of antimicrobial agents in aquatic animals and their merchandise. All members of the WTO, including India, must have an aquatic animal health program that meets the OIE standards. The FAO's Code of Conduct for Responsible Fisheries also provide a good base for the national and international cooperation in harmonizing aquatic animal health management activities. Further, the FAO's "One Health Program" aims for improved animal and public health, enhanced food safety and security, and improved livelihood while protecting the ecosystem.

The information on diseases of national importance may help developing national disease control strategies and to comply with regional and international disease reporting requirements. A national list of diseases would also allow the development of national strategies around some of these diseases. Recently, the Department of Fisheries, Government of India has formulated a Draft on "The Aquatic Animal Disease and Health Management Bill-2019", that justifies the importance of this branch of science. The draft Bill seeks to provide for prevention and control of diseases of aquatic animals, prevention of outbreak, transboundary ingress and inter-regional spread of aquatic animal diseases, regulation of quality usage of inputs in aquaculture, control of residues in aquatic animals and their products for the safety of human health and the environment in view to ensure sustainable production, minimization of economic losses and to meet international obligations of India and for the facilitation of import and export of aquatic animals and their products and matters connected therewith or incidental thereto.

Against these backgrounds, the revised Subject Matter Area under the Aquatic Animal Health Management discipline for the M.F.Sc. and Ph.D. programme aims to generate specialized human resources to benefit aquaculture and allied industries of the country and to understand and manage the aquatic animal diseases and related issues that affect the national and international trade. In this discipline, the conventional courses on bacterial, fungal, viral, parasitic and non-infectious diseases and their pathology have been updated in line with the recent advancements and national and international initiatives as enlightened above, and current subjects such as principles of aquatic animal health management, fish pharmacology and therapeutics, fish immunology, epidemiology and disease surveillance and aquatic wildlife health have been included at Masters level. At the Doctoral level, courses on biotechnological tools in fish health management, molecular virology, fish bacterial diseases mechanisms, pathobiology of fish parasitic infection, immunology and vaccination, cellular pathology, aquaculture medicine and techniques in toxicology have been incorporated in line with the recent developments in disease diagnosis and control as well as national and international regulations.

Course Title with Credit Load
M.F.Sc. in Aquatic Animal Health Management

Course Code	Course Title	Credit Hours
	Major Courses	
AAH 501	Principles of Aquatic Animal Health Management	2+1
AAH 502	Bacterial and Fungal Diseases of Finfish and Shellfish	2+1
AAH 503	Viral Diseases of Finfish and Shellfish	2+1
AAH 504	Parasitic Diseases of Finfish and Shellfish	2+1
AAH 505	Fish and Shellfish Pathology	2+1
AAH 506	Fish and Shellfish Immunology	2+1
AAH 507	Principles of Fish Pharmacology and Therapeutics	1+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
AAH 508	Non-Infectious Diseases and Disorders of Finfish and Shellfish	1+1
AAH 509	Epidemiology and Disease Surveillance	1+1
AAH 510	Aquatic Wildlife Health	2+0
AAH 511	Disease Diagnostic Techniques	2+1
	Supporting courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
AAH 591	Master's Seminar-I	0+1
	Masters' Thesis Research	**30 Credits**
AAH 599	Master's Research (Semester III)	0+15
AAH 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc in Aquatic Animal Health Management

I. Course Title : Principles of Aquatic Animal Health Management

II. Course Code : AAH 501

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the principles of aquatic animal health management, biosecurity and specific issues associated with the system. It helps the graduates to methodically address the problems and to improve the production efficiency and reliability, and reduce economic loss due to diseases

V. Theory

Unit I

Introduction to aquatic animal health management: Introduction to various aspects of health management; Stress response; Definition of health and disease; Pathogen carriers; Simple fish disease models.

Unit II

Legislative framework: Principles of quarantine; Zoning and compartmentalization; Live fish transportation; Import risk analysis; Health certification, Principle, Procedure, The regulatory body for aquaculture health certification.

Unit III

One health concept of OIE: World animal health organization and importance for trading; One health concept of OIE.

Unit IV

Health management measures in an open system: Health management measures in cages, Pen, Reservoirs and open-water aquaculture; Interactions of farmed and Wild animals; Disease exchange with wild

Unit V

Management measures for host, environment and pathogen: Management measures for pathogen; Therapeutics and sanitizers; Management measures for the environment; Bioremediators, Biocontrol agents, Shrimp toilet; Management measures for the host; Specific pathogen-free (SPF), Specific pathogen-resistant (SPR) and Specific pathogen-tolerant (SPT); Probiotics; Immunomodulators; Concepts of vaccination.

Unit VI

Developing management practices and biosecurity principles: Health maintenance, Better management practices (BMP), Good aquaculture practices (GAP), Hazard analysis and Critical control point (HACCP) and Biosecurity principles in aquaculture.

VI. Practical

Case study; Disease risk analysis; Demonstration of different management measures; Demonstration of different diagnostic tools; Application of therapeutics; Application of sanitizers, Disinfectants; Visit to SPF shrimp larval production centres, Biosecure shrimp grow-out farms; Documentation and comparison of different management practices at farm/hatchery level.

VII. Suggested Reading

- *Aquaculture Biosecurity*. Blackwell Pub. Professional, Iowa, 2006
- Mishra BK. 2007. *Disease Management in Freshwater Pisciculture* GeetaSomani, Udaipur.
- Ferguson H.W. 2006. *Systematic Pathology of Fish*. Scotain Press, London
- Patra NC. 2014. *Aquatic Animal Diseases and Management*. Narendra Publishing House, Delhi
- Post G. 1987. *Textbook of Fish Health*. TFH Publications, Inc., Canada
- Sindermann CJ. 1990. *Principal Diseases of Marine Fish and Shellfish*. Academic Press Inc., San Diego.
- Stockham SL. 2002. *Fundamentals of Veterinary Clinical Pathology*. Lowa State Press, Lowa 2
- Sugama K. 1998. *Manual of Fish Diseases Diagnosis*. Nippon veterinary and animal science University, Japan.

I. Course Title : Bacterial and Fungal Diseases of Finfish and Shellfish

II. Course Code : AAH 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the bacterial and fungal diseases of finfish and shellfish that affects the global aquaculture industry. It provides an exhaustive knowledge of bacterial and fungal infections, their virulence, pathogenesis, epidemiology, treatment and control. It also aims to train graduates to systematically diagnose the problems and evolve ways to manage bacterial and fungal diseases.

V. Theory

Unit I

Introduction to microbial infection: Pathogenesis, Virulence Mechanisms, Epidemiology, Prophylaxis, Therapeutic measures.

Unit II

Bacterial diseases of finfish: Aetiology, Epidemiology, Pathogenicity, Virulence, Prophylaxis, Treatment and control measures of bacterial diseases of finfish with emphasis on furunculosis, Aeromoniasis, columnaris disease, Bacterial kidney disease, Bacterial gill disease, Vibriosis, mycobacteriosis, Edwardsiellosis, Flavobacteriosis, Francisellosis, Enteric red mouth disease, Pasteurellosis, Piscirickettsiosis, Streptococcosis, Lactococcosis, pseudomonas septicaemia, Chryseobacteriosis, Clostridial disease, *Aerococcus viridans* infection.

Unit III

Bacterial diseases of shellfish: Aetiology, Epidemiology, Pathogenicity, Virulence, Prophylaxis, Treatment and control measures of bacterial diseases of shellfish with emphasis on Vibriosis, Acute Hepatopancreatic Necrosis Disease (AHPND), *Hepatobacter penaei* infection or Necrotizing Hepatopancreatitis (NHP), Rickettsial diseases, Mycobacteriosis.

Unit IV

Fungal diseases of finfish: Aphanomycosis, Epizootic Ulcerative Syndrome (EUS) in fish- Aetiology, Epidemiology, Pathogenesis diagnosis and management, Cotton wool disease, Branchiomycosis; Aspergillosis.

Unit V

Fungal diseases of shellfish *Lagenidium* spp., *Sirolpidium* spp., *Haliphthoros* spp., *Fusarium* spp., *Aphanomy cesastaci* infection.

Unit VI

Antimicrobial resistance Use and abuse of antibiotics in aquaculture; Antibiotic resistance; Multidrug resistance; Molecular mechanisms.

VI. Practical

Sampling techniques; Culture techniques; Case study; Examination of moribund fish for bacterial diseases; Isolation and identification of bacterial pathogens; Serological diagnostic techniques; Molecular diagnostic techniques; Antibiotic sensitivity assay; Identification of virulence factors; Isolation, culture and identification of fungal pathogens, Maintenance and preservation of microbial cultures

VII. Suggested Reading

- Austin B. 2007. *Bacterial Fish Pathogens.* Springer Publishers, U.K.
- Bullock LG. 2014. *Diseases of Fishes*. NPH, Delhi
- Chan VL. 2006. *Bacterial Genomes and Infectious Diseases.* Humana Press, New Jersey.
- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish.* Washington Sea Grant Publication, Seattle
- Hadwin G. 2017. *Diseases of Fishes*. Bacterial diseases of fishes and identification of fish pathogenic bacteria. Random Pub., New Delhi.
- Inglis V. 1993. *Bacterial Diseases of Fish*. Blackwell Scientific Publications, London
- Inglis V *et al*. 2011. *Bacterial Diseases of Fish*. John Wiley and Sons, New Jersey.
- Snieszko SF. 1971. *Diseases of Fishes*. Book 2A. TFH Publications Inc, Ltd., New Jersey.
- Wilson M. 2002. *Bacterial Diseases Mechanisms.* Cambridge University Press, Oxford.
- Woo PTK and Bruno DW. 2011. *Fish Diseases and Disorders* Vol-3. CABI Publishers, UK.

I. Course Title : Viral Diseases of Finfish and Shellfish
II. Course Code : AAH 503
III. Credit Hours : 2+1

IV. Aim of the course

To provide both basic and applied knowledge on viral diseases of finfish and shellfish that impacted the global aquaculture industry. It imparts an exhaustive knowledge of viral infections, their pathogenesis, epidemiology, treatment and control in fish and shellfish. It also aims to equip graduates to diagnose the problems and evolve ways to manage the diseases.

V. Theory

Unit I

Viral classification, infection and isolation: General biology of viral infections; Virus classification (ICTV); Virus replication; Virulence markers; Viral evasion; Principles of cell culture; Development of primary cell culture; Maintenance of cell lines; Scaling up of cell culture; Characterization and preservation of cell lines.

Unit II

OIE listed viral pathogens of finfish: Pathogenesis, Molecular biology, Epidemiology and control of OIE listed viral pathogens/ diseases of finfish: Epizootic Haematopoietic Necrosis (EHN), Infectious haematopoietic necrosis (IHN), Spring viraemia of carp (SVC), Viral Haemorrhagic Septicaemia (VHS), Infectious salmon anaemia (ISA), Salmonid Alphavirus (SAV) and Red Seabream Iridoviral Disease (RSIVD), Cyprinid Herpesvirus 3 (CyHV-3 or KHV).

Unit III

Non-OIE listed viral pathogens of finfish: Pathogenesis, molecular biology, Epidemiology, and control of non-OIE listed viral pathogens/ diseases of finfish; *Oncorhynchus masou* virus (OMV), Viral Encephalopathy and Retinopathy (VER), Channel Catfish Virus (CCV), Lymphocystis, Tilapia Lake virus (TiLV), Carp Edema Virus (CEV), Piscine orthoreovirus, Cyprinid Herpes Virus-2 (CyHV-2).

Unit IV

OIE listed viral pathogens of shrimp and prawn: Major viral pathogens of commercially important cultured crustaceans with special reference to shrimp and prawn; clinical signs, Pathogenesis, Molecular characterization, Diagnostic methods, Epidemiology and Control associated with white spot syndrome virus (WSSV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Taura Syndrome Virus (TSV), Yellow Head Virus (YHV) genotype-1, Infectious Myonecrosis Virus (IMNV), *Macrobrachium rosenbergii* nodavirus (MrNV).

Unit V

Non-OIE listed viral pathogens of shrimp: Major viral pathogens of commercially important cultured crustaceans with special reference to shrimp and prawn; clinical signs, pathogenesis, molecular characterization, diagnostic methods, epidemiology and control associated with monodon baculovirus (MBV), hepatopancreatic parvo-like virus (HPV), baculovirus penaei (BP), baculovirus midgut gland necrosis virus (BMNV), Laem-Singh virus (LSNV), gill-associated virus (GAV), extra small virus (XSV), shrimp hemocyte iridescent virus (SHIV), reovirus, covert mortality nodavirus (CMNV).

Unit VI

Viral diseases of molluscans: Introduction to viral diseases of molluscans - Ostreid Herpesvirus 1 (OSHV-1), Abalone Herpes Virus (AbHV), Haemocytic Infection Virus disease (HIV), Oyster Velar Virus (OVV)

VI. Practical

Sampling techniques; Case study of viral diseases; Examination of shrimp; freshwater prawn and molluscs for viral infection; Examination of moribund fish for viral diseases, Preservation and processing of samples; Virus isolation and replication, bioassay methods, Serological and molecular diagnostic techniques, Plaque and neutralization assay; Development of primary cell cultures for virus studies, Maintenance of cell lines, Viral bioinformatics.

VII. Suggested Reading

- Adams, JR. 1991. *Atlas of Invertebrate Viruses*. CRC Press, Boca Raton
- Andrewes C. *Viruses of Vertebrates*. Trindall and Cox, Bailliere
- Burnet FM. 1968. *Enzyme, Antigen and Virus*. Cambridge University of Press, Cambridge

- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish*. Washington Sea Grant Publication, Seattle.
- Gibbs, EPJ. 1981. *Virus Diseases of Food Animals: A World Geography of Epidemiology and Control*. Academic Press, London
- Kurstak, E. *Control of Virus Diseases*. Marcel Dekker, Inc., New York.
- Polson, A. 1993. *Virus Separation and Purification Methods*. Marcel Dekker, Inc., New York
- Purohit, SS. 1989. *Viruses, Bacteria and Mycoplasmas*. Bikaner Agro Botanical Publishers.
- Smith KM. 1963. *Viruses*. England Cambridge University Press, Cambridge
- *The Flaviviruses: Structure, replication and evolution* Chambers T.J. Publication: London Elsevier Science 2003.
- Wiedbrauk, D.L. 1995. *Molecular Methods for Virus Detection*. Academic Press, San Diego.
- Woo PTK and Bruno DW. 2011. *Fish Diseases and Disorders* Vol-3. CABI Publishers, U.K.

I. Course Title : Parasitic Diseases of Finfish and Shellfish

II. Course Code : AAH 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the parasitic diseases of finfish and shellfish. It helps to comprehend the taxonomy, morphology, biology, pathology and host-parasite relation including control measures of important parasites of aquatic organisms and to understand the significance of parasites in fish health.

V. Theory

Unit I

Host-parasite relationship: Introduction and concepts of different animal associations; Important ecological terms used in parasitology; General introduction to the classification of protozoan and metazoan parasites; Life cycle; Host-parasite relationship.

Unit II

Protozoan parasitic diseases of finfish: Diseases of importance in aquaculture, Clinical signs, Etiology, pathology, Epidemiology, Host-parasite relationship, diagnosis, treatments and control of the disease caused by protozoan parasites; Amoeba- *Neoparamoeba perurans* (Amoebic gill disease-AGD); Ciliates- *Ichthyophthirius, Cryptocaryon*, *Trichodina*; Flagellates- *Ichthyobodo* (*Costia*) *necatrix, Cryptobia, Amyloodinium, Trypanosoma*, *Trypanoplasma*; Microsporidians- *Glugea, Pleistophora*etc.

Unit III

Metazoan parasitic diseases of finfish: Diseases of importance in aquaculture, Clinical signs, etiology, Pathology, epidemiology, Host-parasite relationship, Diagnosis, Treatments and control of the disease caused by metazoan parasites, Myxozoans- *Myxobolus cerebralis, Spaerospora arenicola; Kudoa thyrsites, Tetracapsuloides bryosalmonae,* etc., Monogeneans- *Dactylogyrus, Gyrodactylus, Diplectanum, Benedenia;* Digeneans- *Diplostomum, Sanguinicola, Neascuscuticola, Schistosoma* etc., Larval trematode infection (metacercaria); Cestodes: *Diphyllobothrium latum, Caryophyllaeus, Ligula*; Nematodes: *Capillaria, Camallanus*; Acanthocephala: *Neoechinorhynchus*

Unit IV

Crustacean parasitic diseases of finfish: Diseases of importance in aquaculture, Clinical signs, Etiology, Pathology, Epidemiology, Host-parasite relationship, Diagnosis, treatments and control of the disease caused by Crustacean parasites; Branchiurans- *Argulus;* Copepods- *Lernaea, Caligus*, *Lepeophtheirus, Ergasilus;* Isopods- *Cymothoa, Cirolina, Nerocila.*

Unit V

Protozoan parasitic diseases of shellfish: Diseases of importance in aquaculture, Clinical signs, Etiology, Pathology, Epidemiology, Host-parasite relationship, Diagnosis, treatments and control of the disease caused by protozoan parasites; Ciliates-*Zoothamnium, Vorticella, Epistylis*; Cephaline gregarines; Microsporidian: Cotton shrimp disease-causing microsporidians, *Enterocytozoon hepatopenaei* (EHP); Haplosporidian.Parasitic diseases of molluscans: *Bonamia, Perkinsus, Marteilia.*

Unit VI

Antiparasitic drugs and parasitic zoonoses: Common anti-protozoal and anti-metazoal drugs applied in aquaculture; Mode of application and their action; Definition and Classification of zoonoses and Approaches to their management; Parasitic zoonoses of fish/shellfish origin: Trematodes (*Heterophyes, Clonorchis, Opisthorchis, Paragonimus, Echinostoma*etc); Cestodes (*Diphyllobothrium, Spirometra*, *Ligula*); Nematodes (*Gnathostoma, Anisakis, Angiostrongylus, Capillaria*etc.).

VI. Practical

Case studies of different organs and tissues of finfish/shellfish infected with ecto- and endoparasites; Collection, preservation and fixation of suitable samples for laboratory examination; Preparation microscopic examination of tissue impression, blood/haemolymph smears; Wet-mount preparation of gill, mucus, skin scrapings etc; Collection of faecal, intestinal content and recovery of parasites; Collection and identification of parasites; Study of morphological characters of adults and developmental stages of the protozoan and metazoan parasites of importance in aquaculture; Preparation of permanent slides, micrometry and photomicrography; Histopathological analysis of parasite-infected tissues; Examination of intermediate host for larval stages; Microscopic examination of already prepared parasitic specimens (collection of permanent slides); Identification of parasites and histological lesions

VII. Suggested Reading

- Austin B *et al*. 1951. *Infectious disease in aquaculture*. Woodhead publishing series in food science, technology and nutrition, Woodhead Pub. Ltd., Oxford.
- Baker JR. 2004. *Advances in Parasitology*. Vol-56 Elsevier Publisher, London.
- Dash G. 2012. *Freshwater Fish Parasites*. New India Publishing, New Delhi.
- Dogiel *et al*. 1961. *Parasitology of Fishes*. NP. London.
- *Infectious disease in aquaculture*. Woodhead Pub. Ltd., Philadelphia 2012
- Kabata Z. 1985. *Parasites and Diseases of Fish Cultured in the Tropics*. Taylor and Francis, London
- Klaus R. 2005. *Marine Parasitology*. CABI Publishing, U.K.
- Maule, A.G. 2006. *Parasitic Flatworms*. CAB International, USA
- Nair PR. 2008. *Encyclopedia of Fish Diseases*. Dominant Publishers, New Delhi.
- *Parasitic Nematodes*. CABI Pub., New York, 2001.
- Petrushevskii GK. 1957. *Parasites and Diseases of Fish*. Leningrad Israel Program for Scientific Translations

- Schmidt GD. 2000. *Foundations of Parasitology*. McMcgraw Hill, New York
- Singha R. 2014. *Parasite Fauna in the Wetland Fishes of India*. Today and Tomorrow Printers and Publishers, New Delhi
- Wallingford. 2012. *Fish Parasites*. CABI, Oxfordshire; Cambridge, MA
- Wiegertjes GF. 2004. *Host-Parasite Interactions*. BIOS Scientific, USA.
- Woo PTK. 2012. *Fish parasites Pathobiology and Protection*. CABI Publishing, UK.
- Zaccone G *et al*. 2009. *Fish Diseases*. Vol-2. Science Publishers, U.S.A.

I. Course Title : Fish and Shellfish Pathology

II. Course Code : AAH 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the structural and functional changes in cells, tissues and organs in relation to the development of various finfish diseases. It also imparts hands-on experience on the laboratory analyses using the tools of chemistry, biomarkers, clinical microbiology and pathology, haematology, etc.

V. Theory

Unit I

General pathology: Brief introduction to finfish and shellfish anatomy and histology; General pathology of finfish and shellfish

Unit II

Pathophysiology of fish: Pathophysiology of finfish and shellfish; Stress and stressors; General adaptation syndrome; Types of cellular adaptations; Hypertrophy, hyperplasia, Atrophy and metaplasia, Neoplasia.

Unit III

Inflammation and cellular pathology: Reversible cellular changes and accumulations; Fatty changes and pigments; Inflammation; Causes of inflammation; Cellular responses to inflammation; Mediators; various patterns of inflammation; The difference between acute and chronic inflammation; Tissue repair; Cell death; Necrosis, Apoptosis, Autophagy; Necroptosis; Their mechanisms and different morphological patterns.

Unit IV

Clinical pathology: Normal constituents of blood; Alterations in the haematological parameters and enzymes with reference to different pathological conditions in finfish; Haematology of shrimp and molluscans; Clotting mechanisms; other host defence mechanisms.

Unit V

Systemic pathology of finfish: Systemic pathology of finfish integumentary system, Respiratory system, Vascular system, Digestive system, Excretory system, Nervous system, Musculoskeletal and Endocrine system due to bacteria, Parasites and viruses.

Unit VI

Systemic pathology of shellfish: Major pathological changes due to infectious diseases in the integumentary system, Lymphoid organ, Gill, Hepatopancreas, Gut and other organs of crustaceans; Major pathological changes due to diseases in molluscans.

VI. Practical

Necropsy techniques; Collection and fixation of tissues; Complete histology and different staining techniques; Examination and interpretation of the pathological changes in fish tissues; Complete blood profile of finfish; Routes of blood collection from fish; Different staining techniques for blood cell visualization; Morphology of blood cells; Total leucocyte count; Differential leucocyte count.

VII. Suggested Reading

- Coles EH. 1986. *Veterinary Clinical Pathology*. W B Saunders Co., Philadelphia.
- Coleman WB. and Tsongalis GJ. 2009. *Molecular Pathology*. Elsevier Publisher, Boston
- Cook DJ. 2006. *Cellular Pathology*. Scion Publishers, Oxford.
- Ellis AE. 1985. *Fish and Shellfish Pathology*. Academic Press, London.
- Ferguson HW. 2006. *Systematic Pathology of Fish*. Scotain Press, London.
- Jones TC. 1997. *Veterinary Pathology*. Williams and Wilkins, Philadelphia.
- Killeen AA. 2001. *Molecular Pathology* Protocols. Humana, U.S.A
- Lloyd RV. 2004. *Endocrine pathology*. Humana Press, Totowa.
- Perkins FO. 1990. *Pathology in Marine Science*. Academic Press Inc., San Diego.
- Roberts RJ. 2012. *Fish Pathology*. Wiley-Blackwell, Chichester
- Salle AJ. 1961. *Fundamental Principles of Pathology*. MacGraw-Hill Co., New York.
- Stockham SL. 2002. *Fundamentals of Veterinary Clinical Pathology*. Lowa State Press, Lowa

I. Course Title : Fish and Shellfish Immunology

II. Course Code : AAH 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on basic principles of fish and shellfish immunology, to understand the immune responses to infection by various fish pathogens and to offer scope for the development of disease protective/prevention measures against bacteria, fungi, viruses and parasites of fish.

V. Theory

Unit I

Introduction to fish immunology: Phylogeny and ontogeny of the immune system; Lymphoid tissues and cellular components of the immune system; T and B cells; Mucosal immune system.

Unit II

Non-specific immune system of finfish: Phagocytosis; Mechanism of phagocytosis; Complement system: function, components; Complement activation.

Unit III

Specific immune system of finfish: Memory function and immunological tolerance; Antigens and antigenicity; Antigen processing; Superantigens; Haptens; Antibody: structure, types, Theories of antibody formation; Regulation of immune response.

Unit IV

Antibody-mediated and cell-mediated immunity: Cell-mediated immune response and its components; Antibody-mediated immune responses; Polyclonal and monoclonal antibody production and application; The basic concept of aptamers, Aptabodies and Edible antibodies.

Unit V

Defence mechanisms of shellfish: Invertebrate defence mechanisms; Quasi immune response

Unit VI

Immunoprophylaxis: Immunomodulation, probiotics; Aquaculture vaccines: History, concept, Development of vaccines; Advances in DNA vaccines, Recombinant vaccines, vectored vaccines, etc; Routes of administration; Adjuvants and ligands; Efficacy and Limitation of vaccines; Immune genes and their regulation.

VI. Practical

Serum separation; Preparation of antigen; Raising of antibodies; Antigen-antibody reactions: Agglutination tests, Precipitation tests: gel diffusion; ELISA; Antibody titration; Western blotting; Isolation of lymphocytes; Non-specific immune response: NBT assay, lysozyme assay; Prophenoloxidase in shrimp; Preparation of a simple vaccine and administration

VII. Suggested Reading

- Abbas AK. 1991. *Cellular and Molecular Immunology*. Saunders Publisher, Philadelphia
- Alt F. 2009. *Advances in Immunology*: Vol-103. Elsevier Publishers, New York
- Alt FW. 2009. *Advance in Immunology* Vol-102. Academic Press, London
- Anderson DP. 2003. *Textbook of Fish Immunology*. Narendra Publishing House, Delhi.
- Cooper EL. 1982. *Immunology and Immunization of Fish*. Pergamon Press, New York.
- Cooper EL. 1982. *General Immunology*. Pergamon Press, Oxford.
- Comparative immunology, microbiology and infectious diseases. Pergamon Press. Oxford, 2002
- Davis BD. *et al*. 1973. *Microbiology Harper and Row*, Publishers, Hagerstown.
- Delves PJ. 1994. *Cell Immunology*. BIOS Scientific Publishers Limited, Oxford.
- Delves PJ. 2017. *Roitts Essential-Immunology*. Wiley Blackwell, UK.
- Eales LJ. 2003. *Immunology for Life Scientists*. John Wiley and Sons, U.S.A.
- Elgert KD. 2009. *Immunology*. John Wiley and Sons, New York.
- Fikrig SM. 1982. *Handbook of Immunology for Students and House Staff*. Verlag Chemic International, Florida
- *Fish and Shellfish Immunology* Elsevier Science, London, 1993.
- Folds JD. 1999. *Clinical Immunology*. ASM Press, U.S.A
- *Fundamental Immunology*. Williams and Wilkins, Philadelphia, 2008
- Gupta P. 2008. *Immunology and Microbiology*. Pointer Publishers, Jaipur.
- Herzenberg LA and Weir DM. 1996. *Immunochemistry and Molecular Immunology* Vol-1. Blackwell Science, Ltd., USA.
- Kaufmann SHE. 2005. *Immunology*. ASM Press, Washington
- Lerner KL. 2003. *World of Microbiology and Immunology*: Vol-I (A-L). Thomson Gale, New York.
- Lerner KL. 2003. *World of Microbiology and Immunology*: Vol-II (M-Z). Thomson Gale, New York.
- Luttmann W. 2006. *Immunology*. Elsevier Publication, London
- Male D. 2006. *Immunology*. Elsevier Publishers, London
- Meyers RA. 2007. *Immunology*. Wiley-VCH Verlag, U.S.A.
- Paul WE. 2008. *Fundamental Immunology*. Wolters Kluwer, USA.
- Richard C. 2015. *Immunology* A Short Course. Wiley Blackwell, UK.
- Sharma DK. 2015. *Immunology*. New India Publishing Agency, New Delhi.

- Stolen JS. 1986. *Fish Immunology*. Elsevier, Amsterdam.
- Swain P and Sahoo PK. 2006. *Fish and Shellfish Immunology* NPH, Delhi.
- Tizard IR. 2009. *Veterinary Immunology: An Introduction*. Elsevier Publishers, Noida.
- Weir DM *et al*. 1996. *Weir's Handbook of Experimental Immunology*. Vol 1. Blackwell Science, Oxford.

I. Course Title : Principles of Fish Pharmacology and Therapeutics

II. Course Code : AAH 507

III. Credit Hours : 1+1

IV. Aim of the course

To learn the principles and protocols of therapeutics in aquaculture, their absorption and elimination. It offers greater knowledge of drugs for the prevention and/or treatment of diseases, and the economic husbandry of fish. It also inculcates the graduates on the legislative framework of chemotherapy for responsible use of aqua-drugs and responsible aquaculture.

V. Theory

Unit I

Therapeutics in aquaculture: Common therapeutants used in aquaculture; Their mode of action, Dose and dosage, Methods of application; Phytotherapy, Phage-therapy, Nanoparticle-based drugs, Antimicrobial peptides, etc.

Unit II

Pharmacology principles: Pharmacokinetics and pharmaco-dynamics; Residual effect and withdrawal period of various chemotherapeutants.

Unit III

Application: Pharmacovigilance; Immunopharmacology; Pharmacogenetics; OECD guidelines.

Unit IV

Impacts of aquadrugs: Drug toxicity and poisoning, Antimicrobial resistance; Antibiotic resistance and its impact on the environment and human health; Legislative framework of chemotherapy in aquaculture; Drug regulation acts and other legal aspects.

VI. Practical

On-farm practical sampling sessions; Case studies; Dose determination; Application of therapeutants; Different methods of delivery of therapeutants in aquaculture; Demonstration of phytotherapy; Determination of MIC of drugs; Determination of MCC of drugs. Extraction of compounds from plants, Methods to identify the active compounds (HPLC).

VII. Suggested Reading

- Adams HR. 2001. *Veterinary Pharmacology and Therapeutics*. Lowa State University Press, Delhi
- Bryan LE. 1989. *Handbook of Experimental Pharmacology*. Vol 91. Springer-Verlag, Berlin.
- Brown KM. 2000. *Applied Fish Pharmacology*. Kluwer Academic Press, London.
- Herwig N. 1979. *Handbook of Drugs and Chemicals used in the Treatment of Fish Diseases*. Charles C Thomas, Springfield
- Khory RN. 1999. *Material Medica of India and their Therapeutics*. Komal Prakashan, Delhi

- Lancaster R. 1980. *Pharmacology in Clinical Practice*. William Helnemann Medical Books Ltd., London
- Moini J. 2009. *Fundamental Pharmacology*. Cengage Learning, New Delhi
- Pandey G. 2017. *Fish Pharmacology and Toxicology*. DPH, New Delhi.
- Riviere JE. *Veterinary Pharmacology and Therapeutics*. John Wiley and Sons, U.S.A

I. Course Title : Non-infectious Diseases and Disorders of Finfish and Shellfish

II. Course Code : AAH 508

III. Credit Hours : 1+1

IV. Aim of the course

To comprehend the etiology and management of different non-infectious diseases and various disorders.

V. Theory

Unit I

Importance of water and sediment quality: Impact of water and sediment parameters on finfish and shellfish health

Unit II

Nutritional imbalance: Studies on the causes, Pathogenesis, Pathology, Diagnosis and differential diagnosis of various diseases due to nutritional imbalance and anorexia; Vitamin deficiencies and mineral deficiencies and their toxicity.

Unit III

Disorders: Metabolic disorders; Skeletal deformities; White faecal syndrome (WHS) in shrimp.

Unit IV

Impact of toxicants on fish health: Algal blooms, Important mycotoxins, Icthyotoxins, Chemical toxins, and Other toxicants and their effects on fish health.

VI. Practical

Case study; Study of gross changes in different tissues inflicted due to various nutritional deficiency; Study of histopathological changes in different tissues inflicted due to various nutritional deficiency; Study of histopathological changes in different tissues inflicted due to various toxicants

VII. Suggested Reading

- *Fish Diseases and Disorders*. CABI, Wallingford, UK 2010
- Leatherland JF. 1998. *Fish Diseases and Disorders*. Vol 2. CABI Publishing, Oxon.
- Sparks A. 1972. *Invertebrate Pathology: Non-Communicable Diseases*. Academic Press, New York

I. Course Title : Epidemiology and Disease Surveillance

II. Course Code : AAH 509

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of epidemiology and surveillance of fish diseases. It aids in the collection of rapid and reliable high-quality information about aquatic animal diseases and production. It also instils the graduates on the collection of fish disease data using inexpensive techniques that are more suitable for Indian aquaculture.

VI. Theory

Unit I

Introduction to epidemiology and concepts: Epidemiological terms; Epidemiological concepts and types; The importance of aquatic animal diseases; patterns of disease-epidemic curves; Epidemiological view of causality; Epidemiological association; Diagnosing disease, levels of diagnosis.

Unit II

Disease surveillance: Disease surveillance; Purpose and objectives of surveillance; Approaches to surveillance, Principles of active and passive surveillance; Sampling Principles and applications; Principles of data and specimen collection; Collection of information from people; Survey design and planning; Prevalence, Production and Incidence rate surveys.

Unit III

Surveillance data management: Principles and data processing, Computerized and manual data management; Epidemiological software for data analysis.

Unit IV

Strategic plan for aquatic animal health: Aquatic animal health information systems; National and regional strategic plan for aquatic animal health; National and international disease reporting: Role of NBFGR, NACA, FAO, OIE, AQUAPLAN, etc., in disease reporting; Emergency disease preparedness.

VII. Practical

Development of questionnaire; Farm survey; Collection of active and passive data on fish diseases; Data entry and data processing; Use of epidemiological software for data analysis.

VIII. Suggested Reading

- Cameron A. 2002. *Survey Toolbox for Aquatic Animal Diseases. A Practical Manual and Software Package*. ACIAR Monograph no 94, 375p
- Caugant DA. 2009. *Molecular Epidemiology of Microorganisms*. Humana Press, New York
- Gibbs EPJ. 1981. *Virus Diseases of Food Animals: A World Geography of Epidemiology and Control*. Academic Press, London
- Gregg MB. 2002. *Field Epidemiology*. Oxford University Press, Oxford.
- Rothman K.J. 2002. *Epidemiology: An Introduction*. Oxford University Press, Oxford
- Thrusfield M. 1995. *Veterinary Epidemiology*. Blackwell Science.

I. Course Title : Aquatic Wildlife Health

II. Course Code : AAH 510

III. Credit Hours : 2+0

IV. Aim of the course

To understand the health issues of aquatic wildlife and enhancing their health and protection. It helps the graduates to appreciate the impact of global climate change on the health of aquatic and marine wildlife populations and be aware of the rehabilitation and handling of dead aquatic animals.

V. Theory

Unit I

Introduction to aquatic wildlife: Introduction to aquatic wildlife: Definition, diversity: cetaceans, Crocodilians, Sea turtles, Frogs, Sea lions, Seals, Sea otters, Insects, Birds; Principles on 'one world and one health'.

Unit II

Aquatic wildlife habitats: Aquatic wildlife habitats; Ecosystem health; Aquatic ecosystem health indicators; Aquatic wildlife-related recreations; recognizing and preventing the impacts of principal stressors.

Unit III

Aquatic invasive species: Examples and role of aquatic invasive species in the transfer of exotic pathogens; prevention and spread of invasive species.

Unit IV

Aquatic wildlife diseases: Diseases of amphibians; Infections with non-hyphal parasitic chytrid fungi *Batrachochytrium detrobatidis* and *B. salamandrivorans*, and ranavirus species; Disease issues in aquatic wildlife; Monitoring of diseases in aquatic wildlife; Infectious (viral, parasitic, bacterial) and non-infectious diseases (malnutrition, toxic algae poisoning, gunshots, boat strikes, shark bites) of aquatic wildlife; Entanglement in ocean trash; Disease reporting in dead aquatic wildlife; Aquatic wildlife die-offs; Fish kills and the causes; Handling of dead aquatic animals; Clean up; Carcass disposal and disinfection procedure; zoo and aquaria medicine.

Unit V

Anthropogenic factors and contaminants on aquatic wildlife: Effect of anthropogenic factors and contaminants on aquatic wildlife; The zoonotic potential of aquatic wildlife diseases; Aquatic wildlife rehabilitations.

Unit VI

Health management issues: Health management issues in game fish, Fish ranging, etc; Health management of free-ranging aquatic wildlife populations; The impact of global climate change on the health of aquatic and marine wildlife populations.

VI.. Suggested Reading

- Biradar RS. 2010. *Aquatic Resources and Health Management*. Narendra Pub. House, Delhi.
- CIFE. 2009. *Genome and Protein-Based Techniques in Aquatic Animal Health Management*. CIFE, Mumbai.
- Humphrey J. 2005. *Aquatic Animal Quarantine and Health Certification in Asia*. Daya Publishing House, Delhi

I. Course Title : Disease Diagnostic Techniques

II. Course Code : AAH 511

III. Credit Hours : 2+1

IV. Aim of the course

To comprehend theoretical and practical aspects of different disease diagnostic techniques used in aquaculture and to take appropriate decisions on fish health management and appropriate choice of treatment.

V. Theory

Unit I

Introduction to fish disease diagnosis: Introduction to disease diagnosis; different roles and levels of diagnosis in aquaculture; The evolution of diagnostic techniques in aquaculture; A brief introduction to diagnostic features of important diseases of finfish and shellfish.

Unit II

Microbiological techniques: Safety in microbiology laboratory; Bio-safety levels and risk groups; Techniques in sterilization; Preparation of microbiological media; Culture techniques; Purification, Preservation and maintenance of bacterial and fungal cultures.

Unit III

Microscopic techniques: Bright field, Darkfield, Phase contrast, Fluorescence and electron microscopy.

Unit IV

Cell culture-based diagnostic methods: Introduction to cell culture techniques; Different cells used for virus isolation; CPE.

Unit V

Protein-based diagnostic methods: Antibody-based diagnostic methods (immunohistochemistry, ELISA, western blotting, lateral flow assay etc), Hybridoma technology and monoclonal-antibody-based diagnosis

Unit VI

Nucleic-acid based diagnostic methods: Nucleic acid amplification methods; Types of PCR: Reverse transcriptase-PCR, Real-time PCR and Other variants of PCR; *In situ* hybridization; Dot blot assay; LAMP etc.

VI. Practical

Sample collection and preparation for microscopic, microbiological, virological and histopathological analysis; Culture of microorganisms using conventional methods; Antibiotic sensitivity testing; Serological techniques in disease diagnosis: SDS-PAGE, Western blotting, ELISA, etc; Cell culture techniques; Molecular techniques in disease diagnosis, Nucleic acid extraction, estimation and different PCR-based diagnosis; Familiarisation of some of the commercially available diagnostic kits used in aquatic animal disease diagnosis.

VII. Suggested Reading

- *Infectious Disease in Aquaculture*. Woodhead Pub. Ltd., Philadelphia, 2012.
- Lucky Z. 1977. *Methods for the Diagnosis of Fish Diseases*. Amerind Publishing Co Pvt Ltd, New Delhi
- Sindermann CJ. 1977. *Disease Diagnosis and Control in North American Marine Aquaculture.* Elsevier Scientific Publishing Company, Amsterdam
- Sugama K. 1998. *Manual of Fish Diseases Diagnosis*. Nippon veterinary and animal science University, Japan.
- Walker P. 2005. *DNA-based Molecular Diagnostic Techniques*. Daya, Delhi 2005

Course Title with Credit Load
Ph.D. in Aquatic Animal Health Management

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
AAH 601	Biotechnological Tools in Fish Health Management	2+1
AAH 602	Molecular Virology of Finfish and Shellfish	1+1
AAH 603	Fish Bacterial Diseases Mechanisms	1+1
AAH 604	Pathobiology of Fish Parasitic Infection	1+1
AAH 605	Immunology and Vaccination of Fish	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
AAH 606	Cellular Pathology	1+1
AAH 607	Aquaculture Medicine	1+1
AAH 608	Techniques In Toxicology	1+1
	Supporting Courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
AAH 691	Doctoral Seminar – I	0+1
AAH 692	Doctoral Seminar –II	0+1
	Doctoral Research	**75 Credits**
AAH 699	Doctoral Research (Semester II)	0+15
AAH 699	Doctoral Research (Semester III)	0+15
AAH 699	Doctoral Research (Semester IV)	0+15
AAH 699	Doctoral Research (Semester V)	0+15
AAH 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
PhD. Aquatic Animal Health Management

I. Course Title : Biotechnological Tools in Fish Health Management

II. Course Code : AAH 601

III. Credit Hours : 2+1

IV. Aim of the course

To understand the advanced biotechnological tools used for fish disease diagnosis. It promises to improve the health of cultured fish and shellfish, and aquaculture production.

V. Theory

Unit I

Molecular diagnostic methods: Molecular diagnostic methods; *in situ* hybridization; Nucleic acid probe-based diagnosis; choice and characteristics of the probe; Probe labelling; Hybridization: Hybridization strategies; Factors affecting the rate of hybridization; Immobilization of nucleic acid on filters; Types of hybridization; Southern, Northern, Dot/Slot blot hybridization; DNA Microarrays: DNA chips, Preparations of DNA arrays; Label and applications; Other related molecular techniques.

Unit II

Proteomic tools: Proteomic tools: Protein structure prediction and determination using NMR, MS/MS, MALDI-TOF.

Unit III

Antibody-based diagnostics: Antibody-based diagnostics; Variants of and advances in ELISA; Hybridoma technology.

Unit IV

Advanced biotechnology tools: eDNA technology; Metagenomics; Next-generation sequencing.

Unit V

Recent advances in biotechnological applications: CRISPER technology; Digital pathology; RNAi technology; Nanotechnological tool in drug and vaccine development.

Unit VI

Safety and regulatory requirements: Environmental concerns of vaccine and other biological products; Vaccination failure and adverse effects; Biosafety and regulatory requirements for fish diagnostics, diagnostic kits, vaccines, etc.

VI. Practical

Nucleic acid extraction; Real-time PCR; Protein profiling; DNA fingerprinting; DNA damage assay; Bioinformatics approaches for recombinant DNA technology; Gene cloning and transformation.

VII. Suggested Reading

- Brown TA. (Ed.). 2002. *Essential Molecular Biology*. Vols. I, II. 2nd Ed. Oxford University Press.
- CIFE. 1998. *Genetics and Biotechnological Tools in Aquaculture and Fisheries*. Mumbai CIFE
- Davbre PD. 1998. *Basic Molecular Biology: Essential Technique*. John Wiley and Sons, New York. p.208
- Lakra WS. 2004. *Fisheries Biotechnology*. Narendra Publishing House, Delhi.
- Lewin B. 2003. *Gene VIII*. Oxford University Press.
- Montet D. 2009. *Aquaculture Microbiology and Biotechnology*. Science Publisher, New Hampshire
- Sambrook J and Russel D. 2001. *Molecular Cloning*. 3rd Ed. Cold Spring Harbour Laboratory

I. Course Title : Molecular Virology of Finfish and Shellfish

II. Course Code : AAH 602

III. Credit Hours : 1+1

IV. Aim of the course

To provide the knowledge on recent advances in the field of finfish and shellfish virology and their management. It imparts a comprehensive knowledge of select viral infections of finfish and shellfish and their management.

V. Theory

Unit I

Viral phylodynamics: Host-virus interactions; viral phylo-dynamics; Phylo-dynamic variation; viral adaptation; Virus-virus interaction (VVI); Emerging viruses; The evolution of new viruses.

Unit II

Molecular virology of finfish: Molecular virology and pathogenesis of selected viruses infecting finfish with special reference to Nervous Necrosis Virus (NNV), Tilapia Lake Virus (TiLV), Cyprinid Herpes virus-2 (CyHV-2) and Iinfectious Pancreatic Necrosis virus (IPNV);

Unit III

Molecular virology of shellfish: Molecular virology and pathogenesis of viruses infecting shellfish with special reference to White Spot Syndrome Virus (WSSV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Infectious Myonecrosis Virus (IMNV) and *Macrobrachium rosenbergii* nodavirus (MrNV).

Unit IV

Viral management: Antiviral drugs and viral vaccines; Bioinformatics on vaccine design and development, Bioinformatics on viral drug design and development

VI. Practical

Cell culture media preparation; Explant culture and suspension culture; Primary cell culture and passaging; Characterization of cell lines (Viable cell counts, karyotyping, counting, staining); Preservation and revival of cells; Virus isolation using cell culture; Transfection techniques; Molecular detection and sequence analysis of finfish viruses; Molecular detection and sequence analysis of shellfish viruses; Collection and analysis of molecular information of various viruses using sequence information available on public domain

VII. Suggested Reading

- Adams JR. 1991. *Atlas of Invertebrate Viruses*. CRC Press, Boca Raton.
- Alan C. 2005. *Molecular Virology*. Academic Press 315 p.
- Andrews C. *Viruses of Vertebrates*. Trindall and Cox, Bailliere
- Burnet FM. 1968. *Enzyme, Antigen and Virus*. Cambridge University of Press, Cambridge
- Butler M. 1992. *Cell Culture*. BIOS Scientific Publishers Limited, Oxford
- Chambers TJ. 2003. *The Flaviviruses: Structure, Replication and Evolution*. Elsevier Science, London.
- Clynes M. 1998. *Animal Cell Culture Techniques* Berlin. Springer-Verlag
- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish*. Washington Sea Grant Publication, Seattle.
- David MK, Peter MH, Diane EG, Robert AL, Malcolm AM, Bernard RStephen ES. 2007. *Fields Virology*. 5th edn. Lippincott Williams and Wilkins. 3177p.
- Dimmock N Easton A and Leppard K. 2006. *Introduction to Modern Virology*. Sixth edn Blackwell publishing. 536 p.
- Flint SJ, Enquist LW, Krug RM, Racaniello VR and Skalka AM. 2000. *Principles of Virology*. Molecular Biology, Pathogenesis and Control.
- Freshney IR. 2010. *Culture of Animal Cells: A Manual of Basic Technique* 6th edition. Wiley-Blackwell, Inc. New York. 732 p.
- Gibbs EPJ. 1981. *Virus Diseases of Food Animals: A World Geography of Epidemiology and Control*. Academic Press, London
- Hoboken NJ. 2011. *Animal Cell Culture*. John Wiley and Sons Inc., New York.
- Kibenge FSB and Godoy MG. 2016. *Aquaculture Virology*. Academic Press, Amsterdam, 568p.
- Kuchler RJ and Stroudsburg D. 1974. *Animal Cell Culture and Virology*. Hutchinson and Ross, Inc.
- Kurstak E. 1993. *Control of Virus Diseases*. Marcel Dekker, Inc., New York.
- Mothersill C and Austin B. 2000. *Aquatic Invertebrate Cell Culture*. Springer –Praxis, Chichester UK. 405 p.
- Murakami H. 1990. *Trends in Animal Cell Culture Technology*. Kodansha Ltd, Tokyo
- Polson A. 1993. *Virus Separation and Purification Methods*. Marcel Dekker Inc., New York
- Purohit SS. 1989. *Viruses, Bacteria and Mycoplasmas*. Agro Botanical Publishers, Bikaner
- Roberts RJ. 2012. *Fish Pathology*. 4th Ed. W.B. Saunders.
- Smith, K M. *Viruses*. Cambridge University Press, Cambridge.
- Wiedbrauk DL. 1995. *Molecular Methods for Virus Detection*. Academic Press, San Diego.
- Woo PTK. and Bruno DW. 2011. Fish Diseases and Disorders: Vol-3. CABI Publishers, UK.

I. Course Title : Fish Bacterial Diseases Mechanisms

II. Course Code : AAH 603

III. Credit Hours : 1+1

IV. Aim of the course

To understand the intracellular and extracellular life cycle of bacterial pathogens, disease mechanisms and mechanisms of survival in host cells.

V. Theory

Unit I

Mechanisms of survival in host cells: Intracellular and extracellular pathogens; Adherence of bacteria to host cells, Molecular mechanisms, Factors involving adherence; Invasion of host cells; Life in phagosome; Resistance to intracellular bactericidal molecules.

Unit II

Mechanisms of survival in the environment: Mechanisms of survival; Survival of bacteria under extreme climate or environment; Viable but non-culturable bacteria (VBNC); Examples of VBNC fish pathogens.

Unit III

Bacterial virulence factors: Bacterial endotoxins and enterotoxins, their molecular structures and mode of action; Host response to bacterial virulence factors, Response to intracellular and extracellular pathogens; Genes involved and regulation of their expression.

Unit IV

Host immune responses to bacterial infection: Immune responses; Cytokines, interleukins, Antibodies and other immunological molecules; Immune evasion mechanism.

VI. Practical

Study of interaction of bacteria with host cells; Estimation of adherence and invasion; Use of erythrocytes to study the interaction of bacteria with host cells; Assay of hemolytic activity; Hemagglutination and its inhibition by mannose, antibodies; Phagocytosis by macrophages and resistance to phagocytosis by pathogens; Assay virulence – LD_{50}; Virulence associated enzyme assay – protease, esterase, chitinase; Specific examples of pathogens: *Edwardsiella tarda* purification of OMPs

VII. Suggested Reading

- Austin B and Austin A. 2007. *Bacterial Fish Pathogens*. Springer Publishers, U.K.
- Bullock LG. 2014. *Diseases of Fishes*. NPH, Delhi
- Chan VL. 2006. *Bacterial Genomes and Infectious Diseases*. Humana Press, New Jersey
- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish*. Washington Sea Grant Publication, Seattle.
- Hadwin G. 2017. *Diseases of Fishes. Bacterial Diseases of Fishes and Identification of Fish Pathogenic Bacteria*. Random Pub., New Delhi.
- Iglewski HB and Clark VL. 1009. *Molecular Basis of Bacterial Pathogenicity*. Academic Press
- Inglis V. 1993. *Bacterial Diseases of Fish*. Blackwell Scientific Publications, London.
- Inglis V *et al*. 2011. *Bacterial Diseases of Fish*. John Wiley and Sons, New Jersey.
- Pohland AE *et al.* (eds). 1990. *Microbial Toxins in Foods and Feeds*. Plenum Press,
- Salyers AA and Whitt DD. 1994. *Bacterial Pathogens – a Molecular Approach*. American Society for Microbiology Press
- Snieszko SF. 1971. *Diseases of Fishes*. Book 2A TFH Publications Inc, Ltd, New Jersey
- Wilson M. 2002. *Bacterial Diseases Mechanisms*. Cambridge University Press, Oxford.
- Woo PTK and Bruno DW. 2011. *Fish Diseases and Disorders* Vol-3. CABI Publishers, U.K.

I. Course title : Pathobiology of Fish Parasitic Infections

II. Course code : AAH 604

III. Credit Hours : 1+1

IV. Aim of the course

To understand the recent advances in the pathobiology of parasitic infection in fish and other aquatic organisms. It also aims at acquiring in-depth knowledge of host-parasite interaction, the role of parasites in ecosystem functioning and parasite evolution.

V. Theory

Unit I

Environmental parasitology: Macro-environmental and micro-environmental influence on parasite incidence; Relevancy of parasites as bio-indicators.

Unit II

Ecological parasitology: Role of parasites in ecosystem functioning; Manipulative parasites; Parasites as ecosystem engineers; Parasites as biological tags; The evolution of parasites; Hyperparasitism; Parasitic adaptation.

Unit III

Molecular parasitology: Host-parasite communication and cell to cell interaction; The interaction between parasites and microbiome; Molecular characterization of parasites; DNA taxonomy and barcoding of parasites.

Unit IV

Immune responses against parasites: Fish immunity and parasitic infection (Immune responses against parasites – monogenean, flagellates, ciliates, myxozoans); Immune evasion strategies of parasites; Parasite vaccines; RNA interference and parasites; Pharmacokinetics of anti-parasitic drugs.

VI. Practical

Isolation and culture of parasites; Molecular characterization and diagnosis of parasites; Use of molecular probes for identification of parasites and tracking life stages of parasites; DNA barcoding of parasites; Parasitic survey of selected fishes (case study).

VII. Suggested Reading

- Baker JR. 2004. *Advances in Parasitology*: Vol-56. Elsevier Publisher, London
- Chandler C. 1961. *Introduction to Parasitology*. John Wiley and Sons, New York
- Cox FEG. 2005. *Parasitology*. Hodder Arnold. U.S.A.
- Dogiel *et al*. 1961 *Parasitology of Fishes*. NP., London
- Garbda J. 1991. *Marine Fish Parasitology*. VCH., Weinheim
- Gupta N. 2014. *Modern Parasitology*. Narendra Publishing House, Delhi
- Klaus, R. 2005. *Marine Parasitology*. CABI Publishing, U.K.
- Lewis EE, Campbell JF and Sukhdeo MVK. 2002. *The Behavioural Ecology of Parasites*. CABI
- Marquardt WC. 2000. *Parasitology Vector Biology*. Academic Press, London.
- Marr JJ. 2003. *Molecular Medical Parasitology*. Academic Press, London.
- Poulin R and Grimes LR. 2007. *Evolutionary Ecology of Parasites*. Princeton University Press.
- Schell S. 1962. *Parasitology*. John Wiley and Sons, New York
- Schmidt GD. 2000. *Foundations of Parasitology*. McMcgraw Hill, New York.
- Sen AB. *Perspectives in Parasitology*. Vol 2. CBS Publishers and Distributors, Delhi

I. Course Title : Immunology and Vaccination of Fish
II. Course Code : AAH 605
III. Credit Hours : 2+1

IV. Aim of the course

To learn the recent advances in fish and shellfish immunology and to understand the concepts of vaccination and the latest trends in fish vaccination

V. Theory

Unit I

Finfish immune mechanisms: Molecular players in mucosal immunity; Major histocompatibility complex; Pattern recognition receptors and immune pathways; Antigen processing and presentation; T-cell activation and differentiation; B-cell activation and differentiation; Classical, alternate, Lectin pathways of complement; Their activation and regulation.

Unit II

Immune evasion: Evasion of the immune response by pathogens; Tumour evasion of the immune response

Unit III

Shellfish immune mechanisms: Immune mechanisms in crustaceans: Prophenoloxidase system; Phagocytosis; Encapsulation; Antimicrobial proteins.

Unit IV

Principles of fish vaccination: General principles of vaccination; Vaccination strategies in aquaculture; Vaccination against bacterial, Viral pathogens and parasites; the influence of environmental parameters on vaccination.

Unit V

Vaccine production and delivery: Types of vaccines, Killed, Live attenuated, Synthetic peptide, Recombinant, Anti-idiotype, DNA and RNAi based vaccines; monovalent and polyvalent vaccines; Nanoparticle-based vaccines; Vaccine production; Quality control; Vaccine composition; Superantigens; Cytokines and therapeutic uses of cytokines; Adjuvants and immunostimulants

Unit VI

Immune gene expression: Immunoglobulin genes; Regulation of immune gene expression; Use of gene-targeted knock-out in immunological research.

VI. Practical

Collection, separation and identification of fish leucocytes; Separation of mononuclear cells; Methods of vaccine preparation Vaccine quality control; Vaccine administration by different routes; Assessment of immune response to vaccination, agglutination test, ELISA, etc; Challenge studies; Designing of RNAi based vaccines; Methods for assessment of the efficacy of vaccines; Examination of hyaline, granular, semi-granular cells of shrimp; NBT assay, phagocytic index, ProPo.

VII. Suggested Reading

- Abbas AK. 1991. *Cellular and Molecular Immunology*. Saunders Publisher, Philadelphia
- Alt FW. 2009. *Advances in Immunology*. Vol. 103. Elsevier Publishers, New York
- Anderson DP. 2003. *Textbook of Fish Immunology*. Narendra Publishing House, Delhi.
- Cooper EL. 1982. *Immunology and Immunization of Fish*. Pergamon Press, New York.
- Davis, BD. *et al.* 1973. *Microbiology* Harper and Row, Publishers, Hagerstown
- Delves PJ. 2017. *Roitts Essential-Immunology*. Wiley Blackwell, UK.
- Delves PJ. 1994. *Cell Immunology*. BIOS Scientific Publishers Limited, Oxford.
- Eales LJ. 2003. *Immunology for Life Scientists*. John Wiley and Sons, U.S.A.
- Elgert KD. 2009. *Immunology*. John wiley and Sons, New York.
- Ellis, AE. 1988. *Fish Vaccination*. Academic Press, London
- Fikrig SM. 1982. *Handbook of Immunology for Students and House Staff*. Verlag Chemic International, Florida

- Folds JD. 1999. *Clinical Immunology*. ASM Press, U.S.A.
- Gaur, RK. 2011. *RNAi Technology*. CRC Press
- Gudding R, Lillehaug A, Midtlyng P J, Brown F. 1997. *Fish Vaccinology*. Karger, Basel
- Gudding R. and Lillehaug, A. 2014. *Fish Vaccination*. Wiley Blackwell, U.K.
- Gupta P. 2008. *Immunology and Microbiology*. Pointer Publishers, Jaipur.
- Herzenberg LA. and Weir DM., 1996. *Immunochemistry and Molecular Immunology* Vol-1. Blackwell Science, Ltd., USA.
- Iwama G and Nakanishi T. 1996. *The Fish Immune System. Organism, Pathogen and Environment*. Academic Press.
- Janis K. 1997. *Immunology*. 3rd Ed. WH Freeman
- Kaufmann SHE. 2005. *Immunology*. ASM Press, Washington
- Lerner KL. 2003. *World of Microbiology and Immunology*: Vol-I (A-L). Thomson Gale, New York.
- Luttmann W. 2006. *Immunology*. Elsevier Publication, London
- Male D. 2006. *Immunology*. Elsevier Publishers, London
- Meyers RA. 2007. *Immunology*. Wiley-VCH Verlag, U.S.A.
- Midtlyng PJ. 2005. *Progress in Fish Vacciniology*. Karger, Basel
- Mishra, V. 2017. *Fish Vaccination*. Delve Pub., New York.
- Mowat N (Ed.) 1999. *Quality Control of Veterinary Vaccines In Developing Countries* (FAO Animal Production And Health). Daya Publishing House.
- Paul WE. 2008. *Fundamental Immunology*. Wolters Kluwer, USA.
- Rabbani SA. 2012. *Development of Edwardsiella tarda* Vaccine Using Outer Membrane Proteins (OMP) in *Labeo rohita*. CIFE, Mumbai.
- Richard C. 2015. *Immunology A Short Course*. Wiley Blackwell, UK.
- Saltzman WM. 2006. *DNA Vaccines Methods and Protocols*. Humana Press, New Jersey
- Sharma DK. 2015. *Immunology*. New India Publishing Agency, New Delhi.
- Stolen JS., 1986. *Fish Immunology*. Elsevier, Amsterdam.
- Swain P, Sahoo PK and Ayyappan S. 2005. *Fish and Shellfish Immunology: An Introduction*. Narendra Publ. House.
- Tizard IR. 2009. *Veterinary Immunology: An Introduction*. Elsevier Publishers, Noida.
- Weir DM *et al*. 1996. *Weir's Handbook of Experimental Immunology*. Vol 1. Blackwell Science, Oxford.

I. Course Title : Cellular Pathology

II. Course Code : AAH-606

III. Credit Hours : 1+1

IV. Aim of the course

To understand the structural and functional changes in cells, tissues and organs and to gain in-depth knowledge of the cellular processes that contribute to the pathogenesis of the disease.

V. Theory

Unit I

Cell structure and function: The cell: types and structure; Parts of a cell; functions and organelles.

Unit II

Basics of cell cycle and regulation: Basics of cell cycle and regulation of cell to cell adhesion and dysregulation during disease; Mechanism of cell injury; Processes during acute and chronic injury.

Unit III

Pathology: Cellular pathological findings; Evaluating disease pathogenesis at the molecular, Cellular and tissue levels with particular reference to the diagnosis of diseases

Unit IV

Cell signalling processes: Introduction to cell signalling processes; Transcriptional and post-translational mechanisms to specific cell-signalling pathways responsible for controlling cell functions such as cell cycle, Cell differentiation, Cell death and Apoptosis.

VI. Practical

Knowledge and understanding of the pathological basis of disease and the use of techniques; Cytopathology; Flow cytometry; Confocal microscopy; Immuno-histochemistry to detect and diagnose diseases; Assays for cell survivability and apoptosis: COMET assay, MTT assay, TUNEL assay, LDH and NR.

VII. Suggested Reading

- Alan Cann. 2005. *Molecular Virology* Academic Press 315 p
- Coleman WB and Tsongalis GJ. 2009. *Molecular Pathology*. Elsevier Publisher, Boston
- Coles EH. 1986. *Veterinary Clinical Pathology*. W B Saunders Co., Philadelphia.
- Cook DJ. 2006. *Cellular Pathology*. Scion Publishers, Oxford.
- Dimmock N Easton A and Leppard K. 2006. *Introduction to Modern Virology*. Sixth edn Blackwell publishing 536 p
- Ellis AE. 1985. *Fish and Shellfish Pathology*. Academic Press, London.
- Ferguson HW. 2006. *Systematic Pathology of Fish*. Scotain Press, London.
- Freshney IR. 2010. *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications*. 6th edition. Wiley-Blackwell, New York.
- Jones TC. 1997. *Veterinary Pathology*. Williams and Wilkins, Philadelphia.
- Killeen AA. 2001. *Molecular Pathology Protocols*. Humana, U.S.A
- Knipe DM, Howley PM, Griffin DE, Lamb RA, Martin MA, Roizman B and Straus SE. 2007. *Fields Virology*. 5th edn. Lippincott Williams and Wilkins
- Lloyd RV. 2004. *Endocrine Pathology*. Humana Press, Totowa.
- Mothersill C and Austin B. 2001. *Aquatic Invertebrate Cell Culture*. Springer-Praxis, Chichester UK. 405 p.
- Perkins FO. 1990. *Pathology in Marine Science*. Academic Press Inc., San Diego.
- Roberts RJ. 2012. *Fish Pathology*. Wiley-Blackwell, Chichester
- Salle AJ. 1961. *Fundamental Principles of Pathology*. MacGraw-Hill Co, New York.
- Stockham SL. 2002. *Fundamentals of Veterinary Clinical Pathology*. Lowa State Press, Lowa

I. Course Title : Aquaculture Medicine

II. Course Code : AAH-607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role, application and impact of aquaculture drugs and chemicals

V. Theory

Unit I

Categorization of aquadrugs: Different chemicals and drugs used in aquaculture and dosages; Categories of aquadrugs: approved, unapproved and conditionally approved aquaculture drugs, Low regulatory priority aquaculture drugs, Investigational new animal drug exemptions for aquaculture drugs and unapproved drugs

Unit II

Pharmacodynamic agents: Anaesthetics and methods of anaesthetizing fish and shellfish; Breeding induction agents; Sex control agents; The action of different drugs in finfish and shellfish.

Unit III

Medicated feeds: Feed top-dressing; binders and stabilizers; Dose and dosage; Bioaccumulation and toxicity; Use of probiotics and immunostimulants in aquaculture

Unit IV

Development of antimicrobial-resistance: Antibiotics – use and misuse including the development of antibiotic-resistant bacteria; AMR, WHONET and ATLAS; Regulatory bodies: safety regulations at national and international levels.

VI. Practical

Demonstration of anaesthetizing fish; Prophylactic application of aquadrugs; Therapeutic application of aquadrugs; Antibiotic sensitivity test; Estimation of dose; Estimation of antibiotic residues; Detection of gut colonization by probiotic bacteria.

VII. Suggested Reading

- Brown L. 1993. *Aquaculture for Veterinarians*. Oxford Pergamon press 1993. 447p
- Brown KM. 2000. *Applied Fish Pharmacology*. Kluwer Academic Press, London
- Herwig N. 1979. *Handbook of Drugs and Chemicals used in the Treatment of Fish Diseases*. Charles C Thomas, Springfield
- Pandey G. 2017. *Fish Pharmacology and Toxicology*. DPH, New Delhi
- Radostits M. 2000. *Veterinary Medicine*. Bookpower Publisher, China
- Singh ISB . 2003. *Aquaculture Medicine.* Cochin University 2003. 336p
- Stockopf MK. 1993. *Fish Medicine*. W.B. Saunders Company, London

I. Course Title : Techniques in Toxicology

II. Course Code : AAH-608

III. Credit Hours : 1+1

IV. Aim of the course

To impart the knowledge of various toxicological methods of drugs used in aquaculture.

V. Theory

Unit I

Principles of toxicological methods: Principles of drug action and assay; regulatory phases of drug development; Dose-response curves and their analysis; Residual effects and withdrawal period of potential drugs.

Unit II

Mechanisms of action of drugs: Toxic indigenous drugs used as antimicrobials and anti-inflammatory agents; Drugs used in chemotherapy their mechanisms of action, Side effects and clinical signs

Unit III

Toxicity tests: Techniques for setting up isolated and intact preparations; Animal toxicity tests for acute, Sub-acute and chronic toxicity; Specific toxicity tests, Immunotoxicity, and carcinotoxicity; Use of cell culture for toxicity assays; Different assays for toxicity testing.

Unit IV

Naturally occurring poisons: Naturally occurring poisons: Mycotoxins, Bacterial toxins, Plant toxins, and animal toxins, Microalgal toxicity; Toxicology of mycotoxins; Types of toxicity and its measurement; Acute, sub-acute or chronic and its manifestations; acute toxicity; Mode of application, Administration, Exposure; *in vitro* tests; Dose-response relationship.

VI. Practical

Measurement of TD_{50}/TC_{50}; Measurement of LD_{50}/LC_{50}; Test for acute, sub-acute and chronic toxicity; Protocols and various specific toxicity tests; Calculation of EC_{50}; Determination of potency ratio, median effective, toxic or lethal doses; Bioassay techniques; Cell culture assay for chemical toxins; Cell culture assay for biological toxins

VII. Suggested Reading

- ASTM Standards on Aquatic Toxicology and Hazard Evaluation. ASTM, Philadelphia 1993.
- Aquatic Toxicology. American Society for Testing and Materials, Philadelphia 1980
- Cockerham LG. 1994. *Basic Environmental Toxicology*. CRC Press, Boca Raton
- Derelanko MJ. 1995. *CRC Handbook of Toxicology*. CRC Press, Boca Raton
- Duffus JH. 1996. *Fundamental Toxicology for Chemists*. The Royal Society of Chemistry, Cambridge.
- Eaton 1976. *Aquatic Toxicology*. American Society for Testing and Materials, Philadelphia
- Finkel AJ. 1983. *Industrial Toxicology*. John Wiley and Sons, London
- Hayes AW. 2008. *Principles and Methods of Toxicology*. CRC Press, U.S.A.
- Heuvel JPV. 1998. *PCR Protocols in Molecular Toxicology*. CRC Press, Boca Raton
- Hoboken NJ. 2010. *A Textbook of Modern Toxicology*. John Wiley and Sons
- Hyde W *et al*. 1977. *Analytical Toxicology Methods Manual*. IOWA State University Press, Ames.
- *Information Resources in Toxicology*. Academic Press, San Diego 2000
- Johnson EM. 1983. *Teratogenesis and Reproductive Toxicology*. Springer-Verlag, Berlin
- Kram DJ. 2001. *Toxicology Testing Handbook*. Marcel Dekker, Inc., New York.
- Malins DC. 1994. *Aquatic Toxicology*. Lewis Publishers, Boca Raton
- Matelev VV. 1971. *Water Toxicology*. Amerind Publishing Co. Pvt. Ltd. New Delhi
- Mayer H. *Aquatic Toxicology and Hazard Evaluation*. America Society for Testing and Concepts Publishing, Philippines
- Metelev VV. 1983. *Water Toxicology*. Amerind Publishing Co Pvt Ltd, New Delhi
- Mothersill C. 2003. *In-vitro Methods in Aquatic Toxicology*. Springer Verlag, UK.
- Niesink RJM. 1996. *Toxicology Principles and Applications*. CRC Press, New York.
- Ostrander GK. *Techniques in Aquatic Toxicology*. Lewis Publishers, New York.
- Pandey BN. 2011. *Fisheries and Fish Toxicology*. A P H Publishing Corporation, New Delhi
- Rand GM. 1985. *Fundamentals of Aquatic Toxicology*. Hemisphere Publishing Corporation, Washington.
- Raychaudhuri SP. 1979. *Environmental Pollution and Toxicology*. Today and Tomorrow's Printers and Publishers, New Delhi
- *The Toxicology of Fishes*. CRC Press, Boca Raton, 2008.
- *Toxicology and Risk Assessment*. Marcel Dekker, Inc., New York, 1996

- Vohora SB. 1999. *Toxicology and Environmental Health*. Department of Medical Elementary and Toxicology, New Delhi
- Ware GW. 1993. *Reviews of Environmental Contamination and Toxicology*. Springer-Verlag, New York.
- Weber LJ. 1982. *Aquatic Toxicology*. Vol 1. Raven Press, New York
- Wells PG. 1998. *Microscale Testing in Aquatic Toxicology*. CRC Press, London 1998.

List of suggested Journals

- *Journal of Fish Diseases*
- *Journal of Fish Pathology*
- *Journal of Immunology and Immunopathology*
- *African Journal of Aquatic Science*
- *American journal of pathology*
- *Applied and Environmental Microbiology*
- *Fish Pathology*
- *Histology and histopathology*
- *Asian Journal of Microbiology, Biotechnology and Environmental Sciences*
- *Cellular Immunology*
- *Clinical and Experimental Immunology*
- *Clinical and Vaccine Immunology*
- *Comparative Immunology Microbiology and Infectious Diseases*
- *Diseases of Aquatic Organisms*
- *Aquaculture research*
- *Fish and Shellfish Immunology*
- *Experimental parasitology*
- *Immunopharmacology and Immunotoxicology*
- *Indian Journal of Animal Health*
- *Indian Journal of Veterinary Pathology*
- *Journal of Aquatic Animal Health*
- *Journal of Clinical Pathology*
- *Journal of Environmental Pathology, Toxicology and Oncology*
- *Tropical Animal Health and Production*
- *Vaccine*
- *Veterinary Clinical Pathology*
- *Veterinary Immunology and Immunopathology*
- *Veterinary Microbiology*
- *Veterinary Pathology*

List of suggested e-Resources

- Aquatic Animal Health Management- FAO
- Biosecurity and Aquatic Animal Health Management
- Aquatic animal health - Network of Aquaculture Centers in Asia-Pacific https://enaca.org
- New vistas in aquatic animal health management http://ciba.res.in/Books
- Aquaculture and aquatic animal health management issues www.oie.int
- Advances in aquatic animal health management https://www.omicsonline.org
- Approaches to managing aquatic animal health in Australia-NCBI https://www.ncbi.nlm.nih.gov
- https://thefishsite.com/articles/health-national-strategies-for-aquatic-animal-health-management
- Journal of fish disease https://onlinelibrary.wiley.com › journal
- Free Classic Pathology Books www.freepsychotherapybooks.org/
- Fish Pathology https://onlinelibrary.wiley.com › doi › book
- Fish Pathology Edition 4 by Ronald J. Roberts https://www.barnesandnoble.com › fish-pathology-ronald-j-roberts

- Fish Vaccines By Alexandra Adams https://www.springer.com › book
- Vaccines for Use in Finfish Aquaculture - Acta Scientific https://www.actascientific.com
- Progress, challenges and opportunities in fish vaccine development. https://www.ncbi.nlm.nih.gov
- A Guide to Bacterial Identification - PREMIER Biosoftwww.premierbiosoft.com › tech_notes › bac-id
- The application of epidemiology in aquatic animal health – NCBI https://www.ncbi.nlm.nih.gov › pmc › articles › PMC3182899
- Maintenance of Fish Health in Aquaculture: Review of Epidemiological Approaches for Prevention and Control of Infectious Disease of Fish https://www.hindawi.com ›
- School on Aquatic Animal Epidemiology and Disease Surveillance https://enaca.org
- Common diagnostic and clinical techniques for fish – NCBI https://www.ncbi.nlm.nih.gov › pubmed
- Fish and Shellfish Immunology: An Introduction - Google Books https://books.google.com › books › about › Fish_and_Shellfish_Immunology
- Fish and Shellfish Immunology: An Introduction www.nphindia.com ›
- Significant and emerging parasitic diseases of finfish https://pdfs.semanticscholar.org ›
- Cellular Pathology Technique | ScienceDirecthttps://www.sciencedirect.com › book › cellular-pathology-technique
- Techniques in Aquatic Toxicology, Volume 2 - CRC Press Book https://www.crcpress.com ›
- Fish models in behavioural toxicology: Automated techniques, updates and perspectives. semanticscholar.org
- Physiological Methods in Fish Toxicology: Laboratory and Field Studies springer.com
- Clinical and Experimental Immunology - Wiley Online Library https://onlinelibrary.wiley.com › journal
- Immunopharmacology and Immunotoxicology https://www.tandfonline.com
- Veterinary Immunology and Immunopathology | ScienceDirect.com https://www.sciencedirect.com

Suggested Broad Areas for Master's and Doctoral Research

- Development of diagnostics for important finfish and shellfish pathogens
- Development of monoclonal antibodies for important finfish and shellfish pathogens
- Development of vaccines for important finfish and shellfish pathogens
- Molecular characterisation of important finfish and shellfish pathogens
- Pathogenesis of finfish and shellfish viruses
- Development of antiviral drugs
- Survival strategies of intracellular and extracellular fish bacterial pathogens
- Molecular mechanism of virulent factors of fish bacterial pathogens
- Microbial management in finfish and shellfish hatchery/nursery and grow-out aquaculture
- Genes involved in the virulence of finfish and shellfish pathogens and regulation of their expression
- Mucosal immunity in finfish and shellfish
- Influence of external factors on finfish and shellfish vaccination
- Development of nanoparticle-based vaccines for finfish and shellfish aquaculture
- Designing and development of RNAi based vaccine.
- Safety and efficacy of aqua drugs/ diagnostics/ vaccines
- Molecular characteristics of finfish and shellfish parasites
- Molecular taxonomy of finfish and shellfish parasites
- Development of management strategies for finfish and shellfish parasitic diseases
- Interaction between finfish and shellfish parasites and microbes
- Immune responses of fish against parasites
- Pharmacokinetics of antibiotics / antiparasitic drugs in fish finfish and shellfish
- Cellular factors that contribute to the pathogenesis of diseases
- Evaluation of disease pathogenesis at the molecular/ cellular/ tissue levels

- Probiotics in finfish and shellfish aquaculture
- Immunostimulants in finfish and shellfish aquaculture
- Impact of AMR bacteria in finfish and shellfish aquaculture
- Residual effect and withdrawal period of potential aquadrugs
- Toxicity related to aquadrugs
- Application of bioinformatics in drug designing
- Application of bioinformatics in aquatic animal health management
- Development of primary cell culture for fish/ shrimp viruses
- Epidemiology, pathogenicity, diagnosis and management of fish/shrimp diseases
- Host-parasite relationship
- Management strategies for fish/ shellfish parasitic diseases
- Pathophysiology of finfish and shellfish diseases
- Immune responses of fish to bacterial/ viral/ fungal/ parasitic infections
- Health management measures in the open water aquaculture system
- Health management measures in recirculatory aquaculture system (RAS)
- Health management measures in biofloc culture system
- Economic loss due to finfish and shellfish diseases in aquaculture
- Surveillance of new and emerging finfish and shellfish diseases
- Management of transboundary aquatic animal diseases
- Risks associated with the import of finfish and shellfish
- Risks associated with the interaction of farmed and wild aquatic animals
- Development of BMP for commercially important aquaculture species
- Finfish and shellfish hatchery diseases and their management
- Non-infectious diseases and disorders in finfish and shellfish and their management
- Nutritional imbalance and disorders in finfish and shellfish and their management
- Nutritional diseases of finfish and shellfish and their management
- Metabolic disorders of cultured finfish and shellfish exposed to pollutants
- Development of alternative therapeutants for aquaculture
- Application of phytotherapy in finfish and shellfish aquaculture
- Potential impacts of chemicals used in aquac ulture on the environment
- Epidemiology and surveillance of aquatic animal diseases
- Aquatic wildlife diseases and their management
- Aquatic invasive species and their impacts in aquaculture and transmission of diseases
- Effect of anthropogenic factors and contaminants on aquatic wildlife health
- Health management issues in game fish and fish ranging
- Impact of global climate change on the health of aquatic animals

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Biotechnology

Preamble
(Fish Biotechnology)

Biotechnology is undoubtedly the most rapidly advancing stream of biology today, and more and more researchers are applying cellular/ molecular approaches to find innovative solutions to myriad concerns and issues related to aquaculture and fisheries. The world today is faced with the challenges of climate change, rising water salinity, aquatic pollution, destruction of natural breeding grounds of aquatic animals, viral and bacterial pathogens, dwindling supply of ingredients for fish feed. In this scenario, India needs to create human resource capable of designing and executing genetic improvement/ germplasm management and conservation programs, all of which rely heavily on an understanding of molecular markers and genetics. Further, biotechnology is applied to management of aquatic environment, fish disease, and nutrition; captive maturation and induced breeding. India needs to diversify and expand the number of cultivated fish and shrimp species and biotechnology is most likely to provide a breakthrough once a critical mass of researchers is created in the country to work in this sector. The world now has its first transgenic fish – AquAdvantage salmon. India's policy is not averse to transgenics for high growth and disease resistance and the country has to still develop capability and human resource in this area. Indian education institutions must move quickly to harness the power of modern tools like genomics, nanotechnology and bioinformatics through trained human resource to achieve rapid advancements in sustainable and profitable fish/shrimp productions systems.

Globally, researchers are turning to new approaches based on molecular biology, biotechnology, genomics and bioinformatics in order to address various issues and concerns related to fisheries and aquaculture. In India, the need for human resource capable of innovative research and teaching is felt acutely in this fast emerging area, particularly as the most rapid advances are being made in this field, and institutions are eager to apply modern tools to keep up with the global standards. In addition, there is plenty scope for start-ups in the area of biotechnology, and hence the current syllabus is designed to encourage students to identify entrepreneurial opportunities and also services required in the national and international biotech industry. For example Biotech entrepreneurs will be required to certify genetically improved fish/ shrimp seed, to certify specific pathogen free seed, to confirm frozen / processed fish and shrimp meat labelling for Indian exports and national consumption, to provide genomics and bioinformatics services; to run disease diagnostic labs. In addition, ICAR, SAUs and international research institutions also need human resource trained in this area to develop new technologies for improvement of domesticated germplasms and conservation of biodiversity to deal with the anticipated challenges of climate change, rising salinity and shortage of freshwater.

Researchers/ Scientists in national and international labs; Assistant Professors in Universities/ Colleges; Private Sector (Research/ Marketing/ Technical Analysts for Biotech, Bioinformatics, Genomics, DNA Sequencing, etc.Companies); Entrepreneurs.

Course Title with Credit Load M.F.Sc. in Fish Biotechnology

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FBT 501	Fundamentals of Molecular Biology	2+1
FBT 502	Concepts of Cell Biology	2+1
FBT 503	Gene Structure and Regulation of Expression	2+1
FBT 504	Genetic Engineering	2+1
FBT 505	Bioinformatics Tools for Fisheries	1+1
FBT 506	Fish Cell Culture	2+1
FBT 507	Aquaculture Biotechnology	2+1
	Minor Courses	**08 Credits**
	(From the subjects closely related to a student's major subject)	
FBT 508	Marine Biotechnology	1+1
FBT 509	Molecular Markers	2+1
FBT 510	Molecular Taxonomy and Phylogenetics	2+1
	Supporting Courses	**06 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common Courses	**05 Credits**
	(The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 3. Intellectual Property and its management in Agriculture 4. Basic concepts in Laboratory Techniques 5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	1 Credit
FBT 591	Master's Seminar	0+1

Course Code	Course Title	Credit Hours
	Masters' Thesis Research	**30 Credits**
FBT 599	Master's Research (III semester)	0+15
FBT 599	Master's Research (IV semester)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fish Biotechnology

I. Course Title : Fundamentals of Molecular Biology
II. Course Code : FBT 501
III. Credit Hours : 2+1

IV. Aim of the course

- To acquaint the students about the structure and organisation of genome.
- To provide knowledge of basic molecular processes involving nucleic acids and protein synthesis and maintenance within a living cell.

V. Theory

Unit I

Structure and properties of genome: Genetic material, Content of the Genome, Structures of DNA and RNA; Stereochemistry of bases and secondary structures; Alternative forms of DNA structure; Organisation of bacterial, viral and eukaryotic genome; Physico-chemical properties of DNA (Tm, Hyper-chromaticity, Kinetic Classes, Buoyant Density etc.).

Unit II

DNA replication: Models of DNA replication in prokaryotes, Eukaryotes and viruses; Molecular events during DNA replication; The Replisome: *E. coli* and eukaryotes; Structure and function of DNA polymerases and types; Importance of Telomere and Telomerase in replication of chromosome termini.

Unit III

Transcription: Transcription in Prokaryotes – Bacterial RNA polymerase, Initiation, elongation and termination; Transcription in Eukaryotes – RNA polymerases and mechanism; Post transcriptional modifications; Structure and synthesis of rRNA and tRNA.

Unit IV

Translation: Genetic code, Codon bias, Types and structures and active centre of ribosomes, tRNA structure, Wobble hypothesis, Mechanisms of translation and post-translational modifications in prokaryotes and eukaryotes and the factors involved in various steps, Concept of polysomes and protein structure.

Unit V

DNA recombination: Homologous and site-specific recombination; Crossing over; Holliday junction; Transposition

Unit VI

Mutations: Types, mutagens. Molecular basis of mutation, Mutations induced by chemicals, radiation, transposable elements; DNA Repair: DNA repair enzymes; Types and mechanisms; Methods for detection of DNA damage.

VI. Practical

Good Laboratory Practices – Biosafety and disposal of hazardous material. Preparation of buffers and reagents. Tissue sampling techniques for isolation of DNA and RNA. Isolation of Genomic DNA by Phenol Chloroform Method. Isolation of Genomic DNA by Salting-out method. Isolation of Genomic DNA by CTAB method. Preparation of Media for cultivation of *E.coli*. Isolation of Plasmid DNA from *E.coli* by alkaline lysis method. Isolation of RNA by TRIzol method. Quality analysis of Nucleic acids by Agarose Gel Electrophoresis. Nucleic acid quantification by spectrophotometer/nanodrop. Protein Purification. Separation of proteins by SDS-PAGE. Separation of proteins by Native PAGE. Detection of mutation by Comet Assay.

VII. Suggested Reading

- Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K and Walter P. 2015. *Molecular Biology of the Cell* (6^{th} edition), New York: Garland Science. 1464 pp.
- Glick RB, Pasternak JJ and Patten CL. 2010. *Molecular Biotechnology: Principles and Applications of Recombinant DNA* (4th edition). ASM Press, WA, USA, 850 pp
- Rodney Boyer. 2005. *Concepts in Biochemistry* (3^{rd} edition). Wiley, NJ, US, 736 pp.
- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. *Lewin's Genes XII*. Jones and Bartlet Publishers, MA, USA 829 pp.
- Lodish H, Berk A, Zipursky LS, Matsudaira P, Baltimore D and James Darnell. 2016. *Molecular Cell Biology* (8th edition). W.H. Freeman and Company Publishers, London, UK, 1280 pp.
- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry* (7th Edition) W.H. Freeman, New York, 1328pp.
- Primrose SB. 1987. *Modern Biotechnology*. Blackwell Scientific Pub., London, UK, 184 pp.
- Watson JD. *et al*. 2017. *Molecular Biology of the Gene* (7 th edition). Pearson Education, London, UK, 912 pp.
- Weaver R. *Molecular Biology*. 2011. McGraw-Hill Education, 912 pp.
- Rastogi, V.B. 2010. *Fundamentals of Molecular Biology*. Ane Books Pvt Ltd, New Delhi, 462pp.
- https://www.ncbi.nlm.nih.gov/books/
- http://bioinfo.ut.ee/primer3-0.4.0/https://all-about-molecular-biology.jimdo.com/
- https://www.molbiolcell.org/
- http://www.web-books.com/MoBio/

I. Course Title : Concepts of Cell Biology

II. Course Code : FBT 502

III. Credit Hours : 2+1

IV. Aim of the course

To outline the basic structure growth and differentiation of prokaryotic and eukaryotic cell To describe the structure and function of biological membranes To discuss the various sub-cellular components and their functions so as to impart an overall understanding of cellular organisation and evolutionary changes

V. Theory

Unit I

Basics of cell biology: Basic concept and evolution of cells, Cells to tissues; Prokaryotic and eukaryotic cell architecture, Cell theory, Diversity of cell size and shape.

Unit II

Organization of cellular organelles: Organization and function of sub-cellular organelles – Cell surface, Cell membrane and types; Cytoplasm; Endoplasmic reticulum; Golgi apparatus; Lysosomes; Mitochondria; Ribosome, Nucleolus; Peroxisomes and Sub-nuclear structures.

Unit III

Membrane transport mechanism: Overview of membrane transport, Active/ passive membrane transport (Case study - Osmoregulation in freshwater and marine fishes) ion channels; carrier proteins.

Unit IV

Cell signalling: Signalling molecules, Cell surface receptors, Secondary messengers and Intracellular signal transduction.

Unit V

Cell division: Cell cycle, Mechanism of cell division, Growth factors; Cell growth and differentiation; Cytoskeletal systems: Microtubules, Microfilaments, and intermediate filaments; Cell motility; Actin-Myosin filaments; Flagella; Cilia; Cell adhesions, Cell junctions and the extra cellular matrix.

Unit VI

Protein sorting: Secretion and targeting; Vesicular traffic; Endocytosis; Exocytosis; Protein translocation and secretary pathways.

VI. Practical

E. coli growth curve. Gram's staining. Bright-field microscopy. Phase contrast microscopy. Fluorescent microscopy. Electron microscopy. Sample preparation for light microscope. Sample preparation for electron microscope. Microtomy. Isolation of organelles. Sub-cellular fractionation. Chromosome preparation. Histochemical techniques

VII. Suggested Reading

- Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K and Walter P. 2015. *Molecular Biology of the Cell* (6th edition), New York: Garland Science. 1464 pp.
- Cooper GM and Robert EH. The Cell: *A Molecular Approach* (6th edition)Hausman, R. E. (2013). Sunderland, Massachusetts: Sinauer Associates. 832 pp.
- Edmund W. 1900. *The Cell in Development and Inheritance* (2nd edition). The Macmillan Company, NY, 396 pp.
- Gartner LP, Hiatt JL and Strum JM. 2011. *Cell Biology and Histology*. Lippincott Williams and Wilkins. 374 pp.
- Gilbert SF and Barresi MJF. 2016. *Developmental Biology* (11th edition). Sunderland; Sianuer Associates Inc Publishers, GIL: 810 pp.
- Lodish H, Berk A, Zipursky LS, Matsudaira P, Baltimore D and James Darnell. 2016. *Molecular Cell Biology* (8th edition). W.H. Freeman and Company Publishers, London, UK, 1280 pp.
- Verma PS. 2004. *Cell Biology, Genetics, Molecular Biology: Evolution and Ecology*. 350 pp.
- ISBN-13: 978-8121924429
- https://www.ncbi.nlm.nih.gov/books/

I. Course Title : Gene Structure And Regulation of Expression

II. Course Code : FBT 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the general principles of gene organization and expression in both prokaryotic and eukaryotic organisms.To explain various levels of gene regulation and to discuss the possibilities of manipulating gene function for the good of mankind in general and fisheries in particular.

V. Theory

Unit I

Gene components: Genes, Types of genes; Gene structure: Promoters, UTRs, ORFs, exons, Introns, Termination signal, Mono- and polycistronic genes, Gene clustering; Overlapping genes (Phi X174 virus).

Unit II

Regulation of gene expression in Prokaryotes: Operon concept: Types of operons, Lactose and tryptophan operons (Lac/Trp), Their structure and mode of regulation; Induction of transcriptional factors by environmental and biological factors (SOS response), Bidirectional promoters.

Unit III

Regulation of gene expression in Eukaryotes: DNA protein interactions (concept of DNA foot printing, EMSA, zinc fingers, leucine zippers, helix turn helix, Z-DNA); Transcription factors, Promoters, Enhancers, Repressors, Insulators, Attenuators, IRES, Alternative splicing.

Unit IV

RNA in gene regulation: Antisense RNA, MicroRNA, Ribozymes, RNA interference. Expression Profiling: Micro array and Real time PCR, RNA seq.

Unit V

Epigenetics: DNA methylation, Genetic imprinting, Histone modifications, Chromatin remodeling.

Unit VI

Mutagenesis: Site-directed mutagenesis and its applications, Transposon induced mutagenesis.

I. Practical

Total RNA extraction. Quality checking of RNA by Agarose Gel Electrophoresis. cDNA synthesis by RT-PCR. Retrieval of Gene information from NCBI/ENSEMBL. BLAST analysis. *In-silico* identification and analysis of promoters, transcription factors and other regulatory elements. Primer designing. Polymerase Chain Reaction. DNA purification from agarose gel. T/A cloning. Screening of recombinant clones by blue white selection. RACE-PCR. Real time PCR for absolute quantification of genes. Real time PCR for relative quantification of genes.

II. Suggested Reading

- Boyer R. 2005. *Concepts in Biochemistry* (3rd Edition). Wiley, NJ, US, 736 pp.
- Cooper GM and Robert EH. *The Cell: A Molecular Approach* (6th edition)Hausman, R. E.

(2013). Sunderland, Massachusetts: Sinauer Associates. 832 pp.
- Gilbert SF and Barresi MJF. 2016. *Developmental Biology* (11th edition). Sunderland; Sianuer Associates Inc Publishers, GIL: 810 pp.
- ISBN-10: 0471661791.Lewin, B. 2005 *Essential Genes*. Benjamin Cummings, 672pp.
- Primrose SB. 1987. *Modern Biotechnology*. Blackwell Scientific Pub., London, UK, 184 pp.
- Rastogi VB. 2010. *Fundamentals of Molecular Biology*. Ane Books Pvt Ltd, New Delhi, 462pp.

I. Course title : Genetic Engineering

II. Course code : FBT 504

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize the students with the basic concepts in recombinant DNA technology. To acquaint the students to versatile tools and techniques employed in genetic engineering and its application in fisheries and aquaculture.

V. Theory

Unit I

Enzymes used in recombinant DNA technology: DNA modifying enzymes - types of restriction endonucleases (Type I, II and III), Alkaline phosphatases, Kinases, Exonucleases, Ligases, Terminal transferases.

Unit II

Vectors in genetic engineering: Plasmids (replication, copy number control and compatibility), Bacteriophages, Phagemids, Cosmids, M13 vectors, High capacity vectors (eg. BAC, YAC, PAC, HAC), Shuttle vectors; Adapters, linkers, ligation, Transformation and selection.

Unit III

Host organisms: Prokaryotic (selected *E. coli* strains) and Eukaryotic (selected yeast strains).

Unit IV

Principle and applications of PCR: Principle of DNA amplification by PCR and applications, Optimization, Prevention of mispriming; Hot Start, Touchdown, Gradient PCR; T/A cloning of amplified products; Characteristics and types of thermostable DNA polymerases.

Unit V

Cloning strategies: Cloning strategies for prokaryotic and eukaryotic constructs, Promoter systems for high expression in *E. coli*; Cloning for in vitro transcription; Expression optimization and affinity purification strategies for recombinant proteins.

Unit VI

Genomic and cDNA library: Shotgun cloning, Construction in high capacity vectors, Screening, and Applications; Chromosome walking. cDNA library: Construction and screening; and Clone characterization.

VI. Practical

In silico DNA sequence analysis for cloning. Insert and vector preparation. Ligation. Preparation of competent cells. Transformation. Selection of transformed cells.

Primer designing. Clone confirmation by colony PCR. Clone confirmation by Horizontal cell lysis. Southern blotting. Western blotting. Labeled probe preparation by nick translation. Random primer labeling of probe

VII. Suggested Reading

- Brown T. 1998. *Molecular Biology* LabFax, Volume 1: Recombinant DNA (2nd edition). Academic Press, MA, USA. 377 pp.
- Brown TA. 2010. *Gene Cloning and DNA Analysis: An Introduction* (6th edition). Wiley-Blackwell. 320 pp.
- Brown TA. 2017. *Genomes* 4 (4th edition). Garland Science, US, 544 pp.
- Green MR and Sambrook J. 2012. *Molecular Cloning: A Laboratory Manual* (4th edition: Vol 1-3.). Cold Spring Harbor, NY, USA 2028 pp.
- Primrose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics* (7th edition). Blackwell Publishing, Oxford UK., 672 pp
- Reece RJ. *Analysis of Genes and Genomes.* 2004. John Wiley and Sons, UK. 469 pp.

I. Course title : Bioinformatics Tools for Fisheries

II. Course code : FBT 505

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the students with the use of biological databases To provide practical knowledge on DNA and protein sequence retrieval and Phylogenetic analysis using softwares

V. Theory

Unit I

Basics of Bioinformatics: Overview of Bioinformatic resources, and applications. Platforms (Linux and Windows) and available software; Databases: Primary databases: nucleotide sequence databases, Protein sequence databases; Secondary databases; Structure databases; Analysis packages.

Unit II

Sequence Alignment: Dot Matrix, PAM, BLOSSUM Matrix, Sequence retrieval from online database, Simple pairwise alignment (BLAST) and Multiple sequence alignment.

Unit III

Sequence analysis: Retrieval of sequences, Sequence quality, Assembly and annotation of Sanger sequencing reads, Identification of cis acting regulatory elements, ORF finding, signal sequences in DNA and proteins, Data analysis tools for SNP and ESTs.

Unit IV

Phylogeny and evolution: Evolution of genome, Basic force of evolution, Variation and divergence of populations, Estimation of divergence time; Phylogenetic species concept, Phylogenetic trees, Clasdistics, Concept of monophyly, Paraphyly and polyphyly, Phylogenetic reconstruction using distance-based methods (UPGMA, Neighbour-Joining), Phylogenetic reconstruction using character-based methods, Maximum Parsimony, Maximum Likelihood and Bayesian Inferences, Principle, methodology, Tree comparisons and statistical tests, Parametric bootstrapping, interpretation of results and limitations.

VI. Practical

Sequence retrieval from databases. Refining the search criteria by modifying different parameters. Sequence submission to databases (NCBI GenBank/BOLD). Pairwise sequence alignment (BLAST). Multiple sequence alignment by ClustalW. Identification of Open Reading Frame (ORF). Primer designing. Restriction site identification. Plasmid map drawing. Protein structure prediction using softwares. Construction of phylogenetic tree using MEGA/MrBayes/Phylip/PAUP. Analysis of results of phylogenetic tree.

VII. Suggested Reading

- Attwood TK and Parry-Smith DJ. 2001. *Introduction to Bioinformatics*. Benjamin Cummings, SF, USA, 339 pp.
- *Bioinformatics: A biologists' Guide to Biocomputing and the Internet*. Eaton Pub Co, 188 pp
- Choudhuri S. 2014. *Bioinformatics for Beginners: Genes, Genomes, Molecular Evolution, Databases and Analytical Tools*. Elsevier Inc. 225pp.
- Liu Z. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. John Wiley and Sons, 557 pp.
- Mount DW. 2004. *Bioinformatics: Sequence and Genome Analysis*. CSHLP, NY, 692 pp. 4. Brown S. M. (2000)
- Rashidi HH and Buehler LK. 2005. *Bioinformatics Basics: Applications in Biological Science and Medicine* (2nd edition). CRC press, FL, USA, 360 pp.
- Xiong J. 2006. *Essential Bioinformatics*. Cambridge University Press, 339pp.

I. Course Title : Fish Cell Culture

II. Course Code : FBT 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on basic cell and tissue culture techniques To acquaint the students with the applications of fish cell culture

V. Theory

Unit I

Basic of fish cell culture: Introduction, History, Development and importance of fish cell culture; Structure and Organization of animal cells; Biology of cultured cells.

Unit II

Primary Cell culture: Basic requirements for fish cell culture: Equipment, Media and supplements, basic aseptic techniques.

Unit III

Cell culture techniques: Establishment and maintenance of fish cell lines; Organ and histotypic cultures; Scaling-up of cell culture; Applications of fish cell culture /cell lines, Overview of methods used for characterization of primary culture / cell lines

Unit IV

Quality control: Quality control of fish cell lines, Prevention, Assessment of contaminants; Detection and cure of contamination, *In vitro* assays for cytotoxicity and genotoxicity assessment, Stem cells; Stem cell cultures, Embryonic stem cells and their applications; Induced Pluripotent Stem Cells and its applications.

Unit V

Applications of fish cell culture: Hybridoma Technology and its applications in fisheries, Overview of three dimensional culture and tissue engineering.

Unit VI

Cryopreservation: Cryopreservation and storage of fish Cell lines, cell repositories.

VI. Practical

General instructions to be followed in cell culture laboratory. Design and layout of a cell culture laboratory. Preparation of cell culture medium and medium filtration. Preparation of primary cell culture from selected fish tissues. Sub culturing by tripsinisation. Cell counting. Maintenance of fish cell lines. Cryopreservation and revival of cells. Measurement of doubling time. Characterisation of cells using cytogenic and molecular markers. Cytotoxicity assessment. Transfection of fish cells.

VII. Suggested Reading

- Baserga R. 1989. *Cell Growth and Division: A Practical Approach*. Oxford Press, London, UK, 172 pp.
- Butler M and Dawson M. 1992. *Cell Culture Labfax*. Academic Press, MA, USA, 274 pp.
- Clynes M. 1998. *Animal Cell Culture Techniques*. Springer, NY, USA 618 pp.
- Freshney RI. 2016. *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications* (7th edition). Wiley-Blackwell, NJ, USA, 728 pp.
- Goswami M and Lakra WS. 2012. *Fish Cell and Tissue Culture: A Text Book*. Narendra Publishing House.
- Masters JRW. 2000. *Animal Cell Culture-Practical Approach*. Oxford Press, London, UK, 334 pp.

I. Course Title : Aquaculture Biotechnology

II. Course Code : FBT 507

III. Credit Hours : 2+1

IV. Aim of the course

To provide an overview of genetic manipulation techniques for improvement of aquaculture production.
To understand the application of biotechnological tools in fish breeding, feed health, processing and other issues in fisheries.

V. Theory

Unit I

Chromosome manipulation: Ploidy manipulation, Sex reversal, Androgenesis, Gynogenesis and applications, Transgenesis in fish: Methods of gene transfer in fishes, Screening, Applications of transgenic fishes, GMOs: Biosafety regulations, ethics and IPR.

Unit II

Molecular markers for aquaculture: Sources and significance of genetic variation, Biochemical and molecular markers, Development and applications of Allozymes, mtDNA markers, RFLP, RAPD, AFLP, Minisatellites, Microsatellites and SNPs; DNA barcoding of fishes, FISH-BOL.

Unit III

Reproductive biotechnology: Overview of broodstock management and seed production, Induced breeding hormones and analogues; Seed certification through molecular techniques; Applications of nanotechnology in fish breeding.

Unit IV

Microalgae culture methods: Indoor, Mass culture, Raceway system; Enrichment of micro algae with micronutrients; Fuel production from microalgae using biotechnological approaches; Pharmaceutical products from microalgae; Macroalage cultivation and propagation.

Unit V

Biotechnological tools in aquatic animal health management: Concept and techniques for the production of SPF and SPR stocks in crustacean aquaculture; Disease diagnostic techniques(PCR, RT-PCR, LAMP) and therapeutics – DNA vaccines and RNAi vaccines.

Unit VI

Biotechnological tools in fish nutrition: Probiotics, and its role in aquaculture; Microbial flocs as feed for aquatic animals; Biofilms, Biofloc, Single cell protein, Bio-encapsulated feeds; Detection of contaminants in fish feed by biotechnology tools; Nutraceuticals, Nutrigenomics.

VI. Practical

Fish Chromosomal manipulation – Androgenesis, Gynogenesis, Triploidy. Allozyme variation by PAGE, Gel imaging and scoring. RAPD and interpretation of results. PCR-RFLP and interpretation of results. AFLP and interpretation of results. Development and validation of microsatellite marker. Disease diagnosis of shrimp/ fish seeds using PCR/RT-PCR. Synthesis and characterisation of nanoparticles. Delivery of nanoparticle conjugated hormones/drugs to fish. Isolation and screening of probiotic bacteria isolated from fish. Identification and culture of spirulina. Culture of live food organisms (Artemia/Rotifer/Moina). Different methods of gene transfer. Development of biofloc.

VII. Suggested Reading

- Liu Z. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. John Wiley and Sons, 557 pp.
- Liu ZJ. 2007. *Aquaculture Genome Technologies*. Wiley-Blackwell, 584 pp.
- Dunham RA. 2004. *Aquaculture and Fisheries Biotechnology: Genetic Approaches.* CABI Publishing, Cambridge, USA. 385 pp.
- Borowitzka MA and Borowitzka LJ. 1988. *Micro-algal Biotechnology*. Cambridge University Press, London, UK, 488 pp.
- Chen F and Jiang Y. 2001. *Algae and their Biotechnological Potential*. Springer Netherlands, 306 pp.
- Gordon R and Seckbach J. 2012. *The Science of Algal Fuels*. Springer Netherlands, 506 pp.
- Lakra. W.S 2004. *Fisheries Biotechnology*. Narendra Publishing House, New Delhi, 240 pp.

I. Course Title : Marine Biotechnology

II. Course Code : FBT 508

III. Credit Hours : (1+1)

IV. Aim of the course

To know and to understand the essential facts and concepts related to marine biotechnology. To give the students an overview of the potential marine resources and their uses.

V. Theory

Unit I

Marine bioresources: Historical background, Overview of the present status of marine biotechnology, Commercially important and potential species, Micro and macro-algae, Their culture and application in aquaculture.

Unit II

Bio-prospecting: Bio-prospecting of genes and allele mining for novel compounds, Methods of bio-prospecting from marine environment; Marine derived pharmaceuticals; Marine bio-resources, Secondary metabolites, Marine proteins and lipids; Marine actinobacterial metabolites, Potential bioactive compounds from soft and hard corals, Marine sponges etc., Marine biotoxins and their pharmacological potential.

Unit III

Marine Enzymes and Polysaccharides: Biotechnological application of Marine Enzymes- amylase, Protease, Lipase, Cellulases and Chitinase from micro algae, bacteria, fungi, actinomycetes, Marine Polysaccharides- alginic acid, agar, Fucoidan and carrageenan from marine seaweeds.

Unit IV

Environmental Biotechnology: Bio-film, Biofuel, Bio-remediation, Phytoremediation; Genetically engineered microbes for marine pollution control, Biofouling and prevention, Antifouling properties of marine organisms (algae, seagrass, marine microbes); Metagenomics; Concepts and applications.

VI. Practical

Identification of microalgae. Isolation and culture of microalgae. Identification of seaweeds. Micro-propagation of seaweeds. Isolation and culture of planktons. Isolation of aerobic microbes from sea. Isolation of anaerobic microbes from sea. Extraction of bioactive compounds from seaweeds. Extraction of bioactive compounds from microalgae. Extraction of bioactive compounds from sponges. Screening of bioactive compounds.

VII. Suggested Reading

- Fusetani N. 2000. *Drugs from the Sea*. Karger Publisher, Switzerland, 158 pp.;
- Karl DM. 1995. *Microbiology of Deep-Sea Hydrothermal Vents*. CRC Press FL, USA, 299 pp.;
- Kim S. 2015. *Springer Handbook of Marine Biotechnology*. Springer, 1517 pp.
- Omum S. 1992. *The Search for Bioactive Compounds from Microorganisms*. Springer-Verlag New York, 336 pp.

I. Course title : Molecular Markers

II. Course code : FBT 509

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with techniques used to estimate genetic variation among individuals and populations for applications in selective breeding and conservation.

V. Theory

Unit I

Genetic variation: Sources and significance of genetic variation; Statistical methods to estimate genetic variation.

Unit II

Biochemical and molecular markers: Type I and Type II markers; Development and applications of Allozymes, mtDNA markers, RFLP, RAPD, AFLP, Minisatellites, Microsatellites and SNPs.

Unit III

Sequencing technologies and applications: Chemical sequencing, Chain termination and NGS.

Unit IV

Genome and transcriptomic sequencing: Whole genome (Nuclear and Mitochondrial) and transcriptome sequencing and their applications.

Unit V

Marker Assisted Selection (MAS): Overview of linkage maps; FISH, QTL and genomic selection, Population genomics and applications.

Unit VI

Application of Molecular Markers in Taxonomy: DNA Barcoding; Metabarcoding.

VI. Practical

Allozyme variation by PAGE. Gel imaging and scoring of allozyme. RAPD. Interpretation of RAPD Gel and data analysis. PCR-RFLP. Interpretation of PCR-RFLP Gel and data analysis. AFLP. Interpretation of AFLP Gel and data analysis. Development and validation of microsatellite marker. Genotyping of SSR markers. Genotyping of SNPs.

VII. Suggested Reading

- Liu ZJ. 2007. *Aquaculture Genome Technologies*. Blackwell Publishing Ltd. pp.551.
- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, pp.606.
- MacKenzie S and Jentoft S. 2016. *Genomics in Aquaculture*. Academic Press. pp. 304.

I. Course Title : Molecular Taxonomy and Phylogenetics

II. Course Code : FBT 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with techniques used to delimit species using DNA / Protein sequence data for application in molecular taxonomy and conservation.

V. Theory

Unit I

Molecular Basis of Evolution: Overview of genome structure; Sources of genetic variation (Recombination, Mutations, Indels, Gene duplication); fast and slow-evolving sequences; Homologous, Paralogous and Orthologous genes, Concept of Neutral theory of molecular evolution.

Unit II

Evolution and Speciation: Allopatric, Sympatric and Parapatric speciation, Factors responsible for speciation Phylogenetic species concept, Phylogenetic trees, Concept of monophyly, paraphyly and polyphyly, Species delimitation, Gene trees and species trees DNA barcoding and concept, BOLD SYSTEMs and WORMS; Principle, Methodology, Application and limitations.

Unit III

Genetic distance measures: Observed and expected distances, Pair-wise distances, inter and intra specific distances;

Unit IV

Concepts in phylogeny: Phylogenetic species concept, Phylogenetic trees, Concept of monophyly, Paraphyly and polyphyly.

Unit V

Phylogenetic tree construction: Phylogenetic reconstruction using distance-based methods (UPGMA, Neighbour-Joining), Principle, Methodology, Interpretation of results and limitations.

Unit VI

Phylogenetic analyses: Phylogenetic reconstruction using character, Based methods, Maximum Parsimony, Maximum Likelihood and Bayesian Inferences, Mesquites, Genepops, Phylogenetic tree importances.

VI. Practical

DNA sequence analysis. Genomic databases. Genbank search and dataset download. Blast tools. EMBOSS tools. Sequence alignment, and editing, Data partition, Selection of the best substitution model. Use of Neighbour-Joining, Maximum Likelihood and Bayesian inference. Re-analysis and interpretation of reference data. Bioinformatic tools (MEGA, Phylip, PAUP, Mr Bayes and Fig Tree) for phylogenetic tree reconstruction.

VII. Suggested Reading

- Hall BG. 2011. *Phylogenetic Trees Made Easy: A How-To Manual* (4theds). Sinauer Associates is an imprint of Oxford University Press.
- Liu ZJ. 2007. *Aquaculture Genome Technologies*. Blackwell Publishing Ltd. pp.551.
- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, pp.606.MacKenzie, S and Jentoft, S. 2016. *Genomics in Aquaculture*. Academic Press. pp.304.
- Xiong J. 2006. *Essential Bioinformatics*. Cambridge University Press, pp.339.

Course Title with Credit Load
Ph.D. in Fish Biotechnology

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FBT 601	Genetic Engineering of Bacteria and Viruses	2+1
FBT 602	Genetic Engineering of Higher Eukaryotes	2+1
FBT 603	Functional Genomics	2+1
FBT 604	Genome Markers in Aquaculture	2+1
	Minor Courses	**06 Credits**
	(From the subjects closely related to a students major subject)	
FBT 605	Biotechnological Applications in Aquaculture	2+0
FBT 606	Nano Biotechnology	1+1
FBT 607	Bioprocess Technology	2+0
	Supporting Courses	**05 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Seminars	**2 Credits**
FBT 691	Doctoral Seminar-I	0+1
FBT 692	Doctoral Seminar-II	0+1
	Research	**75 Credits**
FBT 699	Doctoral Research (II semester)	0+15
FBT 699	Doctoral Research (III semester)	0+15
FBT 699	Doctoral Research (IV semester)	0+15
FBT 699	Doctoral Research (V semester)	0+15
FBT 699	Doctoral Research (VI semester)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fish Biotechnology

I. Course Title : Genetic Engineering of Bacteria and Viruses

II. Course Code : FBT 601

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on various techniques available to produce genetically engineered microbes and their application, design of viral vectors for efficient gene delivery.

V. Theory

Unit I

Genetic engineering of bacteria: Recombinant protein expression in Bacteria, Optimization of expression; Fusion proteins, Purification of recombinant proteins – inclusion bodies, Extracellular targeting, Engineering of signal sequences, Electroporation.

Unit II

Molecular biology of fish DNA/RNA viruses: Major groups of DNA/RNA viruses; Their Cis acting genetic elements and Regulation of protein expression.

Unit III

Genetic engineering of virus: Use of animal viruses like vaccinia, Herpes, Retrovirus, Baculovirus and Adenovirus as cloning vectors, Design of viral vectors – Special features, Cis acting regulatory elements; Strategies to optimize recombinant protein production.

Unit IV

Vectors: Pros and cons of using viral vectors as gene delivery vehicles; Vectors based on bacteriophage lambda, P1 and M13, special features and their application in optimizing recombinant protein production.

Unit V

Scope and application of genetic engineering in virus: Efficient gene delivery strategies, Host-pathogen interaction, Antigenic proteins, Vaccination approaches, DNA vaccines, Diagnostics; non-antibiotic selectable markers for live vaccines and gene therapy, Methods for detection of viral infection, Estimation of viral load by Real Time PCR, etc.

Unit VI

IPR issues in Biotechnology: Patent laws; Global scenario of genetically modified organisms, Intellectual Property Rights (IPR), Patent laws at institutional, national and international level.

VI. Practical

Transformation of bacteria by electroporation, Southern and dot-blot transfer techniques; Restriction mapping of DNA; labelling of DNA probes; PAGE analysis for recombinant proteins. Preparation of primary and secondary monolayer cell culture, use of cell culture in virus cultivation and assay; Viral DNA isolation and restriction analysis; Culture and maintenance of bacteriophages; qRT-PCR. Bacterial mass culture through fermentation technique.

VII. Suggested Reading

- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. *Lewin's Genes XII.*
- Jones and Bartlet Publishers, MA, USA 829 pp. ISBN-10: 1284104494.
- Rodney Boyer. 2005. *Concepts in Biochemistry* (3rd Edition). Wiley, NJ, US, 736 pp. ISBN-10: 0471661791.
- Green MR and Sambrook J. 2012. *Molecular Cloning: A Laboratory Manual* (4th edition: Vol 1-3.). *Cold Spring Harbor*, NY, USA 2028 pp.
- Brown TA. 2017. *Genomes 4* (4th edition). Garland Science, US, 544 pp.

I. Course Title : Genetic Engineering of Higher Eukaryotes

II. Course Code : FBT 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide in-depth knowledge on the techniques available for genetic engineering of higher eukaryotes To describe strategies to optimize recombinant protein production in eukaryotic expression systems

V. Theory

Unit I

Eukaryotic expression systems: Overview of recombinant DNA technology and applications in fisheries and aquaculture, Eukaryotic expression systems; Yeast expression system – Host strains, Special features, Types of vectors (yeast episomal vectors, Integrating vectors and YACs), Yeast two hybrid system.

Unit II

Insect cell expression system: Cell expression system- Special features, Types, baculoviral expression vectors, Polyhedron promoters.

Unit III

Mammalian cell expression system: Special features, Selectable markers; Transfection: Principle, types, Selection; Transduction by viral vectors, Construct design (strong and constitutive promoters, inclusion of introns).

Unit IV

Fish cell expression system: Tissue specific promoters, Constitutive promoters and applications, Strategies for optimizing recombinant gene protein expression in eukaryotic systems; Downstream processing of recombinant proteins.

Unit V

Fish as a model organism: Gene function analysis – Gene knockouts, RNAi, etc; Site directed and transposon mediated mutagenesis, CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) knockdown technology.

Unit VI

Transgenesis: Methods of gene transfer, Integration and detection techniques, *In situ* hybridization; Strategies for gene targeting (homologous sites/cre-lox recombination system) Biosafety regulation, Case studies: AquAdvantageTM salmon and GLoFishTM; fish as bio-factories.

VI. Practical

Gene transfer experiments (electroporation, microinjection). Western blotting for confirming integration and expression of transgene. Southern blotting for confirming integration and expression of transgene. Inverse PCR - Partial RE digestion, designing of primers and interpretation of results. Construction of cDNA library. Screening of cDNA library: Probe designing. Screening of cDNA library using colony hybridization. *in-silico* designing of guide RNA for CRISPR vector.

VII. Suggested Reading

- Boyer R. 2005. *Concepts in Biochemistry* (3rd Edition). Wiley, NJ, US, 736 pp.
- Brown TA. 2010. *Gene Cloning and DNA Analysis: An Introduction* (6th edition). Wiley-Blackwell. 320 pp.
- Brown TA. 2017. *Genomes 4* (4th edition). Garland Science, US, 544 pp.
- Fernandez JM and Hoeffler JP. 1999. *Gene Expression Systems: Using Nature for the Art of Expression*. Academic Press, 480 pp.
- Green MR and Sambrook J. 2012. *Molecular Cloning: A Laboratory Manual* (4th edition: Vol 1-3.), Cold Spring Harbor, NY, USA 2028 pp.
- Hacker and David L. 2018. *Recombinant Protein Expression in Mammalian Cells: Methods and Protocols*.
- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. *Lewin's Genes XII* Jones and Bartlet Publishers, MA, USA 829 pp.
- Wang Y, Zhao S, Bai L, Fan J and Liu E. 2013. *Expression Systems and Species Used for Transgenic Animal Bioreactors*. *Biomed Research International,* 2013.

I. Course Title : Functional Genomics

II. Course Code : FBT 603

III. Credit Hours : 2+1

IV. Aim of the course

To give an introduction to application of modern techniques for functional genome analysis

V. Theory

Unit I

Basics of functional genomics: Genome size estimation; High throughput sequencing platforms for whole genome sequencing; Principles, applications, limitations, Data analysis; Gap filling and linkage groups; Gene annotation; Genome mining for various applications.

Unit II

Transcriptomics: Transcriptome sequencing by RNAseq and NGS, Data analysis, sequence assembly, Annotation, Gene ontology assignment, KEGG pathway analysis.

Unit III

Non-coding RNA: Structure, Processing and analysis of miRNA and Long noncoding RNA.

Unit IV

Global gene expression analysis: DNA Microarray, Subtractive hybridization and differential display for the identification of differentially expressed genes, Identifying candidate genes for various traits of fish species.

Unit V

Proteomics and metabolomics: Overview of proteomics and metabolomics, Bioinformatics tools used in proteomics; Protein databases and interfaces; Principles and Applications of metabolomics and system biology.

Unit VI

Functional genomics in aquaculture: Genomic resources in aquaculture species, Gene expression pattern during fish larvae development, Genomic responses to stress challenges in fish, Functional genomics in fish/shrimp disease control.

VI. Practical

Processing of high throughput sequence data for assembling contigs. Gene annotation and pathway analysis. Mining of transcriptome data for protein coding genes, differentially expressed genes. Mining of data for short and long non coding RNA and their target genes. Ensembl genome browser. DNA microarray. Software for allele mining. Ontology and identification of metabolic pathways. Investigation of aquatic animal pathogens using DNA microarray.

VII. Suggested Reading

- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, 606 pp.
- Overturf K. 2009. *Molecular Research in Aquaculture*. Blackwell Publishing, 395 pp.
- Peruski LF and Peruski AH. 1997. *The Internet and New Biology: Tools for Genomic and Molecular Research*. ASM press, WA, USA, 350 pp.
- Saroglia M and Liu Z.J. 2012. *Functional Genomics in Aquaculture*. John Wiley and Sons, 416 pp.
- Schlena M. 1999. *DNA Microarrays: A Practical Approach,* Oxford University Press, London, UK, 232 pp.;
- Stephen H and Livesey F. 2000. *Functional Genomics: A Practical Approach*, Oxford University Press, London, UK, 272 pp.

I. Course Title : Genome Markers in Aquaculture

II. Course Code : FBT 604

III. Credit Hours : 2+1

IV. Aim of the course

To learn development and application of genomic tools in aquaculture species

V. Theory

Unit I

Molecular markers: Molecular markers in aquaculture (Microsatellites, AFLP, SNPs etc.), and their application; Transcriptome associated markers - Type I markers.

Unit II

Genetic analysis using DNA markers: SNPs: Discovery, Array development, genotyping and Data analysis and applications.

Unit III

DNA marker maps: Radiation hybrid mapping and integrated maps, Genome analysis; Preparation of ordered cosmid libraries, BAC libraries, Shotgun libraries: Construction and characterisation.

Unit IV

DNA sequencing technologies: Conventional and automated sequencing, Metagenomics, NGS platforms – Principles and applications.

Unit V

Case studies: Genotype based sequencing, Case studies of linkage maps (Rohu, Tilapia, European seabass, Channel catfish, *Litopenaeusvannamei*).

Unit VI

Applications: QTL and Maker assisted selection in aquaculture species, Genomic selection in aquaculture breeding programmes, DNA chips, phenomics and association studies.

VI. Practical

Microsattelite development and validation. AFLP and data analysis. Construction of genomic library. Screening of library by colony hybridization. Screening of library by probe labelling techniques. Software related to linkage mapping. SNP discovery and analysis.

VII. Suggested Reading

- Avise JC. 1994. *Molecular Markers, Natural History and Evolution*, Springer, US, 516 pp.
- Caetano-anolles G and Gresshoff PM. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH, NY: 364 pp.
- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, 606 pp.
- MacKenzie S and Jentoft S. 2016. *Genomics in Aquaculture*. Academic Press, 304 pp.
- Overturf K. 2009. *Molecular Research in Aquaculture*. Blackwell Publishing, 395 pp.

I. Course title : Biotechnological Applications in Aquaculture

II. Course code : FBT 605

III. Credit Hours : 2+0

IV. Aim of the course

To acquire knowledge on the latest development in aquaculture biotechnology

V. Theory

Unit I

Reproductive biotechnology: Gonadal steroids, Endocrine control of oogenesis and spermatogenesis, Pituitary and gonadotropins; Fish recombinant gonadotropins – Structure, Synthesis, Evolution, Regulation of gonadotropins and promoters; Pheromones – Types, Evolution, Role in breeding and population management.

Unit II

Neofemale technology: Differential growth pattern in prawns, Androgenic gland ablation, Mating design, Advantages and challenges; Artificial insemination in crustaceans – Definition, Types of thelycum, Insemination methods, Purpose and difficulties.

Unit III

Surrogate broodstock technology: Mechanism of gonad development, Germ cell transplantation (GCT), Primordial germ cells (PGCs), Spermatogonial stem cells (SSCs), GCs transplantation techniques for various developmental stages of fishes; Problems and Future developments.

Unit IV

Biosecurity and Bioremediation: Specific Pathogen Free (SPF) shrimp, Quarantine, Mating design, Nucleus Breeding Centre (NBC), Broodstock Multiplication Centre (BMC) and advantages of SPF stocks; Biosecurity in SPF shrimp hatcheries, Biotechnological approaches for fish pond management through bioremediation; Meta barcoding and its application in aquaculture.

Unit V

Nutrigenomics: Nutrient-gene interactions; Nutraceuticals; Nanotechnology for nutrient delivery in fish; Biotechnologically improved plant protein feed ingredients to replace fish meal in aqua feed.

Unit VI

Seaweed micropropagation: Methods of seaweed cultivation, Propagation methods (Vegetative and Reproduction), Clonal propagation and selection of strains with superior traits; Seaweed tissue and callus culture; Growth regulators and callus induction; Production of micropropagules from callus culture; Cell suspension cultures from seaweed callus; Bioprocess engineering of tissue culture of seaweeds and future prospects.

VI. Suggested Reading

- Allan G and Burnell G. 2013. *Advances in Aquaculture Hatchery Technology*. Woodhead Publishing. 625pp.
- Alday-Sanz, Brock J, Flegel TW, McIntosh RW, Bondad-Reantaso MG, Salazar M and Subasinghe R. 2018. *Facts, Truths and Myths about SPF Shrimp in Aquaculture*. *Reviews in Aquaculture*.
- Bernier N, Kraak GVD, Farrell AP and Brauner CJ. 2009. *Fish Physiology: Fish Neuroendocrinology*. Elsevier. 529 pp.
- Jena AK, Biswas P and Saha H. 2017. *Advanced Farming Systems in Aquaculture: Strategies to Enhance the Production*. Innovative Farming, 2(1): 84-89.
- Mishra SP. 2015. *Plant Tissue Culture*. Ane's student edition. 2nd Edition. 288pp.
- Reddy CRK, Jha B, Fujita Y and Ohno M. 2008. *Seaweed Micropropagation Techniques and their Potentials: An Overview*. *Journal of Applied Phycology* 20(5): 159-167.
- Thomas PC, Rath SC and Mahapatra KD. 2017. *Breeding and Seed Production of Finfish and Shellfish*. DayaPublsihing house. 402.
- Yanong RPE and Erlacher-Reid C. 2012. *Biosecurity in Aquaculture,* Part 1: An Overview. SRAC Publication No. 4707.

I. Course Yitle : Nano Biotechnology

II. Course Code : FBT 606

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint students with the practical knowledge on synthesis and characterisation of nanoparticles.

To explain the importance and applications of nano-biotechnology in fisheries and aquaculture.

V. Theory

Unit I

Introduction to nano biotechnology: Overview of nanoscale materials and nanostructures, Applications in fisheries and aquaculture.

Unit II

Synthesis of different types of nanomaterials: Chemical, Physical and Biological methods, Functionalization of nanoparticles for biological applications.

Unit III

Characterization of nanostructures: Scanning probe microscopy; Electron microscopy; NMR; AFM.

Unit IV

Applications: Biomolecules as nanostructures and their application in nanotechnology viz., Biosensor, Separation of cell and cell organelles, Gene therapy and chromosome/genome mapping, Nanoparticle based genotyping, Nano delivery of bio molecules, Nano-fertilizers, Nanotechnology in Packaging, Nanobarcode Technology, Biobarcode Assay; Nanotoxicity; Environmental behaviour of nanoparticles, Green nanotechnology, Ethical and IPR Issues in Nanotechnology.

VI. Practical

Chemical synthesis of nanoparticles. Green synthesis of nanoparticles. Characterization of nanoparticles by zetasizer. Characterization of nanoparticles by SEM. Nano-conjugation of DNA/protein. Confirmation of nano-conjugation by gel retardation assay. Nanodelivery of various biomolecules. Toxicity assessment of nanoparticles. Patent search on nanotechnology. Field trip to Nanotechnology institutes/labs.

VII. Suggested Reading

- Booker R and Boysen E. 2005. *Nanotechnology*, John Wiley and sons, 371 pp.
- Niemeyer CM and Mirkin CA. 2004. *Nanobiotechnology: Concepts, Applications and Perspectives*, Wiley VCH, Weinheim, 468pp.
- Pradeep T. 2007. NANO: *The Essentials: Understanding Nanoscience and Nanotechnology* McGraw Hill Education, New Delhi.
- Kulkarni, S.K. 2015. *Nanotechnology Principles and Practices*, 379 pp.

I. Course Title : Bioprocess Technology

II. Course Code : FBT 607

III. Credit Hours : (2+0)

IV. Aim of the course

To learn the techniques for bulk processing, production and purification of biologicals.

V. Theory

Unit I

Bioprocessing: Raw materials for bioprocessing, Comparison of chemical and Biochemical processing based on energetics and Environmental issues.

Unit II

Bioprocessing requirements: Development of inocula, Kinetics of enzymatic and

Microbial processes, Optimisation studies, Sterilization of media, Air and equipment, Modes of cell cultivation.

Unit III

Bioreactors: General principles of bioreactor design and their operation, Downstream processing, Separation and Purification techniques, Quality assurance testing; Representative examples of microbial products, Vaccines and vaccine development.

Unit IV

Methods in processing: Immobilization of cells and enzymes: Principles, Methodology and applications, Disintegration of cells, Separation of solid and liquid phases.

Unit V

Isolation and purification: Isolation and purification techniques for proteins and other products based on different physico-chemical properties, e.g., precipitation, adsorption, chromatographic separations, bio-affinity based methods

Unit VI

Post-processing: Principles of bioprocess control, bioprocess automation and Application of computers in bioprocessing, Recombinant products with representative examples.

VI. Suggested Reading

- Ratlidge C and Kristiansen B. 2006. *Basic Biotechnology*. Cambridge University Press, Cambridge, UK, 679 pp.
- Renneberg R. *et al*. 2017. *Biotechnology for Beginners*. Academic Press, MA, USA, 464 pp.
- Waites MJ *et al*. 2001. *Industrial Microbiology: An Introduction*. Wiley-Blackwell, NJ, USA, 304 pp.

List of suggested Journals

- *Molecular Biology Reports*
- *Mitochondrial DNA (DNA sequence)*
- *Gene*
- *Genomics*
- *Nature biotechnology*
- *BMC biotechnology*
- *Biotechnology letters*
- *Biotechnology and bioprocess engineering*
- *Molecular Ecology Resources (Molecular Ecology Notes)*
- *Molecular genetics and genomics*
- *Indian Journal of Biotechnology*
- *BMC genomics*
- *Current Science*
- *Biochemical Genetics*
- *PloS One*
- *Animal Biotechnology*
- *Biotechnology Journal*
- *Biotechnology and Applied Biochemistry*
- *Biotechnology and Genetic Engineering Reviews*
- *Food Technology and Biotechnology*
- *Molecular Biotechnology*
- *Biomed research international*

- *Genomics, proteomics and bioinformatics*
- *Genes and Genomics*
- *International Journal of Molecular Sciences*
- *Biotechnology Advances*
- *Computational and Structural Biotechnology Journal*
- *Applied Microbiology and Biotechnology*
- *Frontiers in Bioengineering and Biotechnology*
- *Current Trends in Biotechnology and Pharmacy*
- *Journal of Molecular Biology*
- *International Journal of Biological Macromolecules*
- *Molecular and Cellular Proteomics*
- *Journal of Cell and Molecular Biology*
- *Microbiology and Molecular Biology Reviews*
- Science Magazines: Scientific American, U.S.A.; New Scientist, U.K.; Everyman's Science (Indian Science Congress Association), etc.

List of suggested e-Resources

- https://www.ncbi.nlm.nih.gov/
- https://www.ebi.ac.uk/
- https://www.ebi.ac.uk/Tools/msa/clustalo/
- https://swissmodel.expasy.org/
- https://www.expasy.org/
- https://www.web-books.com/MoBio/
- http://cellbiol.com/
- https://www.edx.org/learn/molecular-biology
- https://www.icgeb.org/resources/library/
- http://www.biology4kids.com/files/cell_main.html
- https://www2.le.ac.uk/projects/vgec/highereducation/
- https://www.ncbi.nlm.nih.gov/tools/primer-blast/
- http://bioinfo.ut.ee/primer3-0.4.0/
- https://all-about-molecular-biology.jimdo.com/
- https://www.molbiolcell.org/
- http://www.web-books.com/MoBio/
- https://npsa-prabi.ibcp.fr/cgi-bin/npsa_automat.pl?page=/NPSA/npsa_sopma.html
- http://www.bioinformatics.nl/cgi-bin/primer3plus/primer3plus.cgi
- https://www.sciencedaily.com/terms/molecular_biology.htm
- https://plato.stanford.edu/entries/molecular-biology/#toc
- https://molbiol-tools.ca/Alignments.htm
- https://molbiol-tools.ca/Phylogeny.htm
- http://evolution.genetics.washington.edu/phylip/software.html
- https://www.addgene.org/

Suggested Broad Areas for Masters and Doctoral Research

- DNA marker development for species/hybrid identification, stock characterization, MAS/ genomic selection, etc.
- Cytogenetics: genotoxicity assessment; FISH for DNA marker localization
- Molecular interventions for captive maturation and induced breeding
- Chromosome manipulation: androgenesis, gynogenesis and triploidy, monosex populations
- Development of molecular diagnostics and vaccines
- Nanotechnology: Nanoparticle synthesis, functional derivatization for delivery of bio-active molecules, toxicity assessment and mitigation
- Genomics/transcriptomics/proteomics: high-throughput data for mining novel genes and markers for various applications including climate/environment resilient traits
- Cell line tissue culture/ stem cells for various applications

- Transgenesis/gene editing for trait improvement, producing mutants/ model organisms for drug screening
- Epigenetics: Mechanisms and gene expression modulation for various applications
- Cryopreservation for germplasm conservation
- Bio-prospecting of marine organisms for drug development
- Computational approaches in fish genomics and drug designing

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Processing Technology

Preamble
(Fish Processing Technology)

The syllabi for postgraduate programmes in Fish Processing Technology (M.F.Sc., and Ph.D.) were revised with the prime objective of coping up with the developments that have taken place in the field of fish processing sub-sector at national and international levels in recent years and to suit with the developments that would take place in the next five years. Although we have taken the base as the common syllabus revised and adopted by the ICAR BSMA in 2009, the syllabi followed at CIFE Mumbai for M.F.Sc. and Ph.D in Post-Harvest Technology was very much consulted as the syllabi was relooked with the changing scenario in the field and improved. The major changes in revision of the syllabi for the M.F.Sc and Ph.D. programmes in Fish Processing Technology from BSMA 2009 are discussed as under:

M.F.Sc. in Fish Processing Technology

- FPT 501 Low Temperature Preservation of Fish and Shell-fish: The title and content of this course was changed from the earlier course title, Technology of fish freezing and frozen storage without alteration in the credit load. The contents were updated and recent developments in technology and analytical methods included.
- FPT 502: Thermal Processing of Fish and Fishery Products - Unit wise distribution of contents rearranged and aspects on thermal process calculations included.
- FPT 503: Applied Fish Microbiology - Title changed from Techniques in Microbiology incorporating not only the techniques but also basic and applied aspects of fisheries microbiology
- FPT 504 Fish Quality Assurance and Certification – Details of HACCP added
- FPT 505: Applied Fish Biochemistry - Topics on “Pigments” and “Electrophoresis” added
- FPT 506: Value Added Fishery products - With the changes that have taken place in the field of fish processing and value addition both in domestic and export markets it was decided have this new course. However, some of the contents of FPT 508 Technology of Mince based Fish Products (1+1) and a few aspects from the course FPT 506 Cured, dehydrated and Smoked Fishery products (1+1) are included
- FPT 507 Trade Regulations, Certification and Documentation in Export of Fish and Fishery Products – This is a new course with the credit load of 1+1, considering the importance of export trade of fish and fishery products and the need to develop entrepreneurs. Topics on Import regulations, SPS-TBT agreement, Traceability issues for farm reared and wild aquatic products; dealing with returned consignments; Foreign trade regulations in India; Practical on “Preparation of BOL, LC; Preparation of documents for seafood export to different destinations; Study of documents on customs and port procedures for seafood export and import” included.
- FPT 508: Design, Maintenance of Fish Processing Plants and Instrumentation - Topics on “Plant design as pre-requisite for quality management” and “Designing of ETP systems” added. Minor changes in contents of practical also made.
- FPT 509: Microorganisms of Public Health Significance - Topics on “Algal toxins” and “Antibiotic resistance in microbes” added to the contents.
- FPT 510: Molecular Techniques in Seafood Quality Analysis - – This is a new course

with the credit load of 1+1. Considerable developments in molecular analysis have taken place over the past decade and contents of this course reflect all recent developments in seafood analysis.

- FPT 511: Packaging of Fish and Fishery Products - Topics on "Packaging requirements for transportation of live fish and shellfish", "FSSAI requirements and BIS guidelines", "Intelligent packaging; edible packaging", "Disposal and recycling of packaging materials" added
- FPT 512: Fish Byproducts and Waste Utilization – Title changed from Fish Byproducts and Utilization of Fishery Waste with addition of topics on biopeptides, chitooligo- saccharides and chitosan based nanoparticles and also the units rearranged
- FPT 513: Multivariate Analysis in Food Processing and Product Development – This is a new course with the credit load of 0+1, designed for students who take up research on product development.

Ph.D. in Fish Processing Technology

- FPT 601 Principles and Techniques in Seafood Analysis – Title changed from Biochemical Techniques in Fish Analysis (2+1) with additional topics on GCMS, GC MSMS, SEM, TEM introduced
- FPT 602 Functional Properties of Fish and Shellfish Proteins. Rephrasing of the tile carried out. Units rearranged for better coherence.
- FPT 603 Biotechnological Applications in Fish Processing, A new course with a credit load of 2+1. Recombinant DNA technology, Molecular biological and Immunological tools in bacterial detection in foods and molecular techniques in detection seafood adulteration are the novel topics introduced.
- FPT 604 Quality Management Sysems – In addition to the original contents accreditation of analytical laboratories introduced.
- FPT 605 Emerging Trends in seafood Processing, A new course introduced with the credit load of 1+1 to keep abreast of the developments in modern techniques in food processing. Types of novel processing technologies and their applications such as Supercritical Fluid extraction- SCFX, High-Pressure Processing (HPP); pulsed electrical fields (PEF) as a pasteurization technology, Ultrasound processing, Ozone/ CO_2 Processing, Hurdle Technology and Automation in Processing are the topics given focus.
- FPT 606 Nutraceuticals of Aquatic Origin – A new course with a credit load of 1+1 with units of Nutraceuticals and functional foods, Marine bioactive compounds and Delivery of nutraceuticals included
- FPT 607 Toxins and Contaminants – Topics on Antibiotic residues in seafood, micro-plastics, PAHs, Toxicity and accumulation studies added along with other changes made.
- FPT 608: Additives in fish Processing – A new course (1+1) taken from the original syllabus of M.F.Sc. programme updating contents and rearrangements of units.
- FPT 609: Sensory and Physical Analyses – A new course (2+1) with units on basics of sensory and physical analysis, Measuring responses, Physical and mechanical properties of food, and Guidelines for analysis and reporting.
- FPT 610: Environmental Impact of Fishery Industries – Contents updated and units rearranged
- FPT 611: Food Labeling – Title changed from Nutritional Aspects and Nutritional Labeling (2+1) and credit load reduced to 1+1. Contents revised with focus on legislation and labeling requirements.

- FPT 612: Water Quality Management in Seafood Processing – A new course with a credit load of 2+1 giving focus on units including Sources and types of water, Quality criteria, Quality Standards, Water budgeting for processing and treatment. Considering the Union Government's Blue Revolution initiatives in promoting fisheries sector, the syllabi for postgraduate programmes in Fish Processing Technology are framed in such a way that our graduates would be able to man higher positions in fisheries management with skill sets for effective entrepreneurship.

Course Title with Credit Load
M.F.Sc. in Fish Processing Technology

Course Code	Course Title	Course Hours
	Major Courses	**20 credits**
FPT 501	Low Temperature Preservation of Fish and Shell Fish	2+1
FPT 502	Thermal Processing of Fish and Fishery Products	2+1
FPT 503	Applied Fisheries Microbiology	2+1
FPT 504	Fish Quality Assurance, Management and Certification	2+1
FPT 505	Applied Fisheries Biochemistry	2+1
FPT 506	Value Added Fishery Products	2+1
FPT 507	Trade Regulations, Certification and Documentation in Export of Fish and Fishery Products	1+1
	Minor Courses	8 credits
	(From the subjects closely related to a student's major subject)	
FPT 508	Design, Maintenance of Fish Processing Plants and Instrumentation	1+1
FPT 509	Microorganisms of Public Health Significance	1+1
FPT 510	Molecular Techniques In Seafood Quality Analysis	1+1
FPT 511	Packaging of Fish and Fishery Products	1+1
FPT 512	Fish Byproducts and Waste Utilization	1+1
FPT 513	Multivariate Analysis In Food Processing and Product Development	0+1
	Optional courses from other disciplines or MOOC	4
	Supporting courses	**6 credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 credits**
	(The following courses, one credit each will be offered)	

- Library and Information Services
- Technical Writing and Communication Skills
- Intellectual Property and its management in Agriculture
- Basic concepts in Laboratory Techniques
- Agricultural Research, Research ethics and Rural Development Programmes

Course Code	Course Title	Course Hours
	Seminar	**1 Credit**
FPT 591	Seminar I	0+1
	Masters Thesis Research	**30 Credits**
FPT 599	Master's Research (Semester III)	0+15
FPT 599	Master's Research (Semester IV)	0+15
	Total Credit load of M.F.Sc. Program	**70 Credits**

Course Contents
M.F.Sc in Fish Processing Technology

I. Course Title : Low Temperature Preservation of Fish and Shellfish
II. Course Code : FPT 501
III. Credit Hours : 2+1

IV. Aim of the course

Chilling and Freezing are the most common methods of fish preservation and most trade are happening at this form of preservation. A thorough knowledge on the mechanism of action of these methods is essential for any graduate student.

V. Theory

Unit I

Postmortem changes: Structural and chemical features of fish and shellfish as raw material for processing, Factors affecting quality of fresh fish, intrinsic and extrinsic factors, Handling of fish onboard, Landing centres and farm sites-different types of chilling methods, Depuration of bivalves, Assessment of post-harvest loss.

Unit II

Chilled storage and transportation of fish: Heat load calculation, Storage methods- insulated boxes and insulation thickness, Different types of ice, Physical, Chemical, Microbiological and Sensory changes during chill storage, Melanosis and its prevention, Iced storage shelf life, Cold shock, Transportation- live fish/shell fish, transportation of raw fish to local markets and processing centres, Improvements needed in transportation, Refrigerated transport systems, Classification of transport vehicles, cold chain.

Unit III

Freezing of fish and shellfish: Structure of water and ice, Influence of solutes on the structure of water and ice, Phase equilibria and freezing curves of pure water and binary solutions, freezing curves for fish, Determination of freezing points from time-temperature plots, Calculation of freezing time; Crystallization, Nucleation- homogeneous and Heterogeneous nucleation; Super cooling, Crystal growth, Eutectic point, Location of ice crystals in tissue, Changes during freezing.

Unit IV

Freezing methods: Technological aspects of freezing-methods of freezing (plate freezing, IQF, etc), Selection of a freezing method, Product processing and packaging, packing of fresh and frozen fish for consumers, Modified atmosphere packaging, Controlled packaging, Cold storage management-arrangements within a cold storage, handling and stacking systems.

Unit V

Changes in frozen storage: Physical changes, freezer burn and recrystallisation, Different types of recrystallisation, Chemical changes in lipids, Proteins and nucleotides, Freeze denaturation and theories on denaturation, Changes in pH, Bacterial changes, Sensory changes, texture, taste, odour, effect of post-mortem condition on sensory qualities.

Unit VI

Prevention of quality loss during frozen storage: Treatments prior to freezing, Antioxidants, Cryoprotectants and other additives, Theories of cryoprotection, Glazing- importance and methods.

VI. Practical

Handling of fish, crustaceans and mollusks, Evaluation of freshness of fish, crustaceans and molluscs, freezing curve, determination of freezing point, Filleting of fish, treatments, glazing, packaging, freezing, Processing of shrimp, lobster, squid, cuttle fish, crab etc. in different styles, Depuration-treatment with chemicals, Packaging and Freezing, Chemical tests (Histamine, k value) on frozen products and Studies on physical and sensory changes for determination of shelf life.

VII. Suggested Reading

- AOAC manual
- Balachandran KK. 2001. *Post-harvest Technology of Fish and Fish Products*. Daya Publ. House.
- Clucas IJ. 1981. *Fish Handling, Preservation and Processing in the Tropics*. Parts I, II. FAO.
- Fennema K, Powrie WD and Marth EH. 1973. *Low Temperature Preservation of Foods and Living Matter*. Marcel Dekker.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Hall GM. (Ed). 2011. *Fish Processing –Sustainability and New Opportunities.* Wiley-Blackwell.
- Judith A. Evans. 2008. *Frozen Food Science and Technology*, Blackwell Publishing Inc. (Malden)
- SEAFDEC manual
- Nalan Gokoglu, Pinar Yerlikaya. 2015. *Seafood Chilling, Refrigeration and Freezing: Science and Technology,* John Wiley and Sons (Chichester)
- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ.
- Venugopal V. 2006. *Seafood Processing*. Taylor and Francis.

I. Course Title : Thermal Processing of Fish and Fishery Products

II. Course Code : FPT 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide information on various aspects of thermal / heat processing.

To impart knowledge on various types of packaging techniques and materials used in thermal processing.

V. Theory

Unit I

Principles of thermal processing and classification of foods: Mechanisms of heat transfer; Unsteady state of transfer; conduction, convection, radiation; Dielectric and microwave heating, Heat penetration, cold point; Low acid, medium acid and acid foods, Absolute sterility, Statistical sterility, Commercial sterility, Pasteurization and Sterilization, sous-vide.

Unit II

Canning process: Steps involved, Process flow, Additives, Principles and process details, Canning machinery and equipment, Canning process for fish/shellfish, Value added canned products; Spoilage of canned food, physical, Chemical and microbial, Examination of cans and seams, Effect of canning on nutrient profile.

Unit III

Basis of Thermal Process: Heat resistance of bacteria and spores, Decimal reduction time, Thermal death time, "D", "Z" and "F0" values, 12 D value, Significance of survivor curve and Thermal death curve.

Unit IV

Thermal process calculations: Determination of process time and F value; Graphical, formula, Nomogram methods.

Unit V

Emerging trends in containers and heat treatment processes: HTST, UHT processing and aseptic canning, Flexible packing, Retort pouch processing of fish and fishery products principles and techniques; Combination and synergistic effects.

Unit VI

Canning plant location: Practical considerations, Canning plant facilities, Layout and design, Automation in canning lines.

VI. Practical

Operation of over pressure retort for canning, Canning operations for commercial important finfishes, Canning of shrimp and Cephalopods, Retort pouch processing of table fishes, bivalves, crustaceans, Examination of canned fishery products, Sensory evaluation of canned foods, Examination of can seams, Sterility test of canned products, Isolation of Clostridium spp, from canned foods, Heat Penetration Curve and Calculation of F0 Value, Z value, process time.

VII. Suggested Reading

- Da-Wen Sun 2005, *Thermal Food Processing: New Technologies and Quality Issues*, Taylor and Francis (Boca Raton)
- Hall GM. (Ed). 1992. *Fish Processing Technology*. Blackie.
- Hersom AC and Hulland ED. 1980. *Canned Foods*. Chemical Publ. Co.
- Holdsworth SD. 1997. *Thermal Processing of Packaged Foods,* Blackie Academic and Professional
- Larousse J and Brown BE. 1997. *Food Canning Technology*. Wiley VCH.
- Venugopal V. 2006. *Seafood Processing*. Taylor and Francis.
- Warne D. 1988. *Manual on Fish Canning*. FAO Fisheries Tech. Paper 285.
- Zeathen P. 1984. *Thermal Processing and Quality of Foods*. Elsevier.

I. Course Title : Applied Fisheries Microbiology

II. Course Code : FPT 503

III. Credit Hours : 2+1

IV. Aim of the course

To teach nature and activity of microbes in fish and fishery products, microbiological spoilage and preservation, various aspects of Industrial microbiology, importance of fermentation.

V. Theory

Unit I

Introductory microbiology: Classification, nature and activity of microbes in fish and fishery products; Microbiology of marine, Brackish and freshwater fish/ shell fish, Microbiology of spoilage and preservation.

Unit II

Intrinsic and extrinsic parameters of fish and fishery products that influence growth and survival of microorganisms

Unit III

Pathogenic organisms of public health significance in seafood: The etiology of diseases; Conditions for outbreak and prevention, Food infections by *Salmonella, Vibrio parahaemolyticus*, *V. vulnificus,* pathogenic *E. coli*, *Listeria monocytogenes, Campylobacter*; Virulence mechanisms, Their sources, Incidences, Foods involved and Prevention measures.

Unit IV

Fermentation: Batch wise and continuous; Important fermented products and methods of production; Screening of microorganisms, Detection and assay of products of fermentation, Preparation and use of fermentation media, Starter culture, Preparation and maintenance of stock cultures.

Unit V

Microbial injury, Microbial biofilms, Inactive physiological states (spores and VBNC), Unculturable and Uncultured bacteria, Identification of unculturable groups.

Unit VI

Advancement in diagnostic protocols: Molecular methods for detection of microbes in fish and fishery products

VI. Practical

Isolation and characterization of spoilage and pathogenic microorganisms, Sampling for TPC from fresh, iced and frozen fish, Selection of bacterial groups in iced fish, Isolation of fish spoilage bacteria, Enumeration of halophilic bacteria from salted fish, Fermentation by selected microbes, Assay of products formed; microbial composition of fermented fish and Conventional and molecular detection of pathogens.

VII. Suggested Reading

- Alexander N. Glazer and Hiroshi Nikaido 2007. *Microbial Biotechnology: Fundamentals of Applied Microbiology*, Cambridge University Press (Newyork)
- Chakraborthy P. 1995. *A Text Book of Microbiology*. New Central Book Agency.
- Criusted J. 1986. *Methods in Microbiology*. Academic Press.
- Doyle MP, Beuchat LR and Montville TJ. 1997. *Food Microbiology - Fundamentals and Frontiers*. American Society for Microbiology.
- Harry WSJR, Paul JV and John JL. 2000. *Microbes in Action*. Freeman and Co. II (ICMSF). Academic Press.
- KR Aneja. 2008. *Textbook of basic and applied microbiology*, "New Age International (P) Limited, Publishers" (New Delhi)
- Michael J, Pelizar JR and Chan ECS. 1998. *Microbiology*. McGraw Hill.
- Rita Narayanan 2013. *Food Microbiology: basic and applied with laboratory exercises*, New India Publishing Agency (New Delhi)

I. Course Title : Fish Quality Assurance, Management and Certification

II. Course Code : FPT 504

III. Credit Hours : 2+1

IV. Aim of the course

To teach various aspects of quality assurance systems, quality management and national / international certification system.

To teach factory sanitation and hygiene, water quality and standardsTo teach quality affecting parameters

V. Theory

Unit I

Hazards in fish and fishery product: Physical, Chemical, Biological, Quality management, Total quality concept and application in fish trade.

Unit II

Quality assessment of fish and fishery products: Physical, Chemical, Organoleptic and Microbiological quality standards.

Unit III

Inspection and quality assurance: Fish inspection in India, Traceability and authenticity; Factory sanitation and hygienization: National and international requirements, SSOP.

I. Course Title : Applied Fisheries Biochemistry

II. Course Code : FPT 505

III. Credit Hours : 2+1

IV. Aim of the course

- To impart knowledge on macro and trace constituents and nutritive value of fish.
- To create basic understanding about toxins and toxic substances and their toxic effects.
- To give a detailed insight into experimental techniques used in food analysis.

V. Theory

Unit I

Proteins: Classification; structural proteins (actin, myosin, tropomyosin, actomyosin, paramyosin), Sarcoplasmic proteins (myoalbumin, globulin, hydrolases, oxidoreductases); Connective tissue proteins (collagen); Pigments, heme proteins, hemocyanins, Antifreeze proteins, Functional properties of seafood proteins, Solubility, Emulsification, Viscosity, Water holding capacity, Gelation, Denaturation of proteins, Dissociation, Aggregation, Coagulation, Reversibility and their significance to processing and quality.

Unit II

Lipids: Composition and nutritive value, Lipid types and their variations, Fatty acid composition of fish liver and body oils, Lipid fractionation, triglycerides, Phospholipids, Polyunsaturated fatty acids and their beneficial effects on human health, Auto-oxidation of fatty acids, pro- and anti-oxidants, Oxidation indices, lipid protein interactions, Oxidized lipids-protein interactions and their impact on quality, Rancidity, Lipases and phospholipases.

Unit III

Carbohydrates: Classification and biological significance of carbohydrates, Structure and properties of monosaccharides, Disaccharides and polysaccharides, Uses of modified starch and other carbohydrates as food additives (as thickening and binding agents), Changes in Carbohydrates during processing and relationship of carbohydrates to food stability, Gelatinization.

Unit IV

Vitamins: Water soluble and Fat soluble, Heat labile vitamins, Process effecting on vitamins, Minerals; Major, Miner and Trace elements and their health benefits.

Unit V

Seafood flavours and pigments: Flavour, Taste and Odour, Chemical basis of flavour perception, Volatile fatty acids, Influence of processing on flavour, Non-protein nitrogenous compounds; Free amino acids, Peptides, Nucleotides, Guanidines, Urea, Quaternary ammonium compounds.

Unit VI

Fundamental techniques in food analysis: Basic principles of electrophoresis, Chromatography, TLC, Paper and Liquid Chromatography, HPLC, GC and GC-MS. Principle and applications of Spectrophotometry.

VI. Practical

Protein purification based on solubility, Separation of protein based on size and charge in PAGE, Separation of amino acids by TLC and paper chromatography; Enzyme assay by spectrophotometer; Amino acid analysis by HPLC, Determination of protein carbonyls, Extraction of lipids by different methods, Fractionation of lipids by TLC, Analysis of fatty acid composition by GC, Texture profile analysis and Estimation of unsaponifiable compounds in fish oil

VII. Suggested Reading

- Alasalvar C, Miyashita K, Shahidi F and Wanasundara U. 2011. *Handbook of Seafood Quality, Safety and Health Applications*, Wiley-Blackwell (Oxford)
- Anthony TT. 1988. *Handbook of Natural Toxins. Marine Toxins and Venom*. Vol. III. Marcel Dekker.
- Balachandran KK. 2001. *Post Harvest Technology of Fish and Fish Products*. Daya Publ. House.
- Connell JJ. 1995. *Control of Fish Quality*. Fishing News Books.
- Fennema K, Powrie WD and Marth EH. 1973. *Low Temperature Preservation of Foods and Living Matter*. Marcel Dekker.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Hall GM. (Ed). 1992. *Fish Processing Technology*. Blackie.
- H. Allan Bremner 2002, *Safety and Quality Issues in Fish Processing*
- Huss 2007. *Assessment and Management of Seafood Safety and Quality*. Daya Publishing House (Delhi)
- Hui YH, Merle DP and Richard GJ. (Eds.). 2001. *Food Borne Disease Handbook. Seafood and Environmental Toxins*. Vol. IV. Marcel Dekker.
- Huss HH, Jakobsen M and Liston J. 1991. *Quality Assurance in the Fish Industry*. Elsevier.
- John DEV. 1985. *Food Safety and Toxicity*. CRC Press.
- Kreuzer R. 1971. *Fish Inspection and Quality Control*. Fishing News Books.

- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ.
- Shukla RK. 2006. *Total Quality Management Practicing Manager*. New Royal Book.
- Vincent K and Omachonu JER. 2004. Principles of Total Quality. CRC Press.

I. Course Title : Value Added Fishery Products

II. Course Code : FPT 506

III. Credit Hours : 2+1

IV. Aim of the course

To make the students understand the concepts of value addition and to explain the preparation of products from low cost fish.

V. Theory

Unit I

Significance of value addition: Protein deficiency and need for fortification of food, Digestibility and nutritive value of fish meat, Overview of value-added products; Present market trends, Scope of value addition, Types of value addition, important value-added products.

Unit II

Minced fish meat: Equipment for mince preparation, Effect of mincing on physical and chemical properties; Different types of mince-based products, Surimi.

Unit III

Surimi: Basic concepts, Different unit operations, Cryoprotectants in surimi-hypothesis and mechanisms, Packaging, freezing and storage, Quality evaluation of surimi, Kamaboko and analogue products.

Unit IV

Battered and breaded products: Ingredients for batter and breading systems and their functionalities, Freeze dried products, Shelf life and specialties of AFD products, Machinery and equipment for freeze drying.

Unit V

Ready-to-eat and ready-to-cook products: Extruded fish products; Mechanism of extrusion, Types of extruders; Single screw, Twin screw, Mechanical and chemical changes during extrusion, Parameters affecting quality of extruded product, Cook-chill products.

Unit VI

Seaweeds: Resources, global and Indian scenario, Biochemical components in Seaweeds, Edible seaweeds – Nutritive value of seaweeds, Products from seaweeds.

VI. Practical

Preparation of Surimi from low value fish; Evaluation of Surimi gel strength; Evaluation of ATPase activity of actomyosin based products; Preparation of analog products from surimi, battered and breaded products, extruded products, cook-chill products and seaweed-based product.

VII. Suggested Reading

- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Hall GM. (Ed.). 1992. *Fish Processing Technology*. Blackie.

- Hui YH, Merle DP and Richard JG. (Eds.). 2001. *Food Borne Disease Handbook. Seafood and Environmental Toxins*. Vol. IV. Marcel Dekker.
- Nambudiri DD. 2006. *Technology of Fishery Products*. Fishing Chimes.
- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ.
- T Borresen 2008, *Improving Seafood Products for the Consumer,* Woodhead Publishiong Limited (Cambridge)
- Venugopal V. 2005. "*Seafood Processing: Adding Value Through Quick Freezing Retortable Packaging, and Cook-Chilling*", Taylor and Francis (Boca Raton)
- Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products*. John Wiley and Sons.

I. Course Title : Trade Regulations, Certification and Documentation in Export of Fish and Fishery Products

II. Course Code : FPT 507

III. Credit Hours : 1+1

IV. Aim of the course

To create basic understanding about Trade Regulations, Certification and documentation in export of fish and fishery products

V. Theory

Unit I

Trade policy and Legislation on labeling and other standards: Foreign Trade Policy of Fish and Fishery Products in Indian context and world context, Labeling requirements of Fish and Fishery products stipulated by National and International Organizations.

Unit II

Regulations: Export documentation- certificates of origin, Other certificates for Shipment of specific goods, Export licenses; Import regulations, SPS-TBT agreement.

Unit III

Labeling: Legislation on labeling; Labeling requirements for Traceability, Legislation on National and International standard requirements of seafood in export trade.

Unit IV

Export Certification systems: Consignment-wise, In process Quality, Self-Certification, Food safety management system, Pre-shipment inspection, Voluntary food certification scheme, Certificate for export (CFE), Health certificate, Other certification, Traceability issues for farm reared and wild aquatic products; Dealing with returned consignments; Foreign trade regulations in India.

VI. Practical

Documentation protocol for approval of fishing vessel, processing unit and technologist in processing plants. Labeling codes for Traceability of products in Export trade; Preparation of BOL and LC. Preparation of documents for seafood export to different destinations. Study of documents on customs and port procedures for seafood export and import.

VII. Suggested Reading

- Batra GS, Kaur Narinder. 1995. *Foreign Trade and Export Policy*, Anmol Publications Pvt Ltd.

- Cherian Jacob. 1997. *Export Marketing,* Himalaya Publishing House.
- Rathore Kumkum. 1994. *Export Marketing*, Arihant Publishing House.
- Mittal AC. 1991. *Export Management in India*, Omsons Publications.
- EIC, Export of Fresh, *Frozen and Processed Fish and Fishery Products A Guide for Exporters*, Export Inspection Council.

Minor Courses

I. Course Title : Design, Maintenance of Fish Processing Plants and Instrumentation

II. Course Code : FPT 508

III. Credit Hours : 1+1

IV. Aim of the course

To expose the students to design, maintenance of fish processing plant, machinery and the instruments used in fish processing plants.

V. Theory

Unit I

Plant design: Fundamentals of processing plant design, Site selection, Design and preparation of layout of processing plants, Freezing plant, Cold storage, Canning plant, dryers, etc., Plant design as pre-requisite for quality management, Functions and construction of refrigeration system; Tests and inspection, Operation and handling, Pressure-enthalpy (P-H) diagram and basic calculation, Application of P-H diagram, Size and required power of compressor.

Unit II

Maintenance: Maintenance of refrigerating machine, Troubles and causes, Preventive maintenance of machinery and equipment of fish processing plants, IOF, Canning plant, Sausage plant, Artificial dryers, Smoking chambers, etc., Safety controls for freezing and canning plant, Boilers: classification and selection, Boiler mounting and accessories; Boiler maintenance.

Unit III

Affluent water treatment and chlorination: Effluent treatment; Legislation and standards of effluent discharge, Water pollution control measures in the food industry, Waste water treatment process; Dissolved air floatation, Sedimentation, Chemical treatment, Biological treatment, Aeration, Carbon adsorption, Granular media filtration and sludge handling.

Unit IV

Measurement techniques: Sensors, active and passive sensors, Characteristic of sensors for the measurement of temperature, Relative humidity, a_w value, gel strength; Moisture, Freshness, pH, Conductivity, DO, Redox potential, Salinity, Air velocity, Solar energy and Brine concentration.

VI. Practical

Operation and maintenance of machinery and equipment for cold storage plant, freezing plant and canning plant. Operation and maintenance of dryers and boilers. Assembly of a refrigeration unit and charging of refrigerant. Measurement of temperature inside cold storage/freezer, Measurement of temperature in fish during freezing and thawing. Measurement of solar radiation. Designing of ETP systems.

VII. Suggested Reading

- Chupakhim V and Dormenko V. 1985. *Fish Processing Equipments*. MIR Publ.
- Heid JL and Joslyn MA. 1980. *Food Processing Operations*. AVI Publ. 188.
- Shafiur Rahman, Jasim Ahmed 2012. *Handbook of Food Process Design*: vol.1 and 2, Wiley-Blackwell (Oxford).
- Slade Frank H. 1967 *Food processing Plant*, Leonard Hill Books.
- Slade FH. 1997. *Food Processing Plants*. Leonard Hill.
- Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products,* John Wiley and Sons.

I. Course Title : Microorganisms of Public Health Significance

II. Course Code : FPT 509

III. Credit Hours : 1+1

IV. Aim of the course

To teach in detail about food-borne microorganisms of human health significance, food-borne diseases and their prevention.

V. Theory

Unit I

Pathogens in seafood: Sources of pathogens in seafood, Infection and intoxication; Bacteria of public health significance in fish *I* fishery products *I* environments, Epidemiology, Clostridial and staphylococcal food poisoning, Organism responsible and their origin, Growth and toxin production, Nature of toxins, Incidence of poisoning, Foods involved.

Unit II

The etiology of diseases: Conditions for outbreak and prevention, Food infections by *Salmonella, Vibrio parahaemolyticus, V. vulnificus,* pathogenic *E. coli*, *Listeria monocytogenes, Campylobacter, Arcobacter*; virulence mechanisms, Their sources, Incidences, Foods involved and prevention measures.

Unit III

Toxins: Histamine poisoning, Aflatoxins, patulin, Ochratoxin and other fungal toxins found in food, Toxin producer, source, Nature of toxin, Toxicity and significance in foods.

Unit IV

Virus and parasites in fish; Algal toxins; Antibiotic resistance in microbes; Significance of AMR.

VI. Practical

Laboratory techniques to detect and identify pathogens in fish - *E. coli, Staphylococcus aureus, Streptococus faecalis, Clostridium perfringens* and *Clostridium botulinum, Salmonella, Listeria, Vibrio cholere, Vibrio parabaemolyticus* and *V. vulnificus*. Animal bioassay of bacterial toxins.

VII. Suggested Reading

- Anon. 2001. *Food Borne Disease Handbook*. 2nd Ed. Vol. IV. *Seafood and Environmental Toxins*. Marcel Dekker.
- Davis BD, Dulbecco R, Eiser HN and Ginsberg HS. 1980. *Microbiology*. Harpar and Row.
- Doyle MP, Beuchat LR and Montville TJ. 1997. *Food Microbiology - Fundamentals and*

Frontiers. American Society for Microbiology.
- Harry WSJR, Paul JV and John JL. 2000. *Microbes in Action*. Freeman and Co.
- J Hoorfar. *Rapid Detection, Characterization, and Enumeration of Foodborne Pathogens*. ASM Press.
- Michael J, Pelizar JR and Chan ECS. 1998. *Microbiology*. McGraw Hill.
- Roberts D, Hooper W, Greenwood M. 1995. *Practical Food Microbiology: Methods for the Examination of Food for Micro-organisms of Publichealth Significance*, Public Health Laboratory Service (London)
- Silliker JH, Elliof RP, Baired AC and Boyan FL. 1980. *Microbial Ecology of Foods*. Vol. II. (ICMSF). Academic Press.
- Thomas J Montville, Karl R Matthews, and Kalmia E. Kniel. *Food Microbiology: An Introduction*, Third Edition. ASM Press.
- William CF and Dennis CW. 2000. *Food Microbiology*. McGraw Hill

I. Course Title : Molecular Techniques in Seafood Quality Analysis

II. Course Code : FPT 510

III. Credit Hours : 1+1

IV. Aim of the course

To teach basic concepts and techniques in molecular biology and immunology

V. Theory

Unit I

Introduction to molecular biology: Nucleic acids, Structure, Replication, Transcription and translation, Genes, ORF, Organization of genes, Operons, Plasmids. Vectors used in cloning and their structures.

Unit II

Enzymes in molecular biology: Polymerases, Ligases, Restriction Enzymes, Topoisomerases.

Unit III

Molecular methods: Molecular methods and their principles, PCR, RT-PCR, Hybridization, Microarray, AFLP, RFLP.

Unit IV

Immunological techniques in pathogen detection: Antigen-antibody reactions, Immunoassays-ELISA, FAT; Authenticity testing

VI. Practical

Conventional DNA extraction, Application of PCR for pathogen detection, Probe labeling and Southern hybridization, Primer designing, Tm determination, Agarose and protein gel electrophoresis, Cloning of genes, transformation techniques, Bioinformatic analysis of DNA and proteins, In-silico DNA and protein analysis, Restriction digestion, primer and probe designing, Protein structure prediction and Genome comparisons.

VII. Suggested Reading

- Hoorfar. *Rapid Detection, Characterization, and Enumeration of Foodborne Pathogens*. ASM Press
- Helen Kreuzer and Adrianne Massey. *Molecular Biology and Biotechnology: A Guide for Students*, Third Edition. ASM Press.

- Keith Wilson, John Walker, 2013. *Principles and Techniques of Biochemistry and Molecular Biology,* Cambridge University Press (New York)
- Leo M.L. Nollet, Fidel Toldra, 2010. *Handbook of Seafood and Seafood Products Analysis* CRC Press Inc. (Florida)
- Peter Walker 2005, *DNA-based Molecular Diagnostic Techniques: Research Needs for Standardization and Validation of the Detection of Aquatic Animal Pathogens and Diseases*, Daya Publishing House (Delhi)
- Susan Carson, Sue Carson, Heather Miller, D. Scott Witherow, 2012. *Molecular Biology Techniques: A Classroom Laboratory Manual*, Elsevier (Amsterdam)

I. Course Title : Packaging of Fish and Fishery Products

II. Course Code : FPT 511

III. Credit Hours : 1+1

IV. Aim of the course

To learn about different packaging materials, their appropriate use and benefits.

V. Theory

Unit I

Food packaging: Purposes and procedures; Technological aspects of packaging fishery products; Packaging for transport, Shipping and Institutional supplies; Packaging materials; Basic films and laminates, Their manufacture and Identification; Resistance of packaging materials; Development of protective packaging for fishery products.

Unit II

Transportation: Packaging requirements for transportation of live fish and shellfish, Methods of testing for packaging materials for their physical properties; Containers and their testing and evaluation; Package designs; Resistance of packages to hazards in handling; Transport and storage.

Unit III

Standards: Packaging standards for domestic and international trade.

Unit IV

Labeling and printing of packaging materials: FSSAI requirements and BIS guidelines, Intelligent packaging; Edible packaging; Disposal and recycling of packaging materials.

VI. Practical

Determination of grammage of paper and board, bursting strength and burst factor, punctures resistance, water proofness, stiffness of the board, ring stiffness of paper and board, flat crush, tensile strength and elongation at break of plastic films, density of plastic films, breaking length, impact strength of plastic films, tearing strength of paper and plastic films, water vapour transmission rate, oxygen transmission rate, heat seal strength, suitability of plastic films for food contact applications and Identification of plastic films.

VII. Suggested Reading

- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Da-Wen Sun 2012. *Handbook of Frozen Food Processing and Packaging*, CRC Press (Boca Raton)

- Gopakumar K. 1993. *Fish Packaging Technology - Materials and Methods*. Concept Publ.
- Gordon L Robertson. 2005. *Food Packaging: Principles and Practices*, "Marcel Dekker, Inc." (New York)
- Gordon L Robertson. 2010. *Food Packaging and Shelf Life: A Practical Guide*, CRC Press Inc. (Florida)
- Gordon L Robertson. 2013. *Food Packaging: Principles and Practice*, CRC Press (Boca Raton)
- Jerry D'Souza, Jatin Pradhan. 2010. *Handbook of Food Processing Packaging and Labeling*, SBS Publiahers and Distributors Pvt. Ltd. (New Delhi)
- Ponnuswami V. 2012. *Nano Food Packaging: A New Post-harvest Venture*, Narendra Publishing House (Delhi)
- S Subasinghe. 1999. *Retail Packaging of Fish and Fishery Products*, InfoFish
- TK Srinivasa Gopal. 2007. *Seafood Packaging*, Central Institute of FIsheries Technology (Cochin)
- W Steven Otwell, Hordur G Kristinsson, Murat O Balaban. 2006. *Modified Atmospheric Processing and Packaging of Fish: Filtered Smokes, Carbon Monoxide, and Reduced Oxygen Packaging*" "Blackwell Publishing Inc., " (Malden).

I. Course Title : Fish By-products and Waste Utilization

II. Course Code : FPT 512

III. Credit Hours : 1+1

IV. Aim of the course

To teach concepts of utilizing seafood wastes and byproducts from fish and shellfish

V. Theory

Unit I

Fish processing wastes and utilization: Overview of fish processing wastes, by catch and its composition, Liquid and solid wastes in fish processing, Bioremediation, Anaerobic treatment, Production of animal feed, Biodiesel.

Unit II

Fish meal, silage and oils: Fish meal production (dry and wet process), Nutritional importance and Quality requirements, Specifications, Packaging and storage, Fish silage; Acid silage and Fermented silage, Advantages over fish meal, Nutritional value of silage; Fish Oil; Fish body and liver oils, Extraction, Purification, Preservation and storage, Industrial and Nutritional applications of fish oils; Production of concentrates of polyunsaturated fatty acids, Preparation of fatty alcohol and amides, Extraction of shark liver oil, squalene, shark cartilage; ambergris.

Unit III

Fish wastes and utilization: Protein recovery - collagen, gelatin, extraction of enzymes; Shellfish Waste; sources and composition, Conventional uses, Chitin, Chitosan, Glucosamine hydrochloride, Carotenoids from Fish protein hydrolysates-Production and utilization, Biochemical composition and importance in food and nutrition, Functional properties of bioactive peptides; Shellfish waste and its applications, Biogas production from fish waste.

Unit IV

Novel products from fish waste and uses: Uses of Gelatin, Collagen, Shark cartilage, Glucosamine, Carotenoids, Astaxanthin, Bioactive peptides.

VI. Practical

Extraction of collagen from fish waste, gelatin from fish waste and enzymes from fish waste. Preparation of hydrolysates from fish and shellfish wastes. Extraction of chitosan and glucosamine from shrimp shell waste, Recovery of fish oil from fish waste

VII. Suggested Reading

- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Elvevoll EO. *Fish Waste and Functional foods,* Norwegian College of Fishery Science, Department of Marine Biotechnology, Norway. edele@nfh.uit.no
- Fereidoon Shahidi. 2007. *Maximizing the Value of Marine By-Products*, CRC Press Inc. (Florida)
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR. 198
- Venugopal V. 2014. *Fish Industry Byproducts as Source of Enzymes and Their Applications in Seafood Processing, in 'Fish Processing Byproducts: Quality Assessment and Applications*', Sachindra NM, Mahendrakar NS (Eds), Studium Press LLC, USA.
- Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products*. John Wiley and Sons.

I. Course Title : Multivariate Analysis in Food Processing and Product Development

II. Course Code : FPT 513

III. Credit Hours : 0+1

IV. Aim of the course

To create practical knowledge about Multivariate Analysis in Food Processing and product development.

V. Practical

Importance of multivariate analysis in optimization of different variables to achieve desired traits in food processing, product development and sensory evaluation; Design and analysis of controlled experiments: Full factorial, Factorial, Central composite and Box-Behnken Designs. Exercises to develop suitable designs for extruded products and antioxidant extractions by using Unscrambler software; Response surface analysis: Selection of variables, design variables and response variables, selection of samples, modeling the response data using Unscrambler software, checking the predictive ability, response surface plots; Principal Component Analysis (PCA): Principal components, Bi-linear modeling of one single data matrix X, Score plot, Loading plot and Correlation Loadings; Regression: Principal component regression (PCR), Multiple linear regression (MLR), Partial Least Squares Regression (PLSR): Modeling Y from the essence of X data set, Calibration and Prediction Models.

VI. Suggested Reading

- Alvin C. Rencher. 2002. *Methods of multivariate analysis*
- Rao CR. 1993. *Multivariate Analysis: Future Directions*, "North Holland Publishing Co."
- Yiu H. Hui. 2006. *Handbook of Food Science, Technology and Engineering*.

Course Title with Credit Load
Ph.D. in Fish Processing Technology

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FPT 601	Principles and Techniques of Seafood Analysis	2+1
FPT 602	Functional Properties of Fish and Shell-fish Proteins	2+1
FPT 603	Biotechnological Applications in Fish Processing	2+1
FPT 604	Quality Management Systems	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
FPT 605	Emerging Trends in Seafood Processing	1+1
FPT 606	Nutraceuticals of Aquatic Origin	1+1
FPT 607	Toxins and Contaminants	2+1
FPT 608	Additives in Fish Processing	1+1
FPT 609	Sensory and Physical Analyses	1+1
FPT 610	Environmental Impact of Fishery Industries	2+1
FPT 611	Food Labeling	1+1
FPT 612	Water Quality Management in Seafood Processing	2+1
	Supporting Courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
FST 601	Advanced Statistical Methods	2+1
FST 602	Software for Fisheries Data Analysis and Management	0+2
RPE 601	Research and Publication Ethics	1+1
	Total Course Work Credit load	**23**
	Seminar	**2 Credits**
FPT 691	Seminar I	0+1
FPT 692	Seminar II	0+1
	Thesis Research	**75 Credits**
FPT 699	Doctoral Research (Semester II)	0+15
FPT 699	Doctoral Research (Semester III)	0+15
FPT 699	Doctoral Research (Semester IV)	0+15

Course Code	Course Title	Credit Hours
FPT 699	Doctoral Research (Semester V)	0+15
FPT 699	Doctoral Research (Semester VI)	0+15
	Total Credit load for Ph.D. Program	**100**

Course Contents
Ph.D in Fish Processing Technology

I. Course Title : Principles and Techniques of Seafood Analysis
II. Course Code : FPT 601
III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on various instrumental techniques in seafood analysis.

V. Theory

Unit I

Separation of molecules: General principles of separation of micro and macro molecules, Selection of appropriate tools for analysis of fish samples, Outlines of common techniques involved in biochemical analysis.

Unit II

Filtration and centrifugation techniques: Different types of filtration, Types of filters and means of using them; Types of centrifugation (preparative and analytical), concept of Svedberg unit, Selecting appropriate rotor, Relative centrifugal force.

Unit III

Viscoelastic properties, Rheology, Tribology, TPA; IR and FTIR spectrophotometry, Spectrofluorimetry, ICP, Atomic absorption mass spectrometry, Tandem MS/MS.

Unit IV

Microscopy: Fluorescence microscopy, SEM, TEM, XRD.

Unit V

Electrophoresis: General principles, types (native, denatured PAGE, 2D) Chromatographic techniques; General principle, Types of chromatography (adsorption, partition, ion-exchange, molecular sieve, affinity, liquid and gas chromatography, thin layer chromatography).

Unit VI

Chromatography: Partition coefficient, Retention, Resolution, Capacity factor, Theoretical plate, Vandeemter curve, Gel filtration chromatography, Ion exchange chromatography, Affinity chromatography, Hydrophobic interaction chromatography, Paper chromatography, Thin layer chromatography, Reversed-phase chromatography, GC, HPLC, GCMS, LCMSMS

VI. Practical

Characterization of proteins based on solubility: sarcoplasmic, myofibrillar, and stroma; Estimation of proteins- Biuret techniques, Lowry techniques, Dye binding technique and electrophoretic techniques. Amino acid analysis by HPLC. Fatty acid analysis by GC MS, Minerals and heavy metals by Atomic Absorption spectroscopy. Texture analysis by TPA. HPLC- determination of histamine, Demonstration of GC-MS-MS.

VII. Suggested Reading

- Ewing GW. 1997. *Analytical Instrumentation Handbook*. Marcel Dekker.
- Larsen BS and McEwen CN. 1988. *Mass Spectrometry of Biological Materials*. Marcel Dekker.
- Lakshmanan. 2010. *Modern Analytical Techniques* Central Institute of FIsheries Technology (Cochin)
- Leo ML, Nollet, Fidel Toldra. 2010. *Handbook of Seafood and Seafood Products Analysis* CRC Press Inc. (Florida)
- Luis M, Botana. 2014. *Seafood and Freshwater Toxins: Pharmacology, Physiology, and Detection,* Third Edition, CRC Press (Boca Raton)
- Otles S. 2016. *Handbook of Food Analysis Instruments*. CRC Press.
- Pare JRJ and Belanger JMR. 1997. *Instrumental Methods in Food Analysis*. Elsevier.
- Robyt JF and White BJ. 1990. *Biochemical Techniques - Theory and Practice.* Waveland Press.
- Wilson K and Walker J. 2000. *Practical Biochemistry - Principles and Techniques.* Cambridge University Press.
- Wilson RH. 1994. *Spectroscopic Techniques for Food Analysis*. VCH Publ.

I. Course Title : Functional Properties of Fish and Shell Fish Proteins

II. Course Code : FPT 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on the functional properties known to affect product property.

V. Theory

Unit I

Protein properties: Functional properties of fish and shellfish proteins and their importance in food systems, Denaturation and functionality; Changes in functional properties of proteins as affected by icing, Freezing, Drying, Salting and Heating. Modification of proteins for improving functionality- Succinylation and acetylation procedures.

Unit II

Protein structure and function: Protein folding and non-covalent forces stabilizing protein structure; Free energy and entropy, Surface hydrophobicity and its relation to functional properties.

Unit III

Solubility and water sorption of proteins: Factors affecting protein hydration, Viscosity in relation to protein hydration; Methods of estimating viscosity.

Unit IV

Gelation: Definition of gel, Mechanism of formation of gel, Factors affecting the gel formation, Evaluation of gelling capacity- Thermal, Rheological and microscopy.

Unit V

Emulsifying: Theoretical concept of emulsion capacity and stability, Emulsion instability; Creaming, Sedimentation, aggregation vs Brownian aggregation. DLVO theory, microemulsions.

Unit VI

Foaming: Foaming ability of different protein systems with case studies, Foam stability in relation to proteins structure.

VI. Practical

Evaluation of water absorption properties of fish protein, fat absorption properties of fish protein, gelling properties of fish protein, emulsification capacity of fish protein and foam stability of fish/shell fish proteins. Determination of effect of pH on fish protein, temperature on functional properties fish protein and ionic strength on functional properties fish protein. Prediction of functional properties using model compounds. Estimation of surface hydrophobicity and total hydrophobicity.

VII. Suggested Reading

- Cherry JP. 1991. *Protein Functionality in Foods*. American Chemical Society. Washington. D.C.
- Damodaran S and Paraf A. 1997. *Food Proteins and Their Applications*., Marcel Dekker,
- Hill SE, Ledward DA and Mitchell JR. 1998. *Functional Properties of Food Macromolecules*. 2nd Ed. Aspen Publ.
- Nakai S and Modler HW. 1996. *Food Proteins Properties and Characterisation*. VCH Publ.
- Phillips LG, Whitehead DM and Kinsella J. 1994. *Structure, Functional Properties of Food Proteins*. Academic Press.
- Pomeranz, Yeshajahu. 1985. *Functional Properties of Food Components,* Academic Press, "
- Venugopal V. 2006. *Seafood Processing*. Taylor and Francis.
- Zdzislaw E, Sikorski. 2006. *Chemical and Functional Properties of Food Components*, Third Edition, CRC Press Inc. (Florida)

I. Course Title : Biotechnological Applications in Fish Processing

II. Course Code : FPT 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand the recent trends in microbiology and biotechnology research that could be applied in fish processing

V. Theory

Unit I

Basic Concepts: Microbial interactions and their applications in foods; Natural preservatives, Quorum sensing and its inhibitors, Phage therapy, Basic concepts of fermentations, Bioremediation and probiotics; Concepts of biotechnological approaches to product improvement.

Unit II

Microbial genomics: Genomics of bacteria, micro RNA, Microbiome and health, Metagenomics and its applications; Application of bioinformatics.

Unit III

Recombinant DNA technology: Application in food microorganisms, Engineering of microorganisms to produce useful metabolites, Enzymes, Vaccines.

Unit IV

Molecular biological tools: RT-PCR, microarray, Hybridization techniques, Next generation sequencing techniques, biosensors.

Unit V

Immunology: Immunoglobulins, Monoclonal antibodies, Application of antigen and antibody reactions, Immune-magnetic separation, proteomics.

Unit VI

Techniques involved in seafood adulteration: AFLP, RFLP, RAPD, DNA finger printing

VI. Practical

Molecular biological assays for aquatic food borne pathogenic bacteria. Molecular Immunological assays for aquatic foodborne pathogenic bacteria. Molecular Immunological assays for aquatic foodborne pathogenic viruses. Construction of recombinant plasmid. Recombinant protein expression and purification. Transformation. Gene knockout techniques. Construction of gene library. Microbiome studies. Tools used in metagenome analysis.

VII. Suggested Reading

- AM Martin. 2009. *Fisheries Processing: Biotechnological Applications*, Chapman and Hall (Chennai).
- Byong H. Lee 2015. *Fundamentals of Food Biotechnology*. Wiley-Blackwell (Oxford)
- Jennie S Popp, Molly M Jahn, Marty D Matlock, Nathan P Kemper 2012. *Role of Biotechnology in a Sustainable Food Supply*. Cambridge University Press (Newyork).
- Parmjit S Panesar, Satwinder S Marwaha. 2014. *Biotechnology in Agriculture and Food Processing: Opportunities and Challenges*. CRC Press (Boca Raton).

I. Course Title : Quality Management Systems

II. Course Code : FPT 604

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize students with different aspects of quality management systems and evaluation techniques for seafood.
To teach Seafood Quality Assurance and Quality Management Systems.

V. Theory

Unit I

The concept of total quality management: The principles of TQM, Zero defect planning, Quality circle, Quality link, Quality culture, Statistical quality control, Quality evaluation techniques for seafood; Effect of preprocess handling, Transport and storage on quality; Quality costs and evaluation.

Unit II

Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP): Codex guidelines, Concept of HACCP in seafood safety, Risk assessment; HACCP team management role and CCPs and implementation procedure for HACCP, ISO 9000 series of standards.

Unit III

Accreditation of laboratories: Validation requirements; Method of selection, Method of validation, Methods to control accuracy and precision, Primary standards, Reference standards, Reference material (RM), Certified Reference Material (CRM) and Standard Reference Material (SRM).

Unit IV

Sampling: Uncertainty and calculation of uncertainty measurements, Sample accountability; Sampling plan; Probability sampling and non- probability sampling.

Unit V

Proficiency and check samples: Intra and inter laboratory test programme, Proficiency testing programme; Predictive modeling in quality and safety assurance of fishery products.

Unit VI

Traceability, Product Recall, Equipment and machineries calibration

VI. Practical

Developing flow charts and indented use of different frozen and pasteurized fishery products. Preparation of HACCP work sheet for identification of hazards in frozen, canned and pasteurized products. Preparation of HACCP plan form for identified hazards in frozen and canned fishery products. Developing flow charts and indented use of different canned products. Study of correction and corrective action. Detection of important toxic chemicals in seafood.

VII. Suggested reading

- Alasalvar C, Miyashita K, Shahidi F, Wanasundara U. 2011. *Handbook of Seafood Quality, Safety and Health Applications*. Wiley-Blackwell (Oxford).
- Alasalvar C. 2011. *Handbook of Seafood Quality, Safety and Health Applications*. Chichester, West Sussex, UK/; Wiley-Blackwell.
- Anon. 1992. *TQM in New Product Manufacturing*. McGraw Hill.
- Anon. 1994. *Principles of Total Quality*. St. Leuie Press.
- Botana Luis M. 2014. *Seafood and Freshwater Toxins/: Pharmacology, Physiology, and Detection*, Third Edition. Third edit.
- H Allan Bremner. 2002. *Safety and quality issues in fish processing*
- Huss HH. 2003. *Assessment and Management of Seafood Safety and Quality*. FAO Tech. Paper No. 444.
- Huss. 2007. *Assessment and Management of Seafood Safety and Quality*. Daya Publishing House (Delhi)
- Kanduri L and Eckhartt RA. 2002. *Food Safety in Shrimp Processing*. Fishing News Books.
- Kreuzer R. 1971. *Fish Inspection and Quality Control*. Fishing News Books.
- Labbé Ronald G. and García, S. 2013. *Guide to Foodborne Pathogens*. Second edi.
- Shukla RK. 2006. *Total Quality Management Practicing Manager*. New Royal Book.

Minor courses

I. Course Title : Emerging Trends in Seafood Prcoessing
II. Course Code : FPT 605
III. Credit Hours : 1+1

IV. Aim of the course

To give a detailed insight into various advancements in seafood processing technologies

V. Theory

Unit I

Types of novel processing technologies and their applications: Supercritical Fluid extraction- SCFX, High-Pressure Processing (HPP); Pulsed electrical fields (PEF) as a pasteurization technology**,** Ultrasound processing, Ozone/CO_2 Processing.

Unit II

Hurdle technology: Principle and application of hurdle technology, Sous-vide technology, Other applications – Microwave processing, Accelerated Freeze Drying, Ohmic Heating.

Unit III

Trends in packaging: Active and Intelligent Packaging; Application of nanotechnology and Nano biotechnology in fisheries.

Unit IV

Automation in processing: Automation in fish process lines; Efficient process lines; Bionic noses; Machine vision; Robotics

VI. Practical

Effect of microwave cooking on proximate composition, lipid oxidation and texture profile. Formulation of different mince and surimi-based products. Preparation of battered and breaded products from prawns, fish and bivalves. Preparation of MAP products and comparison with chilled products. Super critical fluid extraction principles and procedure. Preparation of High Pressurized Product from fish

VII. Suggested Reading

- Ahmed J. 2010. *Novel Food Processing: Effects on Rheological and Functional Properties*: Boca Raton, Fla./: CRC Press, .
- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Fereidoon Shahidi, Yvonne M. Jones, David Kitts. 2014. *"Seafood Safety, Processing, and Biotechnology"* Taylor and Francis (Boca Raton)
- Hall GM. 2011. *Fish Processing*. Chichester, West Sussex, U.K./; Wiley-Blackwell Pub.
- Hall GM. (Ed.). 1992. *Fish Processing Technology*. Blackie.
- Jacob JP. 2013. *A Handbook on Food Packaging*. New Delhi: Daya Publishing House.

- Joseph P. Kerry. 2012. *Advances in Meat, Poultry and Seafood Packaging* Woodhead Publishiong Limited (Cambridge)
- Nambudiri DD. 2006. *Technology of Fishery Products*. Fishing Chimes.
- Robertson Gordon L. 2010. *Food Packaging and Shelf Life*. Boca Raton, FL/: CRC Press/ Taylor and Francis Group .
- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ. Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products*. John Wiley and Sons.

I. Course Title : Nutraceuticals of Aquatic Origin

II. Course Code : FPT 606

III. Credit Hours : 1+1

IV. Aim of the course

To teach about compounds of nutraceutical importance from the sea

V. Theory

Unit I

Nutraceuticals: An overview; Nutritional and functional value of marine proteins, Lipids and health benefits of omega-3 fatty acids.

Unit II

Functional foods: Functional components from fish processing waste: Extraction and applications of collagen, Collagen peptides, Gelatin and gelatin hydrolysates, Chitosan and glucosamine hydrochloride, Squalene and its clinical significance, carotenoids and their utility.

Unit III

Marine bioactive compounds: Antimicrobial, Cytotoxic substances; Antiviral and antitumor compositions; Secondary metabolites of corals with therapeutic value; Antioxidants from marine sources and antioxidant capacity assays-Ferric Reducing Antioxidant Power Assay, â-carotene bleaching assay, ABTS and DPPH assays.

Unit IV

Delivery of nutraceuticals: Fortification and encapsulation with marine nutraceuticals, Encapsulating methods (spray drying, freeze drying and liposome entrapment), Macromolecules of marine origin used as biopackaging, Edible films and coatings and drug delivery systems.

VI. Practical

Extraction of gelatin and collagen from fish waste. Extraction of fish protein hydrolysate and evaluation of their functional properties. Preparation of Chitin and chitosan from shrimp shell waste. Emulsification of fish oil with different emulsifiers. Preparation of omega-3 fatty acid by urea crystallization method. Encapsulation of omega-3 fatty acids by spray drying and freeze drying. Extraction of carotenoids and determination of their antioxidant capacity by Ferric Reducing Antioxidant Power, β-carotene bleaching and ABTS and DPPH assays. Determination of antimicrobial assays.

VII. Suggested Reading

- Barrow CJ. 2008. *Marine Nutraceuticals and Functional Foods*. Boca Raton/: CRC Press.
- Colin Barrow, Fereidoon Shahidi. 2007. *Marine Nutraceuticals and Functional*

Foods. CRC Press Inc. (Florida)
- John Shi. 2007. *Functional Food Ingredients and Nutraceuticals*, CRC Press Inc. (Florida)
- Jose L Martinez. 2007. *Supercritical Fluid Extraction of Nutraceuticals and Bioactive Compounds*. CRC Press (Boca Raton)
- Kim SK. ed., 2013. *Marine Proteins and Peptides: Biological Activities and Applications*. John Wiley and Sons.
- McNeil Archer D, Giavasis, L, Harvey L. 2013. *Microbial Production of Food Ingredients, Enzymes and Nutraceuticals* Woodhead Publishing Limited (Oxford)
- Se-Kwon Kim. 2013. *Marine Nutraceuticals: Prospects and Perspectives*, CRC Press (Boca Raton)
- Venugopal Vazhiyl 2011. *Marine Polysaccharides/: Food applications*. Boca Raton/ : Taylor and Francis.
- Venugopal V. 2009. *Marine Products for Healthcare: Functional and Bioactive Nutraceutical Compounds from the Ocean*. CRC Press Inc. (Florida)

I. Course title : Toxins and Contaminants

II. Course code : FPT 607

III. Credit Hours : 2+1

IV. Aim of the course

To understand various types of toxins and contaminants in seafood, their impact on human health, and the analytical methods to estimate toxins and contaminants in foods.

V. Theory

Unit I

Food borne pathogens: Status of food borne diseases, Epidemiology; Public health significance of food borne toxins, Pathogens.

Unit II

Marine bio-toxin: Ciguatoxin, Paralytic shellfish toxins, Diarrhoetic shell fish toxins, Scomberotoxins, Brevi toxins, etc., Symptoms, treatment, Pharmacology and detection;.

Unit III

Bacterial toxins: Types, Structure, Mechanisms; Food allergens.

Unit IV

Chemical contaminants of the aquatic environment: Heavy metals (Hg, Cd, Pb, Cr, Ni, As etc.), Pesticides.

Unit V

Antibiotic residues in fish, Microplastics, PAHs; Toxicity and accumulation.

Unit VI

Analytical methods: For different types of marine toxins and tolerance limits, Stability, Bioassays, Pharmacology assays, Immunoassays, Instrumental methods, Persistent pollutants, Toxicity evaluation, Measurement of LC_{50} and factors affecting LC_{50}, Animal tissue analysis.

VI. Practical

Detection of bacterial toxins by assay. Analysis of heavy metals, pesticides and antibiotic residues by ELISA method Estimation of LC50 vale of important pesticides. Quantification of antibiotic residue by LCMSMS.

VII. Suggested Reading

- Anon. 1988. *Handbook of Natural Toxins*. Vol. III. Marine Toxins and Venom. Marcel Dekker.
- Anon. 1988. *Handbook of Natural Toxins*. Vol. IV. Bacterial Toxins. Marcel Dekker.
- Anon. 2001. *Food borne Disease Handbook*. 2nd Ed. Vol. IV. Seafood and Environmental Toxins. Marcel Dekker.
- Edward PR. 1984. *Seafood Toxins*. American Chemical Society, Washington, D.C.
- Luis M Botana. 2000. *Seafood and Freshwater Toxins: Pharmacology, Physiology and Detection*, “Marcel Dekker, Inc.” (New York)
- Moss J, Iglewski B, Vaughan M and Ju AT. 1995. *Bacterial Toxins and Virulence Factors in Disease*. Vol. VIII. Marcel Dekker.
- Nobuhiro Fusetani, William Kem. 2009. *Marine Toxins as Research Tools*, Springer (Dordrecht)
- Zadunaisky J. 1984. *Toxins, Drugs, and Pollutants in Marine Animals* Springer Verlag.

I. Course Title : Additives in Fish Processing

II. Course Code : FPT 608

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize with the use of different additives, their effects, levels and detection

V. Theory

Unit I

Food additives in fish processing: Importance of food additives, Classification of additives- Antioxidants, preservatives, Emulsifiers and stabilizers, Food colors, Flavours, Sequestrants, Anticaking agents, Acids-buffers-bases, Humectants, Firming and Crisping agents, Sweeteners, Enzymes, Nutritive additives, Flour and Bread additives, Cryoprotectants.

Unit II

Food additives and hypersensitivity: Risks and benefits of food additives, Health considerations and safety evaluation; Toxicity, and toxico-kinetics, Genotoxicity, Reproductive toxicity, Sub-acute toxicity, Sub-chronic toxicity, Chronic toxicity, Carcinogenicity, Allergenic effect, Allowable daily intake.

Unit III

Proteins as food additives: Natural antimicrobials- Bacteriocins, Natural antioxidants, Changes in properties of food due to different food additives.

Unit IV

Legal issues in additives: Laws related to additives, Methods of demonstrating safety, GRAS (Generally Recognized as Safe) additives, Problem of adulteration and solution.

VI. Practical

Analysis of processed seafood for TPP residues, citric acid, meta bi-sulphate residues. Analysis of food for presence of undesirable residues of food additives Antibiotics, Antioxidants, Antifungal agents and Colouring agents.

VII. Suggested Reading

- Ashrust PR. 1999. *Food Flavourings*. 3rd Ed. Aspen Publ.
- Belitz HD and Grosch W. 1999. *Food Chemistry*. 2nd Ed. Springer.
- H A Modi. 2012. *Food additives*. Aavishkar Publishers Distributors (Jaipur)
- Hutching JB. 1999. *Food Colour and Appearance*. 2nd Ed. Aspen Publ.
- Michael J. Scotter. 2015. *Colour Additives for Foods and Beverage*. Woodhead Publishing Limited (Oxford).
- NIIR Board. *Food colours, flavours and additives technology hand book*. National Institute of Industrial Research (Delhi)
- Semih Otles. 2012. *Methods of Analysis of Food Components and Additives*.CRC Press (Boca Raton)
- Teranishi R, Buttery RG and Shahidi F. 1989. *Flavour Chemistry – Trends and Developments*. American Chemical Society, Washington D.C.

I. Course Title : Sensory and Physical Analyses

II. Course Code : FPT 609

III. Credit Hours : 2+1

IV. Aim of the course

To obtain expertise in sensory and physical analyses of food products

V. Theory

Unit I

Basics of Sensory and Physical analysis: Development of sensory testing, Human subjects as instruments, Conducting a sensory study, Sensory attributes and their perception.

Unit II

Requirements of Sensory evaluation: Controls for test room, Product and panel, Factors influencing sensory verdicts.

Unit III

Measuring responses: Difference tests, Triangle test, Duo-trio and other tests, attribute difference tests, Concepts of RSM.

Unit IV

Physical and Mechanical properties of foods: Colour, Dielectric properties, Rheology, Viscosity of fluid foods, Viscoelastic behaviour, Texture measurements.

Unit V

Determining thresholds, Selection and training of panel members.

Unit VI

Guidelines for analysis and Reporting: Descriptive analysis techniques, Spectrum descriptive analysis method, Affective tests, Statistical methods and procedures, Guidelines for choice of techniques, Guidelines for reporting results.

VI. Practical

Assessment of taste panelists. Use of different decision-making aids. Determining threshold for different additives, colour and dielectric properties of fish muscle. Evaluation of rheology properties of gel prepared from fish protein. Estimation of Viscosity of fluid foods. Determination of Viscoelastic behavior fish-based products. Texture profile analysis of fish products.

VII. Suggested Reading

- David Kilcast. 2013. *Instrumental Assessment of Food Sensory Quality: a Practical Guide*, Woodhead Publishing (New Delhi)
- Gail Vance Civille, B Thomas Carr. 2015. *Sensory evaluation techniques*, CRC Press (Boca Raton)
- Harry T Lawless. 2012. *Laboratory exercises for sensory evaluation*, Springer (Dordrecht)
- Henryk Jelen. 2011. *Food Flavors: Chemical, Sensory and Technological Properties*. CRC Press (Boca Raton).
- Lawless Harry T. 1991. *Sensory science theory and applications in foods*. Marcel Dekkar, Inc.,
- Michael O'Mahony. 2014. *Sensory evaluation of food: statistical methods and procedures.*"Marcel Dekker, Inc." (New York).

I. Course Title : Environmental Impact of Fishery Industries

II. Course Code : FPT 610

III. Credit Hours : 1+1

IV. Aim of the course

To provide theoretical and practical exposure on Environmental Management Systems in fisheries industry

V. Theory

Unit I

Environmental management systems: Environmental issues (ozone depletion, global warming, etc.), Pollution, Long term ecosystem degradation, Environmental aspects of fisheries industries, Their assessment, Impact and control.

Unit II

Sources of environmental concerns (physical, chemical and microbiological); Environmental review of fisheries industry.

Unit III

Techniques for the identification of environmental aspects; Remediation of environmental pollution, IS/ISO 14000 and its relevance to environmental management system in fisheries industry; Background, policy and planning, Implementation, Checking and review.

Unit IV

Legal issues: International and European laws for environmental protection; National environmental laws.

VI. Practical

Composition analysis of fish processing solid and liquid wastes. Treatment effect on solid waste. Treatment effect on liquid waste. Resident time analysis for processing waste at the site of disposal. Estimation of nutritional composition of dried sludge. Effect of probiotic on effluent treatment system.

VII. Suggested Reading

- Anon. 2000. *Manual of Chemical Methods*. 2nd Ed. Bureau of Indian Standards: IS/ISO 14000: 1996 on Environmental Management System US-EPA.
- Avogadro A, Ragaini RC. 1994. *Technologies for Environmental Cleanup: Toxic and Hazardous Waste Management*. Kluwar Academic Publishers

- Cesceri LS. 1998. *Standard Methods for Examination of Water and Waste Water*. APHA.
- Hurst CJ. 2002. *Manual of Environmental Microbiology*. 2nd Ed. ASM Press.
- Ramamoorthy S. 1991. *Evaluation of Environmental Data for Regulatory and Impact Assessment*, Elsevier Science B.V.
- U Sonesson, J Berlin, F Ziegler. 2010. *Environmental Assessment and Management in the Food Industry: Life Cycle Assessment and Related Approaches*, Woodhead Publishing Limited (Oxford).
- Wise DL. 1994. *Process Engineering for Pollution Control and Waste Minimization*. Marcel Dekker.

I. Course Title : Food Labeling

II. Course Code : FPT 611

III. Credit Hours : 1+1

IV. Aim of the course

To create basic understanding about labeling of different products, guidelines and enforcement

V. Theory

Unit I

Labeling requirements: National and international; Legislation on labeling.

Unit II

Labeling and Traceability: Labeling for product traceability, Components of traceability code – nutrition facts and nutrition labeling, Specific requirements of nutrition labeling.

Unit III

Label design specification: Size, Colour, Barcoding types, Types of labeling for organic foods, GM foods, Irradiated foods, Meat and non-meat foods, Major nutrients Minor nutrients, Essential nutrients, Function of nutrients - providing energy, Tissue building.

Unit IV

Food meant for specific age groups and convalescing people, Serving size, Calculation of nutrition facts based on nutrient composition and serving size, Energy value of foods, EC number.

VI. Practical

Analysis of major and minor nutrients. Calculation of nutrition facts. Preparation of labels for typical food items. Analysis for total calorific value of fish fats, protein and carbohydrates.Estimation of PER, BV and NPU value of fish products.

VII. Suggested Reading

- Akhil Mathur. 2012. *Food Processing, Packaging, Labelling and Marketing*. Anmol Publications Pvt. Ltd. (New Delhi)
- Jerry D'Souza, Jatin Pradhan. 2010. *Handbook of Food Processing Packaging and Labeling*. SBS Publishers and Distributors Pvt. Ltd. (New Delhi)
- Jnsel P, Turna RE and Ross D. 2001. *Nutrition*. Jones and Bartlet.
- Seshadri V. 1998. *Introduction to Clinical Nutrition and Nutritional Labelling*. Marcel Dekker.
- Simpson DS. 1987. *Food Biochemistry and Nutritional Value*. Longman.

I. Course Title : Water Quality Management in Seafood Processing

II. Course Code : FPT 612

III. Credit Hours : 2+1

IV. Aim of the course

To obtain enough knowledge in all aspects of water quality and its management for processing and drinking purpose.

V. Theory

Unit I

Sources and types of water: Type I, Type II, Type III, their characteristics; Reagent grade water specifications, Sources of contamination of drinking water, Ground water contamination, Chemical threats to drinking water quality; Primary water quality criteria; Point source and non-point source of contamination.

Unit II

Water quality criteria: Physical factors (hardness, colour, odour, taste, turbidity, conductivity, pH and Eh), Chemical parameters (physico-chemical parameters in relation to water's natural structure), Microbiological parameters, Important pathogenic organisms and their sources, Salmonella, Pathogenic Staphylococcus, Fecal bacteria, Enteroviruses, Algae, other organisms.

Unit III

Undesirable substances in drinking water: Parameters concerning toxic substances; Toxic metals/metalloids, Cyanides, Pesticides and related products and polycyclic aromatic hydrocarbons; Organic compounds and their tolerances; Polychlorinated biphenyls, pentachlorophenol, 2, 4, 6 trichlorophenol, chlororesorcinol, total nitramine and haloforms in potable water.

Unit IV

Water quality standards: Indian standard, US PHS, EEC, WHO standards. Examination of water; Microbiological examination; frequency, public supply with intermediate storage and without intermediate storage; Examination for undesirable and toxic substances; Method of analysis, sampling, etc.

Unit V

Water budgeting and treatment: Budgeting of water for different processing methods; Affluent water treatment and disinfection methods: purification and treatment of water, Chlorination of water, Use of chlorine dioxide ($Cl0_2$) ozonization, UV radiation and reverse osmosis; Implications of chlorination and trihalomethane compounds in drinking water.

Unit VI

Effluent Water treatment and disinfection methods: Primary treatment, Secondary treatment, Methods of waste water treatment in seafood industries.

VI. Practical

Estimation of available chlorine, undesirable physical and chemical objects present in the fish processing water. Examination of microbiological quality of water used in fish processing industry. Estimation of BOD and COD of effluent water. Effect of ozonation and chlorinationon water quality.

VII. Suggested Reading

- Zachritz Walter H. 1991. *Wastewater Treatment: Options for Louisiana Seafood Processors*. Louisiana Sea Grant College Program.
- Walters. 1981. *Industrial Effluent Treatment,* Applied Science Publishers Ltd (London).
- Frank R Spellman. 2013. *Handbook Water and Wastewater Treatment plant Operations*. CRC Press (Boca Raton).
- Baird Rodger B. 2017. *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, USA.

List of suggested Journals

- *Journal of Food Science and Technology*
- *Journal of Food Safety*
- *Journal of Food Protection*
- *Journal of Food Science*
- *Fishery Technology*
- *Applied and Environmental Microbiology*
- *FEMS Microbiology Letters*
- *Food Science and Technology International*
- *Food Science and Technology Research*
- *Food Technology*
- *Applied Biochemistry and Biotechnology*
- *Applied Biochemistry and Microbiology*
- *Current Science*
- *Packaging Technology and Science – International Journal*
- *Journal of Aquatic Food Product Technology*
- *International Journal of Current Microbiology and Applied Sciences*
- *Food Control*
- *Journal of Environmental Biology*
- *Indian Journal of Geo Marine Sciences*
- *Food Science and Biotechnology*

List of suggested e-Resources

- http://www.fao.org/3/v3630e/v3630e03.htm
- http://www.fao.org/3/v7180e/v7180e06.htm
- https://www.ncbi.nlm.nih.gov/pubmed/6746595
- https://link.springer.com/chapter/10.1007/978-1-4613-1113-3_4
- http://www.fao.org/3/y5979e/y5979e03.htm
- https://pdfs.semanticscholar.org/424f/9b8c413044e308d28cfcfefd36899114ca67.pdf
- https://onlinelibrary.wiley.com/doi/10.1002/9781118346174.ch4
- https://www.sciencedirect.com/science/article/pii/S2214241X16300499
- https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2672.1971.tb02291.x
- http://www.fao.org/3/X5624E/x5624e08.htm
- https://www.tandfonline.com/doi/pdf/10.1080/10408399509527708
- https://www.mpeda.gov.in/MPEDA/general_description.php#
- https://www.fda.gov/food/food-imports-exports/seafood-imports-exports
- http://www.fao.org/3/x5625e0f.htm
- http://www.ifpkochi.nic.in/IFPS3.pdf
- http://agris.fao.org/agris-search/search.do?recordID=US201300091650
- http://www.scielo.br/scielo.php?script=sci_arttext and pid=S0101-20612019000500146
- http://www.genaqua.org/uploads/pdf_19.pdf
- http://drs.cift.res.in/handle/123456789/1086
- https://onlinelibrary.wiley.com/doi/10.1002/9781118346174.ch10
- http://www.fao.org/fi/staticmedia/MeetingDocuments/WorkshopAMR17/presentations/22.pdf
- http://drs.cift.res.in/handle/123456789/1514

- https://www.tandfonline.com/doi/abs/10.1080/08982119908919278
- https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118434635.ch11

Suggested Broad Areas for Master's and Doctoral Research

- Changes in muscle during freezing
- Technology to improve shelf-life of seafood
- Novel packaging and transportation methods of seafood
- Prevention of nutrient loss during frozen storage
- Molecular markers development for identifying adulteration
- Nutritional changes during frozen storage
- Development of new value-added fishery products
- Effective utilization of fish wastes
- Development of product from discarded fish
- Development low cost tools to detect pathogens in seafood
- Occurrence and virulence characteristics of emerging pathogens in seafood
- Evaluation and prevention of anthropogenic contaminants during processing seafood
- Effect of different processing methods on quality and shelf-life of fish
- Assessment of algal, fungal and biological toxins in seafood
- Effective methods for treatment of waste water from processing industries
- Water budgeting for various seafood processes
- Development of new ready to eat fish products
- Assessment and monitoring method for quality standards of processing plants
- Development of sensors for quality detection
- Designing of instruments used in fish processing plants
- Development of low cost and sustainable packaging materials
- Utilization of nanotechnology in fish processing industry
- Automation in seafood processing and quality determination
- Application of AI in seafood processing and quality evaluation

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fishing Technology and Engineering

Preamble
(Fishing Technology and Engineering)

India has 8,118 kms coastline, 2.02 million sq. km Exclusive Economic Zone, 0.530 million sq. km Continental Shelf, 1,95,210 km of Rivers and Canals and 7.892 million ha of inland water bodies which results in capture fish production of over 7.0 million metric tonnes. Fisheries sector in India has shown impressive growth with an average annual growth rate of 10.88% during the year from 2014-15 to 2018-19. Fish production reached an estimated/ level of 11.6 million tonnes in 2017. In that year, the estimated production for capture fisheries was of almost 5.4 million tonnes (3.8 million tonnes from marine and 1.6 million tonnes from inland water). There are 2.39 lakh fishing crafts (58,911 mechanized, 75,591 motorized, 104,270 Non-motorized) operating various types of fishing gears along the coast, with 7 major fishing harbours, 75 minor fishing harbours and 1,537 landing centres are functioning to cater to the needs of over 4.0 million fisher folk engaged in capture fisheries.

To provide sustained and holistic development of fisheries in the country both the state and central governments recently offers various scheme namely, Blue revolution, Scheme for empowerment of traditional fishermen in Deep Sea fishing, Fisheries and Aquaculture Infra structure Development project. Hence, it is the need of the hour to increase the quality of syllabus in Master's degree and Doctoral program in 'Fishing Technology and Engineering encompasses mainly fishing gear and craft technology for responsible and sustainable capture fisheries, Fishing harbors and fishing fleet management, advanced fish processing machineries and refrigeration systems subjects apart from newly added courses like Deep sea fishing, GIS and Remote sensing to meet the demand of the industry.

The following topics namely Aimed fishing using the modern electronic devices like echo sounder, Sonar and trawl eye, Refrigeration in deep sea fishing vessels- design and working of RSW and CSW, Power transmission in fishing vessels, Sea Laws, Deep sea fishery resources, Weather and warning, Familiarization of meteorological equipments onboard, Weather forecasting and weather prediction at sea, Basics of sound in water-Ultra sonic sound and its characteristics, Recent advances in fishing vessel navigation, Aerial Photography, Remote Sensing, Digital image processing, Image rectification and Image enhancement - Filtering - band rationing, Image classification - supervised and unsupervised classification, Remote sensing application in soil and water conservation, **GIS** - types - raster - vector, Data base management systems - Data types - spatial - non-spatial, Spatial data models, Spatial referencing, Map projections, Data input, Editing, Encoding, Raster data analysis, Vector data analysis, NOAA and IRS- Satellites for Ocean and Fisheries studies- Digital image processing and interpretation, Application of remote sensing and GIS to fisheries and aquaculture planning and development, **PFZ-**Basics and application- Validation of PFZ data- INCOIS- Data Dissemination-Fishermen knowledge in PFZ were added.

By considering the vast opportunity and requirements in the field of fishing industry Doctoral program in 'Fishing Technology and Engineering is a must and this programme mostly deals with modern fishing technology to meet the global standards. Subjects like Mechanization in Fishing, Advanced Fishing Gear Designing and Construction, Fishing

Gear Selectivity, Deep Sea Fishing, Sustainable Fishing Methods, Fishing Harbour Planning, Construction and Management, Electronic Navigation and Sea Safety for Fishing Vessels were dealt in the programme.

The above new additions and updates will scale up the knowledge of the students to face the challenges of the competitive global fishing industry.

Course Title with Credit Load
M.F.Sc. in Fishing Technology and Engineering

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FET 501	Advanced Fishing Gear Technology	2+1
FET 502	Advanced Fishing Craft Technology	2+1
FET 503	Responsible Fishing	1+1
FET 504	Refrigeration and Electrical Engineering	2+1
FET 505	Marine Engineering	1+1
FET 506	Introduction to Deep sea Fishing	1+1
FET 507	Fishing Harbour and Fleet Management	1+1
FET 508	Acoustics, Navigation and Seamanship	2+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
FET 509	Engineering Graphics	0+1
FET 510	GIS And Remote Sensing in Fisheries	2+1
FET 512	Sea Safety and Disaster Management	1+1
FET 513	Fish Processing Machinery	1+1
	Supporting Courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common Courses	**5 Credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FET 591	Master's Seminar I	0+1
	Masters' Thesis Research	**30 Credits**
FET 599	Master's Research (Semester III)	0+15
FET 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fishing Technology and Engineering

I. **Course Title : Advanced Fishing Gear Technology**

II. **Course Code : FET 501**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To teach advanced fishing gear technology, To learn design modification of existing fishing gears, To learn selectivity of various fishing gears.

V. **Theory**

Unit I

Fishing gear design drawings: Survey of various fishing gears; Conventional and current practice for the representation of fishing gear by FAO specifications for scale drawing; The use of computers in the scale drawing of fishing gear to determine the defects in gear, design to develop new gears.

Unit II

Fishing gear selection: Use of fishing gear materials and their comparison; Selection of fishing gear, Analysis of the parameters of specific fishing gears and the derivation of empirical relationships for use in the design process.

Unit III

Fishing gear design and construction: Factors responsible for the choice of fishing gears; Design and construction of bottom, Mid-water and surface trawl; Gill nets and tangle nets; Types of gill nets – Simple gill net, vertical lines gill net, Framed gill nets, tangle nets and their technical characteristics, Two and three walled trammel nets, Combined gill nets; Purse seines and their classification, Longlines, Pole and Lines, Trolling line, Traps – Their classification and general principles of construction.

Unit IV

Light and electricity in fishing: Attraction of fish – fishing with electricity and application in various fishing methods, Light fishing, Fish pumps; Operation and mechanization of long lining and jigging.

Unit V

Gear Selectivity: The selectivity of trawl fishing gears, Gill nets, Purse seine and longline, Design of otter boards for various types of trawl fishing; Factors to be considered in gill netting in selection of meshes for the different fishes; Aimed fishing using the modern electronic devices like echo sounder, Sonar and Net sonde.

Unit VI

Testing fishing gear: Case studies relating to towed, surrounding and static fishing gear and their energy consumption, Fishing gear testing – full scale and model testing in flume tanks, methods of testing a fishing gear, External forces acting on fishing gears, The influence of design features on the overall economic performance of fishing gears.

VI. Practical

Exercises on scale drawing of different types of fishing gears. Use of computer software's programme in the design of trawl gears. Model net calculations, Calculations of energy requirements of different gears. Onboard experience of different fishing methods. Use of net monitoring instruments. Study of fishing gears through models of nets and field study. Making sketches. Reading of gear designs. – Trawl nets, Purse seines, Gill net and Long line. Familiarization with design drawing software. Design of otter boards and other accessories. Survey of gears and preparation of designs according to scale by taking measurements from a net.

VII. Suggested Reading

- Baranov FI. 1969. *Selected Works on Fishing Gear* Vol. I *Commercial Fishing Techniques*, Israel Programme for Scientific Translations, Jerusalem, 631p.
- Baranov FI. 1977. *Selected Works on Fishing Gear*. Keterpress Enterprises. Israel: 259 p. • Ben-Yami M. 1994. Purse seining manual, FAO Fishing manual, 416p.
- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publishing House – Delhi: 207 p.
- Bjordal and Lokkeborg S. 1998. *Long Lining*, Fishing News Books Ltd. Farnham, 208p.
- Brandt AV. 1984. *Fish Catching Methods of the World*. Fishing news books Ltd., London, 432p.
- FAO. 1987. *Small Scale Fishing Gear*: 19 – 44pp.
- Fridman AL. 1986. *Calculations for Fishing Gear Designs*, FAO Fishing manual, Fishing News Books, Ltd., Farnham, 264p.
- John Garner. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books Ltd. England: 91p
- Kristionsson H. 1975. *Modern Fishing Gear of the World*. The White Friars Press Limited. London: 594 p.
- Shaul Hameed M and Boopendranath MR. 2000. *Modern Fishing Gear Technology*: 193p.
- Sreekrishna Y and Shenoy Latha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research. New Delhi, 342p.

I. Course Title : Advanced Fishing Craft Technology

II. Course Code : FET 502

III. Credit Hours : 2+1

IV. Aim of the course

To teach advanced aspects of fishing craft design, To learn about modification of existing craft layout, To learn about fishing craft stability.

V. Theory

Unit I

Fishing craft: Different types of fishing crafts – trawler, stern and side trawler, Purse seiner, Long liner, Gill netter, troller etc; Main differences in the method of construction and design; Consideration regarding the speed and other fishing requirements, Deck layout and deck equipments of fishing vessels based on the fishing method; Planning internal capacities of fish hold, Engine room, Crew accommodation, Fuel tanks and Freshwater tanks.

Unit II

Boat materials: Choice of the construction materials; Comparison of materials used in fishing boat construction; Bio-deterioration of wood – marine fouling and boring organisms, Preventive measures, Raw materials, properties, Merits and demerits of FRP, Steel, Aluminium and Ferro-cement, Corrosion – types, Fundamentals, measurement and preventive measures.

Unit III

Steering gear and Hull: Principles of operating steering arrangement; Remote control; Rudder – principles – types; Steering gear – Principle and operation – Mechanical and Hydraulic; Principal dimensions of boat, Importance of shape of underwater hull, Classification and description of hull forms based on shape; Form coefficients and proportionality coefficient for different types of vessels; Various ship motions at sea; Hull resistance; Behaviour of boats to waves from different sides.

Unit IV

Stability aspects of fishing vessels: Factors affecting stability; Longitudinal stability – Trim, Moment of change of trim by 1 cm; Transverse stability – List, heel, LOLL, Meta centric height and meta centric radius, GZ curve, Degree of vanishing stability, Free surface effect, Hydrostatic curves, Dynamic stability, Stability criteria, Safety measures to restore stability in fishing vessels; Inclining experiment.

Unit V

Propellers and Power: Powering of fishing boats; power transmission system in fishing vessels; Effects of wetted surfaces on speed; Types of propellers; Designing principle power requirements of various types of fishing boats, Auxiliary power, Propulsive efficiency, Use of kort nozzle.

Unit VI

Construction of fishing boat: Layout of a typical boat building yard, Various stages of construction, Description of various machines and tools used in boat building yard, Stages of wooden boat building – Sheathing of wooden hull – Steel boat construction and FRP boat construction, Inspection of fishing boat under construction, Care and maintenance of fishing boats – Factors causing damage, Hull protection methods and maintenance schedule, Inspection of damaged fishing vessels, Regulation of fishing vessels and classification of societies in various countries.

VI. Practical

Basic principles of drawing, drawing of fishing vessels – line drawing – sectional view of the boat and keel assembly – half breadth & body. Visit to boat building yards for on – the – spot study of different stages of wooden boat construction and to study the layout. Identification of various tools and machines used in boat building. Study of various stages of boat construction with the help of boat models and making their sketches. Calculation of various dimensions; Study of deck lay outs of different types of fishing vessels and preparation of sketches; Visit to dry dock

VII. Suggested Reading

- Fyson JF. (ed). 1985. *Design of Small Fishing Vessels*, Fishing News Books, Oxford.
- Marine institute. 1988. *Proceedings of the World Symposium on Fishing Gear and Fishing Vessel Design*, The Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, Newfoundland, Canada, 610p.
- Pike D. 1992. *Fishing Boats and Their Equipments*. Fishing News Books. Oxford: 184p.
- Ponnambalam A. 2003. *Fishing Craft Technology*. CIFNET. Cochin: 157p.
- Ponnambalam A. 2003. *Fishing Craft Technology*. CIFNET. Cochin: 158p.
- Sanisbury JC. 1996. *Commercial Fishing Methods-an Introduction to Vessels and Gear*, Fishing News Books Ltd., Farnham, 352p.
- Shenoy Latha. 1988. *Course Manual in Fishing Technology*, CIFE, Mumbai, 95p.
- Sreekrishna Y and Shenoy Latha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research, New Delhi, 342p.
- Tan-olofTraung. 1967. *Fishing Boats of the World*. Fishing News (book) limited. London. 635p.
- Yadav YS. 2002. *Traditional Fishing Craft of the Bay of Bengal*. BOBP. Chennai: 55p.

I. Course Title : Responsible Fishing

II. Course Code : FET 503

III. Credit Hours : 1+1

IV. Aim of the course

To teach various responsible fishing techniques, To learn about damage to the environment & biodiversity by existing fishing methods, To learn about methods of reducing by catch in trawl net.

V. Theory

Unit I

CCRF: Scope and objectives of FAO Code of conduct for Responsible Fisheries, Articles of CCRF – Description of the code, Analysis of marine catch data (present & past); analysis of CCRF concept.

Unit II

By-catch: Elaboration of Article 8 – Fishing operations; By-catch and discards – Definitions, By-catch estimation methods, by-catch reduction devices, turtle excluder devices, Finfish and shrimp excluder devices. Selective fishing gear and practices: Selectivity of trawls, gill nets and lines – Environmentally friendly fishing methods and fishing gears – Energy conservation and resource enhancement.

Unit III

Fish Aggregation Devices (FADs and Artificial reefs): Objectives, Types of FADs and artificial reefs; Design and construction of FADs and artificial reefs; Energy optimization in fisheries – Methods of energy conservation in fish harvesting. Remote Sensing and PFZ: Application of Remote sensing, PFZ and GIS in fisheries.

Unit IV

IUU - Illegal, Unregulated and Unreported fishing methods; Destructive and prohibited fishing systems and practices. Effect of fishing on non-target species: Effect of bottom trawl and gill nets on benthic fauna and habitats; Conservation methods issues and implications for biodiversity.

VI. Practical

Study of design and operation of BRDs and TEDs; Preparation of document listing and prohibited fishing practices; compilation of package of practices for energy conservation; interpretation of SST and Ocean colour charts, Study of Potential Fishing Zone (PFZ) maps; problems on fishing gear selectivity; studies on impact of various fishing gears on environment and biodiversity.

VII. Suggested Reading

- Bergstrom M. 1983. *Review of Experiences with and Present knowledge about Fish Aggregating Devices*, BOBP/WP/23 Bay of Bengal programme, Madras.
- CIFNET MODULE III & IV. *Code of Conduct for Responsible Fisheries*. 61-69pp.
- FAO. 1995. *Code of Conduct for Responsible Fisheries*, FAO, Rome, 41p.
- FAO. 1996. *Fishing Operations*, FAO Training Guidelines for responsible fisheries No.1, FAO, Rome 26p.
- FAO. 2003. *Fisheries Management*. 2. The ecosystem approach to fisheries, FAO
- Michel Kaiser and Groot. *Effect of Fishing on Non-target species and Habitats* Blackwell publishing
- *Technical Guidelines for Responsible Fisheries* – No.4, Suppl.2, FAO Rome.

I. Course Title : Refrigeration and Electrical Engineering

II. Course Code : FET 504

III. Credit Hours : 2+1

IV. Aim of the course

To teach engineering aspects about refrigerators, freezers, To learn about heat-load calculation and COP, To teach electrical aspects of fishing vessel.

V. Theory

Unit I

Principles of refrigeration: Refrigeration cycle; Vapour Compression system, Vapour absorption system, Steam Jet Refrigeration System, Solar energy based refrigeration systems; Application of Refrigeration in fisheries, Refrigeration in sea food processing plant – Refrigeration in deep sea fishing vessels – design and working of RSW and CSW – Coefficient of Performance (CoP) – ton of refrigeration – Refrigerator efficiency calculations.

Unit II

Heat load and efficiency: Heat load calculations – Insulations in freezers and cold stores – Frosting and defrosting in freezers and cold stores; Refrigeration in factory Trawlers; Types of Refrigerated transport.

Unit III

Refrigerants: Types and properties, Use of different refrigerants in seafood processing industry; Brine solution and dry ice refrigeration.

Unit IV

General structure of electrical power systems: Power transmission and distribution via overhead lines and underground cables, Steam, Hydel, Gas and Nuclear power generation, Principal and application of DC Networks, Single phase AC Circuits, Three phase AC circuits, Magnetic Transformers, Induction motor, DC Motors etc.

Unit V

Electrical Measuring Instruments: DC PMMC instruments shunt and multipliers, multi-meters, Moving iron ammeters and voltmeters, Dynamometer, Wattmeter, AC watt-hour meter, Extension of instrument ranges.

Unit VI

Principles and working of electronic components: Audio, R.F. circuits; Electron tubes, Transistors; Principles of electronic circuits; Amplifiers, Oscillators, Rectifier, Tuned circuits – Transmission of reception.

VI. Practical

Practical Visit to refrigeration plants, heat load calculations. Handling and operation of refrigeration equipments – compressor, condenser, evaporator, liquid return system, gas purging, oil drain, oil charging, refrigerant charging, defrosting; Ice making and harvesting; study of various automatic control devices; expansion valves, L.P. and H.P. switches, solenoid valves. Study of various types of fish processing machineries; electrical motors, transformers, GPS, SONAR etc.

VII. Suggested Reading

- Ayyappan VP. 2002. *Elements of Electrical Technology*. CIFNET. Cochin. 96p.
- Joshy CD and Devadhason M. 2001. *Basic Electronics and Fish Finding Equipments*. CIFNET. Cochin: 42p.
- Shawyer M and Medina Pizzali AF. *The Use of Ice on Small Fishing Vessels*. FAO. Rome: 102p.
- Sternin UG, Nikonorou IV and Bumeister Yu K. 1976. *Electrical Fishing*. Keter. Publishing House Jerusalem Ltd. 258p.

I. Course Title : Marine Engineering

II. Course Code : FET 505

III. Credit Hours : 1+1

IV. Aim of the course

To teach engineering aspects of marine engines, To learn about effective utilization engine powers during fishing and propulsion, To study about system of fishing vessels.

V. Theory

Unit I

Engine characteristics: Capacity of cylinders, IHP, BHP, FHP, BMEP, Torque determinations; SFC values, IC engines – Working cycles – Indicator diagrams – Performance number – Supercharging – Engine performance curves – Duel-fuel engines, Handling of IC engine and maintenances – Engine and boiler room arrangements – Steering gears – auxiliary engines – Heat exchangers – Propeller Shaft driver steam generators.

Unit II

Efficiency of engines: Compression ratio and thermal efficiency; Volumetric efficiency; Mechanical efficiency different ratings – continuous, peak, intermittent, Feel and lubricant – Strokes – Cooling method – Running characteristics – Size weight – Power requirement; Propulsion system – Combinations of engine, power transmission and propeller.

Unit III

Function of main engine: Friction, Clutch, Hydraulic coupling, Gearbox, Thrust; Bearing, Shafting, Propeller, Auxiliary machinery systems – Requirements of a winch, windlass, line and net hauler – estimation of their driving torque and power; Operation of a hydraulic steering gear; Rudder torque.

Unit IV

Engineering structure; Floating offshore structures –Diving – Underwater vehicles, Estimation grower requirement for various types of fishing – Efficiency group of fishing techniques – Resistance group of fishing methods – Computation of engine power.

VI. Practical

Study of basic machine parts, shafts, keys, couplings, levers, joints, pulleys, belts, gears and bearings. Study of Engine parts, engine testing, dissembling and assembling a running condition marine engine; study of marine diesel engines, fuel consumption testing with load; Propeller calculations using the computers; calculations related to engine power- Power transmission in fishing vessels.

VII. Suggested Reading

- Calder N. 1992. *Marine Diesel Engines*. Waterline Books. England: 153-168pp.
- Fishery Engineering. CIFNET. Cochin, 68-211pp.
- Nina Morgan. 1990. *Marine Technology Reference Book*. Butterworth – London.
- Rethinadhas C. 2002. *Marine Engineering*. CIFNET, Kochi, 156p.
- RK Rajput. 2006. *Thermal Engineering* Laximi Publication, New Delhi
- Watson GO and Harvey RA. 1971. *Steering Gear*. Newnes – Butterworths, London: 306–328 pp.

I. Course Title : Introduction to Deep Sea Fishing

II. Course Code : FET 506

III. Credit Hours : 1+1

IV. Aim of the course

To learn international law of the sea, To learn about deep sea fishing policies, To learn deep sea techniques.

V. Theory

Unit I

Sea Laws: UNCLOS – Law of the sea, Base line -territorial waters, Contagious zones, EEZ and High Seas, Basics of Deep-sea Fishing-National deep-sea policies

Unit II

Deep sea fishery resources: Oceanic Tuna and tuna like fishes, Oceanic Squids.

Unit III

Deep sea fishing gears and accessories – Tune long lining, Gill netting and squid jigging, Deckequipments in deep sea fishing vessel, Mother boat concept and factory vessels in deep sea fishing.

Unit IV

Weather and warning: Wind, Wave, Current, Cyclones, Squally weathers, Doldrums, Weather forecasting and weather prediction at sea – Weather equipment and storm signals, Preparation and management of deep-sea fishing vessels.

VI. Practical

Familiarization of meteorological equipments onboards. Storm signals and visit to signalling stations. Visit to deep sea fishing vessels to study the layout, manpower, facilities for deep-sea navigation and fishing, instruments and fleet management. Study on deck equipments in deep sea fishing vessels. Visit to fisheries departments and MPEDA to know about the initiatives on deep-sea fishing.

VII. Suggested Reading

- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publishing House – Delhi: 207 p.
- Capt H Subramaniam. 2015. *Marine Meteorology,* Nut Shell Series, Book No.2 Vijaya publication, Bombay.
- DJ Randall and AP Farrell. 1997. *Deepsea Fishes*. Academic press, USA.
- Garner J. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House.
- *International Convention for the Safety of Life at Sea*. Universal Publishing Corporation. Mumbai: 1-334pp.
- NR Merrett and RL Haedrich. 1997. *Deepsea Demersal Fish and Fisheries*. Chapman & Hall, London.
- PS Balachandran. 2013. *Manangement of Deepsea Fisheries*. Random Publications.New Delhi.
- Sudhakararao. 2009. *Deep Sea Fisheries of India*. B.R.Publishing Corporation. New Delhi.
- U Shanker Rao. 2012. Deep sea fishing in India (From trawler to table). Biogreen books

I. Course Title : Fishing Harbour and Fleet Management

II. Course Code : FET 507

III. Credit Hours : 1+1

IV. Aim of the course

To teach fishing harbour design and construction, To learn about fishing fleet that management and manning regulations in fishing harbour.

V. Theory

Unit I

Fishing vessel: FAO classification of fishing vessels, Indigenous fishing boats of India – fishing boats of maritime states of India, Fishing boats used in the inland and brackish waters, Account of mechanized boats introduced in India.

Unit II

Rules and Management: Personnel management, Planning of fishing cruises, Fishing fleet capacity, Fleet registration, fleet insurance, Seaworthiness assessment, Tonnage measurements Statutory rules and regulations under MSA, Classified societies, Manning regulations and requirements; Regulations to prevent collisions at sea.

Unit III

Classification and functions of fishing harbour: Facilities – waterside and landside facilities, Services and utilities provided, Layout of a modern fishing harbour, Stages in the planning of fishing harbours, Dredging.

Unit IV

Economic evaluation: On fishing harbour project, Dry docks and slipway – Fishing harbour management and maintenance.

VI. Practical

Visit to dry dock; Visit to Fishing harbour, Study of boats with the help of boat models and making sketches; Visit to various vessel types of fishing vessel.

VII. Suggested Reading

- FAO. 1960. *Report to Government of India on Fishing Harbours Based on the Work of Carl GB Juke and CRB Juke*. FAO Report No. 1242 ETAP, pp.147.
- FAO. 1962. *Second Report to Government of India on Fishing Harbour Based on the Work of BW Johnson*. FAO Report No. 1538 EPTA, pp. 99.
- Ramakrishnan TK. 2007. *Ocean Engineering*. Gene – Tech Books. New Delhi: 233p.
- Sciortino SA, Barcali A and Carlesi M. 1995. *Construction and Maintenance of Artisanal Fishing Harbours and Village Landingss*. FAO. Rome: 136p.
- Sreekrishna Y and ShenoyLatha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research, New Delhi, 342p.

I. Course Title : Acoustics, Navigation and Seamanship

II. Course Code : FET 508

III. Credit Hours : 2+1

IV. Aim of the course

To learn engineering aspects of fish acoustic equipments, To learn navigation and seamanship for fishing vessel safety.

V. Theory

Unit I

Basics of acoustic fish detection: Basics of sound in water-Ultra sonic sound and its characteristics-Acoustic surveys in fish population studies- Acoustic equipments used in fishing.

Unit II

Acoustic Equipments: Advanced models of Echo sounder – Major components, specifications and uses; Sonar – specifications, types; Instruments used for evaluation of underwater gear performance, Acoustic trawl monitoring system.

Unit III

Navigation: Fishing vessel navigation – Recent advances in fishing vessel navigation – Methods of signalling in fishing vessels- Fixing of vessel position, Navigational charts- Rules of the road.

Unit IV

Electronic Equipments: Global positioning system (GPS); Vessel monitoring systems (VMS) and AIS (Automatic Identification System) Navigation – Types, Navigational equipments, RADAR, Autopilot, Chat plotter.

Unit V

Seamanship: Handling of fishing vessels under all conditions at sea- Ropes and rope works– Their types, Handling; strength and preservation; Knots and splices; Anchoring mooring; Steering; Rolling and pitching.

Unit VI

Accidents at sea: Accidents- causes- Preventive measures- Preparedness for Fishing vessels.

VI. Practical

Chart work and navigational equipment, chart reading, position fixing, direction and distance in navigation -calculations; Operation of echo sounder, Sonar, GPS, Radar identification and study of navigation and fishing lights and day signals, distress signals and navigational equipments like compass, chronometer, aneroid barometer, sextant and logs

VII. Suggested Reading

- CIFNET. 2004. *Fishery Engineering:* 212-238pp.
- FAO. 1998. *Fishing Operations. – Vessel Monitoring Systems*, FAO Technical Guidelines for Responsible Fisheries No. 1, Suppl. 1, FAO Rome.
- Joshy CD and Devadhason M. 2001. *Basic Electronics and Fish Finding Equipments*. CIFNET. Cochin: 31-42pp.
- Larkin FJ. 1998. *Basic Coastal Navigation*, 2nd edn, Sheridan House Inc., New York: 273 p.
- MacLennan DN and Simmonds EJ. 1992. *Fisheries Acoustics, Fish and Fisheries Series* 5, Chapman and Hall, London, 323 p.
- Mitson RB. Fisheries SONAR. *Fishing News* Books Ltd. England: 274p.
- Sreekrishnan Y and ShenoyLatha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research, New Delhi, 342 p.

I. Course Title : Engineering Graphics

II. Course Code : FET 509

III. Credit Hours : 0+1

IV. Aim of the course

To teach practical aspects of computer aided engineering graphic.

V. Practical

- Introduction to Engineering Graphics – Drawing instruments and their use – Different types of lines – Lettering & dimensioning – Familiarization with current India Standard Code of Practice for Engineering Drawing. Introduction to scales. Introduction to orthographic projections – Horizontal, vertical and profile planes – First angle and third angle projections – Projection of points in different coordinates – Projections of lines inclined to one of the reference planes.
- Projections of lines inclined to both the planes – True lengths of the lines and their angles of inclination with the reference planes – Traces of lines. Projection of plane laminae of geometric shapes inclined one of the reference planes – inclined to both the planes – auxiliary projections.
- Projections of polyhedral and solids of revolution – Frustum – projection of solids with axis parallel to one of the planes and parallel or perpendicular to the other plane – Projections with the axis inclined to one of the planes. Projections of solids with axis inclined to both the planes – Projection of spheres. Sections of solids by planes perpendicular to at least one of the reference planes – True shapes of sections, Developments.

VI. Suggested Reading

- Bhatt ND. *Elementary Engineering Drawing*, Charter Publishing House, Anand, 2002.

I. Course Title : GIS and Remote Sensing in Fisheries

II. Course Code : FET 510

III. Credit Hours : 2+1

IV. Aim of the course

To learn to use GIS and Remote sensing to foster the sustainable use of natural fisheries resources

V. Theory

Unit I

Aerial Photography: Basics of photography- terminologies- Photogrammetry - Stereoscopy - Principal points - Parallax and its measurement, Colours - Composite colour images.

Unit II

Remote Sensing - Electromagnetic Spectrum - Radiation laws - Interaction with atmosphere and surfaces, Spectral reflectance of earth materials and vegetation, Satellite Remote Sensing - Resolution - Scanning - Sensors, Land Observation Satellites - Visual image interpretation

Unit III

Image and Data: Digital image processing, Image rectification and Image enhancement - Filtering - Band rationing, Image classification - Supervised & unsupervised classification, Remote sensing application in soil & water conservation.

Unit IV

GIS - Types, raster, vector, Data base management systems, Data types, Spatial - non-spatial, Spatial data models, Spatial referencing, Map projections, Data input, Editing, Encoding, Raster data analysis, Vector data analysis.

Unit V

Satellite Application: NOAA and IRS- Satellites for Ocean and Fisheries studies- Digital image processing and interpretation, Application of remote sensing and GIS to fisheries and aquaculture planning and development.

Unit VI

PFZ- Basics and application- Validation of PFZ data- INCOIS- Data Dissemination- Fishermen knowledge in PFZ

VI. Practical

Study of satellite information, interpretation of satellite pictures for resource management, case studies on remote sensing and GIS applications. Development of GIS with local parameters related to fisheries- INCOIS data processing and interpretation- Collection and Validation of INCOIS PFZ data. INCOIS data dissemination methods among coastal fishermen. Survey of effectiveness and usefulness of PFZ data.

VII. Suggested Reading

- Bhatia B. 2008. *Remote Sensing and GIS*, Oxford University Press, New Delhi.
- FAO *Technical Manuals on Remote Sensing and GIS in Fisheries and Aquaculture*.
- Josef G. 2005. *Fundamentals of Remote Sensing*, Universities Press (P) Limited, Hyderabad.
- Kumar S. 2005. *Basics of Remote Sensing and GIS*, FirewellMedi, Laxmi Publications, New Delhi.

I. Course Title : Sea Safety and Disaster Management

II. Course Code : FET 512

III. Credit Hours : 1+1

IV. Aim of the course

To teach theoretical aspects of sea safety and disaster management, To learn about bad weather preparation and situation handling. Crew management during disaster.

V. Theory

Unit I

Introduction to sea safety: Safe navigation procedures for fishing vessels; Distress Signals and DAT (Distress Alert Transmitter), and communication systems like VHF, SSB and INMARSAT; Familiarization with safety devices like SART, EPIRB and GMDSS.

Unit II

Accidents: Accidents associated with marine environment-crossing surf, Bad weather, Poor visibility storms, Loss of power at sea, Loss of way, Grounding, Collisions. Injuries from fish, Animals and machinery, Man, overboard and capsizing. **Signals for fishing vessel safety:** Agencies involved in fishing vessel rescue operations, Keeping watch at sea – Preventing collusions – Heavy weather preparations -Crew management.

Unit III

Fire onboard and Firefighting equipment: Fir accidents at sea- Types and causes for fire accidents-Firefighting methods- fire extinguishers-First aid at sea; **Weather warning:** Weather warning signals and weather reporting system for fishing vessels; Bad weather preparations for fishing vessels. Stranding and beaching of fishing vessels and refloatation procedures; Measures to enhance sea safety; International conventions related to sea safety

Unit IV

Types of natural and man-made hazards in fisheries: Cyclone, Tsunami etc., Characteristics and impact of various disasters, Preparedness for disasters at sea, Mass evacuation, storm shelters and survival platforms.

VI. Practical

Study on various Distress Signals, Study on communication systems like VHF, SSB and INMARSAT; Familiarization with safety devices, study of fire fighting equipments used in fishing vessels, study of impact of various disasters, Disaster preparedness at sea. Weather warning signals. Sea safety equipments, Crew management during disaster.

VII. Suggested Reading

- Bist. 2000. *Safety and Security at Sea a Guide to Safer Voyages*. Butterworth, New Delhi.
- FAO. 1975. Code of Safety for Fisherman and Fishing Vessels. International Maritime Organization – London: 109p.
- *International Convention for the Safety of Life at Sea*. Universal Publishing Corporation. Mumbai: 1-334pp.
- Larkin FJ. 1998. *Basic Coastal Navigation*, 2nd edn, Sheridan House Inc., New York: 273p.
- Sreekrishna Y and Shenoy Latha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research. New Delhi, 342p.
- Udayaprakasan. 1997. *Rule of the Road Signal and Buoyage*. CIFNET, Cochin: 1- 78p.

I. Course Title : Fish Processing Machinery

II. Course Code : FET 513

III. Credit Hours : 1+1

IV. Aim of the course

To teach engineering aspects of various equipments related to fish processing, To learn about design and layout of factory vessels and Processing factory designs

V. Theory

Unit I

Machines: Theory of machines; Transmission of power; Friction wheels; Toothed gears; Belt drive and drivers- Importance and need for the use of machineries in fish processing, Advancements in fish processing machineries.

Unit II

Graders and Deskinners: Conveyers-types and working, Graders-basic principles and types, Washers and Slime removing in fishes- Deskinners-types and working principles, **Descaling and filleting machines:** Descaling – machineries-types and working, Filleting machines, types and working, Gutting machines and Deheaders, Types and working, Quick freezers.

Unit III

Slicers and filleting machines: Fish slicing machines-types and working, Fish filleting machines-types and working, Deboners, Types and working, Advanced Thermal processing machineries, High pressure processing equipments, Advanced canning machineries

Unit IV

Boilers and extruders: Boilers -types and working. Extruders-types and working-Twin screw extruders, Various Packaging machines. Machineries for fish meal plants. **Maintenance:** Fish processing Equipment Maintenance- Daily, weekly, monthly and annual Maintenance. Safety aspects of machineries and workers.

VI. Practical

Study of various types fish processing machineries-washer, grader, deheader, filleting machine, retorts; calculation of power requirements and power transmission. Study of boilers and its operation, canning equipments, Twin screw extruders. RSW and CSW in fishing vessel- design and capacity calculations. Implements required for sushmi grade tuna processing onboard of the vessel. Packing machineries, Maintenance of various fish processing machineries

VII. Suggested Reading

- EIRI Engineers. 2000. *Modern Packaging Technology Engineers* India Research Institute, Delhi.
- Gopakumar K. 2002. *Text book of Fish Processing Technology*. ICAR Publication, New Delhi.
- Heldman. 1975. *Food Process Engineering,* AVI Publishing Company, Westport.
- Kondrashova. 1984. *Shipboard Refrigeration and Fish Processing Equipment*. Amerind Publishing Co. Pvt. Ltd., New Delhi.
- Novikov. 1982. *Hand Book of Fishery Technology* – Vol. I, Amerind Publishing Co. Pvt. Ltd., New Delhi.
- Slade. 1967. *Food Processing Plant*. Leonard Hill book, London.
- Stansby. 1963. *Industrial Fishery Technology* Reinhold Publishing Corpn. London.

Course Title with Credit Load
Ph.D. in Fishing Technology and Engineering

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FET 601*	Mechanization in Fishing	1+1
FET 602*	Advanced Fishing Gear Designing and Construction	2+1
FET 603*	Fishing Gear Selectivity	1+1
FET 604*	Deepsea Fishing	2+1
FET 605*	Sustainable Fishing Methods	1+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
FET 606	Fishing Harbour, Planning, Construction and Management	**2+1**
FET 607	Electronic Navigation and Sea Safety for Fishing Vessels	**2+1**
	Supporting courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
FET 691	Doctoral Seminar – I	0+1
FET 692	Doctoral Seminar –II	0+1
	Doctoral Research	**75 Credits**
FET 699	Doctoral Research (Semester II)	0+15
FET 699	Doctoral Research (Semester III)	0+15
FET 699	Doctoral Research (Semester IV)	0+15
FET 699	Doctoral Research (Semester V)	0+15
FET 699	Doctoral Research (Semester VI)	0+15
	Total PhD Program Credit Hours	**100 Credits**

*Major compulsory courses

Course Contents
Ph.D. in Fishing Technology and Engineering

I. Course Title : Mechanization in Fishing

II. Course Code : FET 601

III. Credit Hours : 1+1

IV. Aim of the course

To learn various mechanized systems used in the fishing industry, To study the power requirements of fishing vessels, To study about deck equipment's of fishing.

V. Theory

Unit I

Resources: Marine fisheries resources of India, Types and history of fish harvesting systems, History of mechanization of fishing craft in India.

Engines for fishing boat: Advances in marine engines, Selection of marine engines, Turbo engines, Installation and engine handling, Estimation of power requirements- Powering of fishing vessels, BHP, IHP, SHP, EHP, QPC. Propellers- Types, Construction, Selection, Factors involved in propeller performance, Propeller nozzle.

Unit II

Deck fittings: Mast, Derrick, Pulley, Fair leads, Gallows, Gantries, Trawl winch, Try net winch, Pumps, Triplex roller, Power block, Capstan, Purse winch, Purse davit, Guide roller, Rail roller.

Unit III

Fishing Systems: Line hauler, Net hauler, Trap hauler, Rudder, working principle, Types, Quadrant assembly, Mechanized trawl system, Mechanized purse seine system, Mechanized gillnetting system, Automatic and semi-automatic long lining system, Mechanization in trap fishing.

Unit IV

Hydraulic system: Principle, Components, Application of hydraulic systems in fishing equipments, Trawl winches, Net hauler, Line hauler, Power block etc., Maintenance of marine engine and equipments

Fish Processing Methods onboard: Design and fabrication of insulated fish holds, CSW and RSW systems, Chill Storage onboard a vessel, Fish Processing Equipments on board a vessel.

VI. Practical

Marine engine types, working, starting system, fuel system, cooling system, lubrication system, power transmission, Propellers types and working, visit to mechanized boat building yards- construction aspects of trawler, gill netter, long liner, purse seiner etc. to study the on-board deck layout and equipments. Basic calculations for hydraulic system and marine engine power ratings, IHP, BHP, SHP. Design of fish holds CSW, RSW systems and Fish Processing Equipments. Estimation and optimization of energy in fishing.

VII. Suggested Reading

- Ben-Yami.M. 1994. *Purse Seining Manual*. Fishing News Books. A division of Blackwell scientific publication Ltd.
- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publ. House.
- Devan Aranha. 2004. *Marine Diesel Engine*. Shroff publishers and distributers Pvt. Ltd, Mumbai
- Fyson JF. (Ed). 1985. *Design of Small Fishing Vessels*. Fishing News Books. Marine Institute. 1988. *Proc. World Symposium on Fishing Gear and Fishing Vessel Design*, The Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, Newfoundland, Canada
- Garner J. 1988. *Modern Deep Sea Trawling Gear*. Fishing News Books.
- Leela Edwin, P Pravin, VR Madhu Saly, N Thomas, MP Ramesan, MV Baiju, Renju Ravi, PH Dhihu Das, MR Boopendranath, B Meenakumari. 2014. *Mechanised Marine Fishing Systems: India*. Central Institute of Fisheries Technology, KOCHI.
- *Module I- Fishing Technology*.2004.CIFNET, Cochin.
- Rethinadhas. 2002. *Marine Engineering*, CIFNET Publication, Cochin
- Sainsbury JC. 1996. *Commercial fishing methods- An Introduction to Vessels and Gears*. A division of Blackwell scientific publication Ltd.
- Sreekrishna Y & Shenoy L. 2001. *Fishing Gear and Craft Technology*. ICAR.
- Srivastava UK, Dharma Reddy, B Subrahmanyam, VK Gupta. 1986. *Impact of Mechanization on Small Fishermen; Analysis and Village Studies*. Concept publishing company, New Delhi.

I. Course Title : Advanced Fishing Gear Designing and Construction

II. Course Code : FET 602

III. Credit Hours : 2+1

IV. Aim of the course

To learn advanced fishing gear designing, To study the construction of various fishing gears, To learn fishing gear survey techniques.

V. Theory

Unit I

Fishing gear design: Principle of mechanism of fish catching, Fishing gear design process, Traditional and modern techniques used for net designing, Computer aided fishing gear designing.

Unit II

Net fabrication: Design drawings and specifications of fishing gears, Reading of fishing gear design; General scheme of presentation, Conventions adopted on the specific drawings trawl net, gill net, Surrounding net, Dredges, Pots, and lines, Estimation of weight of netting, Indian standard conventions adopted for netting panels, Lines and ropes, accessories, Method of representation on drawing.

Unit III

Fishing gear construction: Forms of fibre; Natural, synthetic and their properties; Construction of yarn, Twine, Rope, Advancement in fishing gear materials, Fishing gear construction – Shaping of netting, mounting of netting, Hanging, assembly of netting, Mending-Taper ratio, Hanging coefficient, Take up ratio.

Unit IV

Factors affecting fishing gear design: Design consideration of gill net, Bottom trawl, Mid water trawl, Purse seine and long line, Trap, Cast net, Surrounding gear, Designing of square mesh cod-end, TED, BRD, Recent advancement in the construction of passive fishing gear; Gill nets, Trammel net, Traps, Non-return devices in traps and barriers, Hook and line, long line; Barriers.

Unit V

Recent advancements in the construction of active fishing gears: Trawl net, Purse seine, Cast net, Surrounding nets.

Unit VI

The influence of design features on the overall economic performance of fishing gears, Technical flaws of fishing gear designs and their impact on fuel efficiency, Modelling principle, Trawl net-based flume tank tests.

VI. Practical

Designing and construction of eco-friendly gill net, trawl net, trammel net, trap, long line, purse seine. Calculation on cutting rate, shaping, twine surface area, hanging ratio, buoyant and sinking force. Estimation of twin surface area, drag of the trawl, horizontal spread between otter board. Practice on scale drawing of different types of fishing nets, computer software application in designing of fishing gears. Construction of square mesh cod-end, Construction of Bycatch Reduction Device and Turtle Excluder Device. Estimation of quantity of netting materials for long line, gill net and trawl. Designing of model nets

VII. Suggested Reading

- Baranov FI. 1969. *Selected Works on Fishing Gear*. Vol. I. Commercial Fishing Techniques. Israel Programme for Scientific Translations, Jerusalem.
- Baranov FI. 1977. *Selected Works on Fishing Gear*. Keterpress Enterprises. Israel.
- Ben-Yami M. 1994. *Purse Seining Manual*. FAO Fishing Manual.
- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publ. House.
- Bjordal A & Lokkeborg S. 1996. *Long Lining*. Fishing News Books.
- Brandt AV. 1984. *Fish Catching Methods of the World*. Fishing News Books.FAO. 1987. Small Scale Fishing Gear.
- Fridman AL. 1986. *Calculations for Fishing Gear Designs*. FAO Fishing Manual. Fishing News Books.
- Garner J. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House
- Kristionsson H. 1975. *Modern Fishing Gear of the World*. The White Friars Press.
- Sreekrishna Y & Shenoy L. 2001. Fishing Gear and Craft Technology. ICAR.

I. Course Title : Fishing Gear Selectivity
II. Course Code : FET 603
III. Credit Hours : 1+1

IV. Aim of the course

To learn trawl net selectivity, To learn gill net selectivity, To learn fishing hook selectivity.

V. Theory

Unit I

Selectivity: Terminologies related to selectivity, Bycatch, Discard, Ghost fishing, Catch quality, Significance of fishing gear selectivity, size selective fishing gears, species selective fishing gears.

Unit II

Selectivity of trawl: Introduction, Trawl selectivity parameters, Selection factor, L25, L50, L75, Trawl selection curve, Factors affecting the selectivity of trawls, Method of measuring selectivity of trawls, Covered cod-end method, Trouser trawl cod-end method, Twin trawl method, Alternate hauls, Parallel hauls; Limitations of trawl net selectivity-square-mesh code end- spatial temporal variation in availability of stock on selectivity – TED, BRD.

Unit III

Selectivity of gill net: Introduction, Estimation of gill net selection, Length at first capture (Lb), Mean selection length (Lc), Length of escapement (Ld) selectivity curves, Factors influencing the selectivity of gill net, Methods of measuring selectivity - Direct estimate, indirect estimate, Girth measurements, Fishing mortality, Selectivity of hook and line – introduction, estimation of hook and line selection, selectivity curves, factors influencing the selectivity of hook and line, Methods of measuring selectivity, Size selectivity of hook, Effect of Hook and Bait Size, Estimation of the size selectivity of hooks, Impact of hook shape on hook selectivity.

Unit IV

Fisheries management – Impact of selective fishing on ecosystem, Impact of selective capture of top carnivorous- Recruitment over fishing, Growth over fishing, Fishing holidays, FADs, ARS as management tools.

VI. Practical

Optimum mesh size estimation for gill net. Lb – Length at first capture, Lc – mean selection length and Ld- escapement length. Gill net selection factor. Selectivity curves for trawl. Trawl selection range and trawl net selection factor. L25, L50 and L75. Fishing hook selectivity.

VII. Suggested Reading

- Sparre P and SC Venema. 1992. *Introduction to Tropical Fish Stock Assessment*-Part 1: Manual by, FAO Fish. Tech. Pap., Rome.
- Holger Hovgard, Hanslassen. 2000. *Manual on Estimation of Selectivity for Gill Net and Long Line Gears in Abundance Surveys* by FAO technical paper 397.
- Sreekrishna Y & Shenoy L. 2001. *Fishing Gear and Craft Technology*. ICAR.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House.
- *Module I- Fishing Technology*. 2004. CIFNET, Cochin.
- Thomas SN, Leela Edwin, P Pravin, MP Remesan, P Muhamed Ashraf, MV Baiju and Madhu VR. 2012. *Fish Harvesting Systems for Resource Conservation*. CIFT, Cochin.

I. Course Title : Deepsea Fishing

II. Course Code : FET 604

III. Credit Hours : 2+1

IV. Aim of the course

Familiarization of deck equipment's on deep sea fishing vessel, Familiarization of bridge equipment's, Familiarization of engine room equipment's of deep-sea vessel.

V. Theory

Unit I

Deep sea fishing vessels: History of Deep-Sea Fishing, History of deep-sea fishing in India, Deep sea fishing initiatives, Committee on Deep sea fishing, Fishing Vessels and Deep-Sea Fishing, Types of fishing vessel, Mother vessel, Factory trawler, Thoothoor model, Design features of fishing vessels, Medium and large vessels.

Unit II

Deep sea resources: Fin Fishes, Shell fishes and other fishery resources of deep sea, Deep Sea Fishing Potential, Deep sea fishing resources of India, Exploitation of resources, FSI initiatives, Depth wise abundance.

Unit III

Fishing surveys: The Deep-Sea Prawn Fishery, Exploratory Surveys, The Trawling Grounds, Operations and the Catches, Area-wise Catch Distribution, Exploratory Surveys by FORV Sagar Sampada.

Unit IV

Details of Fishing - Catches and the Catch Rate, Species Composition, Biological Observations, Studies by Fishery Survey of India, Operations of Chartered Trawlers, Distribution and Abundance of Deep-Sea Prawns, Fishing Grounds, Catch Per Unit of Effort, Seasonality in Fishing Effort, Seasonal Variation in Catch Rate.

Unit V

Deep sea fishing gears: Fishing gears for deep sea fishing, Modification to the Gear, Area of Fishing Commercial Operations, Operations of Large Trawlers,Operations of Medium Trawlers, Estimation of Resource Potential Management Measures, Eco-friendly deep-sea fishing.

Unit VI

Govt. initiatives and sea safety: Various schemes of central and state governments to promote deep sea fishing in India and Tamilnadu, Sea safety aspects of deep-sea fishing vessels, Modern electronic equipments for deep fishing and navigation.

VI. Practical

Familiarization of deck equipment's on deep sea fishing vessel, net hauler and line hauler, Familiarization of bridge equipment's, Familiarization of engine room equipment's of deep-sea vessel. Illustration of boat, gears used in deep sea fishing. Fishing trips.

VII. Suggested Reading

- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publishing House – Delhi: 207 p.
- Capt. H Subramaniam. 2015. *Marine Meteorology*, Nut shell series, Book No.2 Vijaya publication, Bombay.
- DJ Randall and AP Farrell. 1997. *Deepsea fishes*. Academic press, USA.
- Garner J. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House.
- *International Convention for the Safety of Life at Sea*. Universal Publishing Corporation. Mumbai: 1-334pp.

- NR Merrett and RL Haedrich. 1997. *Deepsea Demersal Fish and Fisheries*. Chapman & Hall, London.
- PS Balachandran. 2013. *Manangement of Deepsea Fisheries*. Random Publications. New Delhi.
- Sudhakararao. 2009. Deepsea Fisheries of India. B.R.Publishing Corporation. New Delhi.
- U Shanker Rao. 2012. Deep sea fishing in India (From trawler to table). Biogreen books.

I. Course Title : Sustainable Fishing Methods

II. Course Code : FET 605

III. Credit Hours : 1+1

IV. Aim of the course

To learn various fishing methods and gears for the sustainable exploitation of aquatic resources

V. Theory

Unit I

Sustainable fishery: Definition of sustainability, Rules and regulations for sustainable fishing, FAO- code of conduct for responsible fisheries, Properties of a sustainable fishery, Present scenario and problems of sustainable fishing, Trends in global and Indian fishery, Environmental defects.

Unit II

Impacts of unsustainable fishing: Habitat degradation due to trawling, purse seining, Habitat modification, changing the ecosystem balance, Climate change, Ocean pollution, Disease and toxins, Remediation for sustainable fishery, Fisheries management, Ecosystem based fisheries, Marine protected area, Laws and treaties, Awareness campaigns, Sustainable fishing gears and devices, Designing of eco-friendly long line, Eco-friendly gillnet, Eco-friendly trawl net, Techniques reducing the risk of unsustainability, IUU fishing, Eco-friendly fishing methods and gears.

Unit III

Application of advanced methods: GIS, Remote sensing, PFZ, The Sustainability Challenges for Fisheries-Environmental challenges, Economic challenges, Social challenges, Organizational challenges.

Unit IV

Issues related to the sustainability: Environmental, Economic, Governance arrangements, Monitoring and enforcement, Legislation and policy, Endangered fish species of India, Government regulations, Present fishing policies adopted in developed nations for sustainable fishing.

VI. Practical

Visit to fishing harbour and landing centre to study technical draw basics of fishing gear with respect to their eco friendliness. Study designing of eco-friendly fishing devices, square mesh cod end, traps with escape vents, designing of longline with circular hooks. PFZ maps and table, GIS, remote sensing application in fisheries.

VII. Suggested Reading

- CIFNET MODULE III & IV. *Code of Conduct for Responsible Fisheries*. 61-69pp.
- FAO. 1995. *Code of Conduct for Responsible Fisheries*, FAO, Rome, 41p.
- Maheswari K. 2011. *Sustaining Marine Fisheries*. Sonali publication, New Delhi.

- Patel AN & Singh S. 1992. *Remote Sensing – Principles and Applications*. Scientific Publ.
- Raval NB. 2013. *Combating Marine Pollution*. Cyber tech publication, New Delhi.
- Sinha PC. 2007. *Fishing Conservation Management and Development*. SBS Publishers and distributers pvt. ltd, New Delhi
- Valavanis VD. 2002. *GIS System in Oceanography and Fisheries*. Taylor & Francis.

I. Course Title : Fishing Harbour, Planning, Construction and Management

II. Course Code : FET 606

III. Credit Hours : 2+1

IV. Aim of the course

To learn Fishing Harbour Planning, To learn Planning Construction and Management of Fishing Harbour, To learn advanced methods for preventing sea erosion.

V. Theory

Unit I

Classification and functions of fishing harbour and Fish Landing Centre: Water side and land side facilities, Site selection for fishing port, Planning and construction, Environmental impact assessment, Indian Standard codes.

Unit II

Hydrographic surveys- Vertical depth measurements, Horizontal position fixing; Specifying hydrographic surveys, Outline design and project formulation, Preliminary design, Final design, Construction phase of a port, Maintenance dredging and reclamation construction cost estimation.

Unit III

Harbour management: Structures, Size and composition, Artisanal landing, Management body, Best management practices, Port operations, Boatyard operations, Prevention of pollution.

Unit IV

Requirements for dredging - Volume estimates, Dredging techniques, Disposal of dredged sediments, Environmental impacts of dredging, Dredging of fairways, Minimum width, Minimum depth.

Unit V

Breakwater: Parameters for the construction of a breakwater; Construction methods; Floating breakwaters; Quays, Jetties, Slipways, Construction materials for fishing harbour.

Unit VI

Dry docks; Fishing harbour management and maintenance; Shore-based infrastructure, Advanced methods for preventing sea erosion, Dreading of fishing harbours.

VI. Suggested Reading

- Carl A Thoresen. 2003. *Port Designers Handbook Recommendation and Guidelines*. Thomas Telford, London.
- Chandrasekaran.S and A.K. Jain, 2017. *Ocean Structure, Construction, Materials and*

Operations. CRC Press, Taylor & Francis Group.
- Moffat and Nichol Engineers. 1983. *Construction Materials for Coastal Structures*. Virginia, USA, US Army Corps of Engineers Coastal Engineering Research Center.
- Quinn AD. 1972. *Design and Construction of Ports and Marine Structures*. McGraw-Hill, Inc., New York.
- Sciortino JA. *Fishing Harbour Planning, Construction and Management*, FAO Fisheries and aquaculture technical paper 539, FAO, Rome.
- Thomas stevenson, *Design and Construction of Harbours*, A treatise on Maritime Engineering, Cambridge University Press.
- Tsinker Gregory. 1997. *Handbook of Port and Harbor Engineering - Geotechnical and Structural Aspects*. Springer science and business media. B.V.

I. Course title : Electronic Navigation and Sea Safety for Fishing Vessels

II. Course code : FET 607

III. Credit Hours : 2+1

IV. Aim of the course

To learn electronic navigational equipment's, To learn sea safety practices followed in the fishing vessels, To learn position plotting and chart work.

V. Theory

Unit I

Electronic navigation-I: Introduction, Terminologies and definitions related to electronic navigation, Global Positioning System, Echo sounder, Speed log, Electronic chart display and information system.

Unit II

Electronic navigation-II: Automatic Identification System (AIS), Voyage data recorder, Gyro-Compass, Auto Pilot and Course Recorder, Radio Direction Finder, VHF, Marine radio.

Unit III

Signalling: Introduction, Terminologies and definitions, Flag signalling, International code of signals, Single letter and two letter signals, Morse code, Flash light signals, Arm signals

Unit IV

Safety: Conventions on sea safety, Global Maritime Distress and Safety System (GMDSS).

Unit V

Lifesaving appliances for fishing vessels: Life buoy, Life jacket, Buoyant apparatus etc., Ship handling, Equipment, Manoeuvring and Mooring operations, Preventing Collisions at sea, Accident hazards.

Unit VI

Communication during emergencies: Danger message, Distress and rescue procedure, Distress signals Fire fighting and checking and data recording of the safety instruments in boats, Emergencies at sea, Disaster management at sea for fishing vessel.

VI. Practical

Chart work; operation of navigational equipment viz., echo sounder, Sonar, GPS, Radar and communication systems like VHF, familiarization with sea safety devices like Chart Plotter, AIS, DAT, SART, EPIRB and GMDSS; navigational and fishing lights and shapes, distress signals and navigational equipment's compass, chronometer, aneroid barometer, sextant and speed logs. Visit to fishing vessel for familiarization of navigational equipment's.

VII. Suggested Reading

- Bhatia and Sinha. 2003. *Modern Electronic Navigation Aids*, Lata publications, Mumbai.
- Capt SK. Puri. 2011. *Manual of the Rule of the Road*, Marine Publication of India, New Delhi.
- Capt VK. Bhandarkar. 1976. *Seamanship*, Bhandarkar Publications, Mumbai.
- Capt H Subramaniam. 2016. *Practical Navigation,* Nutshell Series Book 1. Vijaya Publication, Mumbai.
- Capt SK Puri. 1997. *Chart work of Mariners*. Marine Publications of India, Mumbai,
- Capt FS. Howell. 1977. *Navigation Primer for Fishermen*. Fishing News Books Ltd, England.
- Graham Danton. 2014. *Theory and Practice of Seamanship*, Routledge, Abington.
- Sreekrishna Y and Shenoy L. 2001. *Fishing Gear and Craft Technology*. ICAR, New Delhi.

List of suggested Journals

- *Fishery Technology*
- *Indian Journal of Ecology*
- *Journal of Indian Ocean studies*
- *Fisheries Research -ISSN: 0165-7836*
- *Aquacultural Engineering*
- *Fish and Fisheries*
- *Fisheries Science*
- *Fisheries and Aquaculture Journal -ISSN 2150-3508*
- *Journal of Fisheries Science and Technology*
- *Developments in Aquaculture and Fisheries Science*
- *Indian Journal of Fisheries*
- *International Journal of Fisheries and Aquaculture*
- *Journal of Fisheries and Aquatic Science*
- *American Fisheries Society Portal*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *Turkish Journal of Fisheries and Aquatic Sciences*
- *Marine Ecology Progress Series*
- *Marine Policy*
- *Reviews in Fish Biology and Fisheries*
- *Fisheries Oceanography*
- *ICES Journal of Marine Science*
- *Marine Biology*
- *Reviews in Fisheries Science*
- *Ecological Modelling*
- *Fisheries*
- *Marine and Freshwater Research*
- *Fisheries Research*
- *Marine and Coastal Fisheries*
- *Fishery Bulletin*
- *Ocean & Coastal Management*
- *Journal of Fish Biology*
- *Ecology of Freshwater Fish*
- *Environmental Biology of Fishes*

- *Bulletin of Marine Science*
- *Transactions of the American Fisheries Society*
- *California Cooperative Oceanic Fisheries Investigations Reports*
- *Marine Resource Economics*
- *Fisheries Management and Ecology*
- *North American Journal of Fisheries Management*
- *Fisheries Oceanography*
- *Proceedings of the National Academy of Sciences, USA*
- *Freshwater Biology*
- *General and Comparative Endocrinology*
- *Journal of Cetacean Research and Management*
- *PLOS ONE*
- *Environmental Biology of Fishes*
- *Limnology and Oceanography*
- *Journal of Shellfish Research*
- *Molecular Ecology*
- *Ecosystems*
- *North American Journal of Fisheries Management*
- *Fisheries Bulletin*

List of suggested E-resources

- World Fish Center: www.worldfishcenter.org
- Food and Agricultural Organization of the United Nations (FAO): www.fao.org
- FishBase: www.fishbase.org
- International Union for Conservation of Nature (IUCN): http://cms.iucn.org
- OneFish: one internet portal. all fisheries research: www.onefish.org
- Bangladesh Fisheries Research Forum (BFRF): http://bfrf.org
- National Institute of Fisheries Post Harvest Technology: www.nifphatt.gov.in
- Central Institute of Fisheries Nautical and Engineering: www.cifnet.gov.in
- Fisheries Science Institutes: www.icar.org.in
- Central Marine Fisheries Research Institute: www.cmfri.org.in
- World Fishing: www.worldseafishing.com
- Central Institute of Fisheries Technology (ICAR CIFT): www.cift.res.in
- Innovative solutions for the fishing industry: www.fishing-tech.com
- World Fishing & Aquaculture: www.worldfishing.net
- Fishing Methods and Gear | Fisheries Technologies: www.nap.edu
- New technologies in Fisheries: www.oecd.org
- Fishing and Farming Methods from the Seafood Watch: www.seafoodwatch.org
- Office of Science and Technology: www.fisheries.noaa.gov
- Unsustainable fishing: www.wwf.panda.org
- The history of fishing: www.alimentarium.org

Suggested broad areas for Master's and Doctoral research

- Design upgradation of existing fishing gears for sustainable catch.
- Selectivity studies of fishing gears.
- Development of new fishing gear design and efficiency studies
- Catch Per Unit Effort(CPU) studies for different fishing gears
- Design upgradation of fishing crafts.
- Fouling effects on fishing crafts and Prevention methods.
- Problems of Wooden crafts with boring organisms.
- Efficiency of modern fishing gear materials under different conditions
- Abrasion studies for fishing gear materials
- Energy Optimization of fishing crafts
- Design and efficiency studies of Bycatch Reduction Devices
- Design and efficiency studies of Turtle Excluding Device(TED)

- Bycatch studies.
- Studies on ap[plication of remote sensing in fishing
- PFZ validation studies.
- Studies on FADs.
- Effect of fishing on non-target species
- Heat load calculations Design and layout upgradation of Processing Plants.
- Marine engine power ratings under various load conditions
- Energy efficient fishing methods
- Dry docking efficiency studies
- Anti-fouling studies in fishing vessels
- Design and functions of fishing harbours
- Modern tools for navigation/Electronic navigation
- Application of electronics in fishing
- Application eco-sounder in location fish shoals
- Low cost waste treatment systems and their Design
- Management options for ballast water
- Disaster management strategies
- Use if ICT in disaster preparedness
- Study of power requirements for different processing machinery
- Factors determining the selection of processing machinery

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fisheries Economics

Preamble
(Fisheries Economics)

Though fisheries economics is an integral part of Fisheries Science, the PG and Ph.D. programmes are offered in few campuses for strengthening sustainability, development and welfare of fisherfolk. Desired information on fish and fisheries need to be collected, inform and convince the people about the value of new and better technology packages, make further refinement to suit them and motivate them to adopt it and draw benefit from it. The research in various thrust areas of fisheries economics provides information to planners and policy makers for the fisheries development in India by offering the PG programmes and technical man power development in colleges and research institutes. The syllabus is designed to introduce doctoral and graduate students of fisheries economics to the process of scientific research in social sciences considering development taking place in allied subjects. Accordingly the syllabus is revised to take care of the changes in the data collection and processing and dissemination in developing data based fisheries management, market-led fisheries management and fisheries advisory services. New courses introduces is based on the emerging trend requirements for the graduating students. There are new and interesting contents are added in the subjects from socioeconomics to econometric tools which require continuous updation.

Course Insides

The economics principles and concepts could be applied to study the individual fisherman, households and firms' behavior in decision making, allocation of resources and understanding the fundamental relationships in the aggregate, macroeconomic activity, public policy goals and alternative policy proposals regarding inflation, economic growth, unemployment, and scarcity affecting fisheries. The purpose of the course is to give students a thorough understanding of the principles of economics that apply to the decisions of individuals-both consumers and producers-within the larger economic system. It is a subdivision of economics that studies how people, firms and households decide on how to allocate their limited resources taking fishermen as an example. The socioeconomics of fisherfolk means and ways of their welfare. Marine capture fisheries and aquaculture are important sources of food and livelihoods for fishermen. Climate change is the change of climate which is attributed directly or indirectly to fisheries activities that alters the composition of fish production and which is in addition to natural climate variability observed over comparable time periods. Fisheries is one of the important sectors which has been most exposed to vulnerability affected by climate change. The measure of livelihood status of fishermen warrants welfare schemes for their socioeconomic development. To make the students understand about the socioeconomic conditions of the fisherfolk and to assess their standard of living to draft various means of welfare schemes and its economic impact on the productivity of fisheries and livelihood and to study about the various policies and regulations to cope up with the climate change. Economic valuation provides a means for measuring and comparing the various benefits of fisheries resources and their ecosystems, and can be a powerful tool to aid and improve their wise use and management. The current limitations to valuing the services provided by inland fish and fisheries make comparison with other water resource users extremely difficult. This list can serve to demonstrate the importance of inland fish and fisheries, a necessary first step to better incorporating them into agriculture, land-use, and water resource planning, where they are currently often underappreciated or ignored. It also aims to provide an overview of the concept and methods for payment for ecosystem services and their policy implications. This course is aimed at providing a rigorous and application-oriented treatment of different valuation techniques for measuring the value of aquatic environmental goods and services. R & D Management is the discipline of designing and leading R & D processes, managing R & D organisations and ensuring smooth transfer of new know-how and technology to other groups or departments involved in innovation. To move towards innovation in fisheries and aquaculture, priorities for policy makers can set out the basis for a comprehensive and action-oriented approach. Technology diffusion with the number of inventions that seek patent protection through national, regional or international routes in a given jurisdiction. It shows the extent to which firms and individuals seek to "protect" the relevant markets for their inventions.

The international and domestic markets play a very important role in the development of fisheries sector in the country. Apart from ensuring the nutritional and food security, it also helps in minimising the post – harvest losses, increases revenue and enhance employment opportunities. Marketing intelligence is the everyday information relevant to a company's markets, gathered and analysed specifically for the purpose of accurate and confident decision- making in determining market opportunity, market penetration strategy and market development metrics. The main purpose is to give an idea about the marketing intelligence and business analysis applied in the fisheries sector. The trade of the fish and fisheries products are an important means of income particularly in India. This course gives an insight to the various aspects of the fisheries trade at a global level. The importance of small-scale fishers and developing countries at a global level in producing and supplying fish and fishery products put them at the forefront in facing specific trade measures. At the consumer level, increasing awareness is driving demand for traceability systems and certification schemes intended to guarantee the sustainability and quality of a growing array of fish and fishery products. In order to level the playing field and provide clarity to the market, FAO supported the development of a common benchmark tool for fishery certification schemes. The main purpose is to familiarize students with basic concepts and principles of economics applied to international trade with reference to fisheries. Finance and project management provides an insight knowledge about investing in sustainable fisheries to support thriving oceans and communities. The accounting of cost input in different phases of project, complete ledgering of inventories and the financial inflow in a production system in an integral part of management. The profitability of any production system is derived by financial control in projects. Econometric is the application of statistical methods to economic data in order to give empirical content to economic relations. Econometrics uses statistical methods after adapting them to the problems of economic life. These adopted statistical methods are usually termed as econometric methods. Such methods are adjusted so that they become appropriate for the measurement of stochastic relationships. These adjustments basically attempt to specify attempts to the stochastic element which operate in real world data and enters into the determination of observed data. To make acquainted students with econometric tools applied to social sciences. This course on quantitative and econometric analysis focuses on practical applications that are relevant in fields such as economics, finance, public policy, business, and marketing

Learning upshots

To apply economic concepts and techniques to a range of specific issues in the management of aquatic fisheries resources; to analyse markets and industries and the economic challenges facing private business, public institutions and international organizations and to know the relevant markets for fish and aquaculture products, how these markets work, and how they affect production. Most of the courses are compulsory and demands active participation from the students. Emphasis to be placed on direct student participation, in the form of literature search and data retrieval, oral presentations, record fieldwork, assignments and computer labs. The examination form varies between courses and includes: written examinations, record, presentations of report using data science and analytics. The final examination is based on the thesis and an open oral examination

Course Title with Credit Load
M.F.Sc. in Fisheries Economics

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FEC 501	Microeconomics	2+0
FEC 502	Macroeconomics	2+0
FEC 503	Socioeconomics, Vulnerability and Fisherfolk welfare	2+1
FEC 504	Fishery Regulations and Ecosystem Valuation	2+1
FEC 505	Marketing Intelligence and Business Analysis	2+1
FEC 506	International Fisheries Trade	1+1
FEC 507	Fisheries Finance, Accounting and Control	2+1
FEC 508	Introduction to Econometric Tools	1+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
FEC 510	Management of R & D Innovations and Policy	1+1
FEC 511	Economics of Fisheries Enterprises	1+1
FEC 512	Fisheries Development Planning and Policy	2+0
FEC 513	Fisheries Project Management	1+1
	Supporting Courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common Courses	**5 Credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FEC 591	Masters' Seminar	0+1
	Total Course Work Credits	**40 Credits**
	Masters' Thesis Research	**30 Credits**
FEC 599	Masters' Research (Semester III)	0+15
FEC 599	Masters' Research (Semester IV)	0+15
	Total M.F.Sc Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fisheries Economics

I. Course Title : Microeconomics

II. Course Code : FEC 501

III. Credit Hours : 2+0

IV. Aim of the course

To teach economics theories that apply to the decisions of individual consumers and producers and also firms.

V. Theory

Unit I

Consumer theory: Theory of Demand, Consumer Behaviour, Cardinal Utility theory, Indifference Curves theory, Income and Substitution effect, Derivation of demand curve, Consumer surplus, Equilibrium of the consumer, Elasticity of demand, Market demand, Constant elasticity demand function

Unit II

Production economics: Basic theory of the firm, Concepts, Production functions, Isoquants derivations and applications, optimization behaviour, Alternative models, Short run and long run cost functions; Total price effect, Substitution effect, Output effect and Profit maximization effect decomposition analysis, Analytical approaches, joint products, Concepts and constrained optimization.

Unit III

Production theory: Theory of production and costs, Production functions, Returns to scale, Long run analysis of production, Law of variable proportions, Technological progress, Equilibrium of the firm, Choice of optimal combination of factors of production, Derivation of cost function from production function, Production function of a multiproduct firm, Iso-revenue curve of the multiproduct firm, Linear production functions, Linear programming.

Unit IV

Theory of costs: Theory of costs, Cost curves, Traditional theory of costs, Modern theory of costs, Short and Long run costs, Marginal cost, Minimum Average Total Costs, Analysis of Economies of Scale, Social and Private costs.

Unit V

Factor pricing: Theory of Price in Perfectly Competitive markets, The supply curve of the firm and industry, Short run equilibrium of the firm and industry, Equilibrium of firm and industry in long run, Optimal Resource Allocation, The stability of equilibrium, Dynamic equilibrium with lagged adjustment, Futures market- Hedging/ risk assumption.

Unit VI

Welfare economics: General Equilibrium theory- Two commodity exchange-

Production and exchange, Multimarket equilibrium, General equilibrium and allocation of resources, Factor ownership and income distribution, Welfare economics, Pareto optimality, Maximization of social welfare, Welfare maximizing state.

VI. Suggested Reading

- Brickley J, Smith C and Zimmerman J. 2008. *Managerial Economics & Organizational Architecture* (4^{th} Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- David M Kreps. 1990. *A Course in Microeconomic Theory*. Princeton University Press.
- Dewitt K.K. 2002. *Modern Economic Theory*. Sultan Chand & Co.
- Geetika GP and Choudhury PR. 2011. *Managerial Economics* (2^{nd} Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- Haran J. 2012. *Managerial Economics*. Jaipur: Garima Publications
- Henderson JM and Quandt RE. 2000. *Microeconomic Theory: A Mathematical Approach*. McGraw-Hill.
- Jhingan ML and Stephen JK. 2012. *Managerial Economics* (2^{nd} Ed.). Delhi: Vrinda Publications (P) Ltd.
- Jhingan ML. 2004. *Micro Economic Theory*. Vikash Publishing House Pvt. Ltd. New Delhi.
- Koutsoyiannis A. 2003. *Modern Microeconomics*. The Macmillan Press.
- Salvatore D. 2011. *Principles of Microeconomics* (5^{th} Ed.). Oxford: Oxford University Press
- Shrivastava OS. 2013. *Modern Managerial Economics: Including Micro and Macroeconomics*. New Delhi: Anmol Publications Pvt. Ltd.
- Silberberg E & Suen W. 2001. *The Structure of Economics – A Mathematical Analysis*. McGraw-Hill.
- Varian Hal R. 1992. *Microeconomic Analysis*. W. W. Norton and Co.
- Varian Hal R. 1999. *Intermediate Microeconomics*. Affiliated East-West Press

I. Course Title : Macroeconomics

II. Course Code : FEC 502

III. Credit Hours : 2+0

IV. Aim of the course

To understand the basic concepts and principles of macroeconomics including the analytical tools used for them.

V. Theory

Unit I

Basic concepts: Nature and Scope of Macroeconomics, Methodology and Keynesian Concepts National income, Concepts and measurement (GNP, NNP, PI & DI), methods for measuring national income, Importance of NI analysis, Nominal and Real GDP, Balance of Payments (BoP), Meaning, Structure, Deficit and surplus, Disequilibrium, control measures.

Unit II

Theory of income and employment: Classical theory of Employment and Say's Law, Modern theory of Employment and Effective Demand, Consumption function, Investment and savings; Consumption function, Average propensity to consume and marginal propensity to consume, Measure of propensity to consumption, Keynes's theory of consumption and The determinants of consumption, Importance of consumption function.

Unit III

Investment and Saving: Saving function, Average propensity to save and marginal propensity to save; Investment function, Meaning, Types of investment, Determinants of the levels of investment, Marginal efficiency of investment, Induced investment.

Unit IV

Multiplier and accelerator: Concept of Multiplier and Accelerator, Output and Employment, Rate of interest-Classical, Neo classical and Keynesian version, Theory of Multiplier, Concepts of investment multiplier, derivation of investment Multiplier, Importance of multiplier; Aggregate demand and supply; Unemployment, Meaning, types; Full employment.

Unit V

Monetary and fiscal policy: Inflation-meaning, types, Inflationary gap, Cause and effect of inflation, Control measures for inflation; Monetary policy – Meaning, Objective, instruments, Fiscal policy – Meaning, Objective, Fiscal policy for economic growth, merits and Demerits of the fiscal policy.

Unit VI

Public finance and expenditure: Public finance and Public expenditure – Concepts, types of public expenditure, Growth of public expenditure, Effects of public expenditure on production and distribution; Government expenditure (Taxation) – Government budget constraints; Tax- meaning, Classification, Characteristics of good tax system, Problems of equity in taxation.

VI. Suggested Reading

- Ahuja HL. 2007. *Macroeconomics: Theory and Policy*. S. Chand & Co.
- Collier Macmillan Dornbusch. 2006. *Macroeconomics* McGraw Hill Publication.
- Deepashree VA. 2012. *Macroeconomics* (5ht Ed). New Delhi: Ane Books Pvt. Ltd.
- Eugene A Diulio. 2006. *Macroeconomics*. 4 Ed. Schaums' Outlines.
- Gardner Ackely. 1987. *Macro-Economic: Theory and Policy*.
- Gardner Ackley. 1987 *Macro-economics: Theory and policy*. Macmillan Publishing Co., Inc., New York.
- Gregory Mankiw N. *Macroeconomics,* 2004,Worth publishers, New York
- Gupta GS. 2010. *Macroeconomics: Theory and Applications* (3rd Ed.). New Delhi: Tata McGraw Hill Education Private Limited
- Haran J. 2012. *Managerial Economics*. Jaipur: Garima Publications
- Kennedy EP. 2012. *Macroeconomic Essentials: Understanding Economics in the News* (3rd Ed.). New Delhi: PHI Learning Private Limited.
- Kennedy MMJ. 2011. *Macroeconomic Theory*. New Delhi: PHI Learning Private Limited.
- Maheshwari Y. 2012. *Managerial Economics* (3rd Ed.). New Delhi: PHI Learning Private Limited.
- Mankiw, N.G. 2004. *Macro-economics*, World Publishers, New York.
- Mankiw MG. 2012. *Principles of Macroeconomics* (6th Ed.). Delhi: Cengage Learning India Pvt. Ltd.
- Reddy MK and Saraswathi S. 2007. *Managerial Economics and Financial Accounting*. New Delhi: PHI Learning Private Limited
- Robert J Gordon. *Macroeconomics*, Addison-Wesley, New York. Shapiro, E. *Macroeconomic Analysis*. Galgotia Publications, Delhi.
- Shapiro E. *Macroeconomic Analysis*. Galgotia Publications, Delhi.
- Tailor RK. 2012. *Principles of Managerial Economics*. Jaipur: RBSA Publishers
- Thomas F Dernburg. *Macro-economic-Concepts, Theories and Policies*, McGraw Hill Book Company, London.
- Walsh EC. 2010. *Monetary: Theory and Policy* (3rd Ed.). New Delhi: PHI Learning Private Limited.

I. **Course Title** : **Socioeconomics, Vulnerability and Fisherfolk Welfare**

II. **Course Code** : **FEC 503**

III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To make the students understand about the socioeconomic conditions of the fisherfolk and the impact of climate change over it to assess their standard of living to draft various means of welfare schemes to them.

V. **Theory**

Unit I

Factors affecting socioeconomic status: An over view of socioeconomic status of fisherfolk in India, Livelihood and Income, Indebtedness, Poverty, Inequality and unemployment in fisheries, Regional disparities in wage, work and livelihood security, Equity theory; Risk and uncertainty in fisheries, Standard of living of fisherfolk, Saving, Income, Consumption, poverty, Health status.

Unit II

Socioeconomic analysis: Concepts in socioeconomics, Gender discrimination, Income inequality, Gini coefficient and Lorenz curve, Theil index, Livelihood Index, Engel's curve, Duncan Socioeconomic Index (SEI), Occupational Status Score (OSS), Household prestige (HHP) score, Recent measurement of economic development NEW (New Economic Welfare), MRW (Measurement of Economic Welfare), PQLI (Physical Quality Living Index), HDI (Human Development Index)- Green GNP Index.

Unit III

Fisheries and climate change: Fisheries and climate change, Fisheries policy, Issues for future impact and adaptation, Socio economic condition and Fisheries policy, Fisheries and sustainability, Biodiversity of climate change, Indian fisheries current scenario in climate change, climate change threat, Impact of climate change in fisheries, Dynamics of climate change, Futuristic endeavour.

Unit IV

Climate change impact analysis: Economic impact on climate changes, Climate change mitigation and adaptation, Ongoing initiatives and future strategies for fisheries sector, Methods and tools for climate change adaptation- Impacts of climate driven extreme events and disasters in fishermen communities, Social impact on climate change, Vulnerability assessment, Top down and Bottom up approaches, Socio-economic vulnerability, Criteria and indicators, Vulnerability assessment framework and methods, Exposure, Sensitivity and Adaptive Capacity, Vulnerability Index– SeVI

Unit V

Legal instruments to mitigate climate change: An overview of international legal and policy framework to address climate change developed over time and points out some of the key issues under negotiation, History of international climate change negotiations and Nations Framework Convention on Climate Change (UNFCCC), Key provisions of the UNFCCC, Its organisational structure, and different Party groups under the Convention, Kyoto Protocol and its associated bodies, as well as key commitments by Parties, An overview of main negotiation issues, Highlights some of the key issues relevant for a future climate change regime.

Unit VI

Welfare economics: Fundamental theorems of welfare economics, Promising features of welfare economics, Welfare Schemes for fisherfolk in India, Women empowerment in Fisheries, Overview of fisherfolk welfare schemes, Fisheries Cooperatives, Corporations and NGOs in fisherfolk welfare development.

VI. Practical

Assessment of socioeconomic parameters of fisherfolk in marine fisheries sector; Assessment of socioeconomic parameters of fisherfolk in inland fisheries sector; Consumption and savings behaviour of fisherfolk; Nutrition and Health analysis of fisherfolk; Case studies on effects on climate change in world fisheries with special emphasis to Indian fisheries; Climate change impact on coastal fisheries and aquaculture in India; Case studies on sustainability of fisheries sector in India; Case studies on climate change driven disasters affecting the fishermen communities in India; Effectiveness of fisherfolk welfare schemes; Impact of welfare schemes on fisherfolk

VII. Suggested Reading

- Bahuguna P. 2011. *Rural Marketing*. New Delhi: Centrum Press
- Brander KM. 2007. *Global Fish Production and Climate Change.* Proceedings of the National Academy of Sciences, 104(50): 19709-19714.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- CMFRI-NICRA Annual Report, 2015-2016, Marine Fisheries, Report of work done at CMFRI submitted to CRIDA, pp. 27.
- De Silva SS and Doris Soto. 2009. "*Climate Change and Aquaculture: Potential Impacts, Adaptation and Mitigation." Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge*. FAO Fisheries and Aquaculture Technical Paper 530: 151-212.
- Delgado CL, Wada N, Rosegrant MW, Meijer S and Ahmed M. 2003. *Outlook for Fish to 2020: Meeting Global Demand*. Penang, International food policy research group and worldfish centre.28 pp.
- Glick P, Stein BA and Edelson NA. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*. Washington, DC, National Wildlife Federation. 168 pp. (also available at https://www.nwf.org/Educational-Resources/ Scientific-Reports/ 2011/01-19-2011-Scanning-the-Conservation-Horizon).
- Gopalakrishnan A *et al*. 2016. *Climate Change Impact on Coastal Fisheries and Aquaculture* in the SAARC region: Country paper- India, 1-25.
- Higgins Benjamin. *Economic Development: Problems Principles & Policies.* Universal Book, New Delhi
- IPCC – Intergovernmental Panel on Climate Change – https://www.ipcc.ch
- IPCC 2007: Climate Change 2007: *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.
- Ishwar C Dhingra, "*The Indian Economy, Environment and Policy*", published by Sultan Chand, ed. 2006, pp. 53.56,641.
- Khader V. 2008. *Empowerment of Fisher Women*. Udaipur: Agrotech Publishing Academy
- Khan NA. 2009. *Fundamentals of Entrepreneurship.* New Delhi: Anmol Publications Pvt. Ltd.
- Kindleberger, Charles P. *Economic Development*, McGraw Hill International. Meir, Gerald M. *Leading Issues in Economic Development*.

- Kumar D. "*Climate Economics- Impact and Assessment of Climate Change*", published by Dominant Publishers, ed. 2012.
- Kumari, Sonia. Zacharia PU, Kripa V, Sreenath KR and George Grinson. 2015. *Distribution Pattern and Community Structure of Zoanthids (Zoantharia) along the Coast of Saurashtra, Gujarat, India. Journal of the Marine Biological Association of the United Kingdom*, 96(8): 1577-1584.
- McMichael AJ. 2001. *Impact of Climatic and other Environmental Changes on Food Production and Population Health in the Coming Decades*. The Proceedings of the Nutrition Society, 60 (2): 195- 201.
- NICRA- *National Initiative on Climate Resilient Agriculture* – www.icar.nicra-icar.in
- NOAA- *National Oceanic and Atmospheric Administration* – https://www.noaa.gov
- Ogier EM, Davidson J, Fidelman P, Haward, M, Hobday AJ, Holbrook N, Hoshino E & Pecl GT. 2016. *Fisheries Management Approaches as Platforms for Climate Change Adaptation:* Comparing theory and practice in Australian fisheries. Marine Policy, 71: 82–93.
- Rathakrishnan L. 2008. *Empowerment of Women Through Entrepreneurship*. New Delhi: Gyan Publishing House
- Singh K. 2012. *Rural Development: Principles, Policies and Management* (3rd Ed.). New Delhi: SAGE Publications.
- Thakur AK and Sharma P. 2009. *Micro-credit and Rural Development*. New Delhi: Deep & Deep Publications Pvt. Ltd.
- Tiwari S and Tiwari A. 2007. *Women Entrepreneurship and Economic Development*. New Delhi: Sarup & Sons
- Todaro, Michael P and Smith SC. *Economic Development*. Pearson Education.
- UNFCC- *United Nations Framework Convention on Climate Change* – https://unfcc.int

I. Course Title : Fishery Regulations and Ecosystem Valuation

II. Course Code : FEC 504

III. Credit Hours : 2+1

IV. Aim of the course

To provide an overview of the concept and methods for payment for ecosystem services and their policy implications. This course is aimed at providing a rigorous and application-oriented treatment of different valuation techniques for measuring the value of aquatic environmental goods and services.

V. Theory

Unit I

Fisheries regulations: Fisheries Regulations, Imperative needs for the regulation of marine fisheries in India, Types of fishery regulations, Possible objectives of fisheries regulations; Fisheries regulations followed in the maritime states of India.

Unit II

Aquaculture guidelines: Aquaculture; Guidelines under CRZ notification of 1991 and its Amendments, Land leasing policies, Regulations on use of chemicals and antibiotics, Features of Aquaculture Seed (Quality Control) Relevant Central/state legislative provisions of Environment, Wildlife, Water, Biodiversity: (riverine, reservoir and aquaculture), Processing in different States.

Unit III

Ecosystem valuation: Environmental and ecosystem valuation, The concept of value and valuation –Theoretical basis of valuation – Consumer surplus, Compensating variation and equivalent variation, Cost-benefit analysis of a conservation project, Ecosystem valuation, Payment for ecosystem services, Ethical issues in valuation, choice of discount rate.

Unit IV

Methods of valuation - Revealed preference methods: Taxonomy of ecosystem values, Use value, non-use value, Direct and indirect use value, Existence value, Bequest value and option value, Revealed preference methods, Change in productivity method – Averting behavior and substitutable private, and Environmental goods, Models for bundled attribute goods, Hedonic of differentiated commodities, Discrete choice model of differentiated commodities, Hedonic property value model, Replacement cost approach, Substitute goods approach, Travel cost methods.

Unit V

Methods of valuation –Stated preference methods: Stated preference methods, Contingent behavior, contingent valuation techniques, Willingness to accept and willingness to pay, Bidding games, Choice experiment approach, Combining revealed preference and stated preference methods, Discrete choice models for stated preference data, Validity of stated preference data, Other methods, Benefit transfer.

Unit VI

Risk valuation and assessment: Morbidity and Mortality Risk Valuation, Risk assessment and the environment, Conceptual models, Health production model, Endogenous mortality risk, Measuring the value of a statistical life, Wage hedonics, Valuing health changes, Defensive expenditures and cost of illness, Economic valuation of biodiversity, Measurement of carbon sequestration benefits, Measurement of climate change impact, Agronomic vs. economic methods, Ricardian model, Just-Pope model.

VI. Practical

Contemporary global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms; Fishery regulation in India; Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques; Recreation demand models of environmental valuation – Contingent valuation techniques – Environmental Resource Accounting Techniques; Practical considerations and comparison of instruments of environmental policy; Non-Point source pollution control methodologies - economic valuation and environmental economics; Exercises on change in productivity method; Replacement cost method with examples and insights from literature; Exercises on hedonic pricing. Travel cost method – design and application with example, Stated preference approaches – Contingent valuation methods; Measuring WTP and WTA – Empirical exercises

VII. Suggested Reading

- Adamowicz, Wiktor, Peter Boxall, Michael Willioams, and Jordon Louviere. Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation. *American Journal of Agricultural Economics* 80: 64-75 (February 1998).
- ASC – *Aquaculture Stewardship Council* – https:// www.asc.aqua.org
- Bartik, Timothy J. Measuring the Benefits of Amenity Improvements in Hedonic Price Models, *Land Economics* 64(2): 172-183 (May 1988).
- Bavinck M. 2001. *Marine Resource Management: Conflict and Regulation in the Fisheries*

of the Coromandel Coast. Sage Publications.

- Berkes F. 2001. *Managing Small-scale Fisheries: Alternative Directions and Methods*. IDRC.
- Bromely W Daniel. *The Hand Book of Environmental Economics* (Madison: Black Well Publications), 1995.
- Carlson GA, Miranowski J & Zilberman D. 1998. *Agricultural and Environmental Resource Economics*. Oxford Univ. Press.
- Champ, Patricia A, Kevin J Boyle and Thomas Brown. *A Primer on Nonmarket Valuation*. Boston, Dordrecht, London: Kluwer Academic Publishers, 2003.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- Dillman, Don A. *Mail and Internet Surveys: The Tailored Design Methods*. New York: John Wiley and Sons, 2000.
- Dixon, John A, Louise Fallon Scura, Richard A Carpenter and Paul B. Sherman,"*Economic Analysis of Environmental Impacts*" (London: Earthscan Publications Ltd.), 1995.
- FAO – *Food and Agriculture Organization* – www.fao.org
- Fisher, Antony C. *Resource and Environmental Economics* (London: Cambridge University Press), 1981.
- Freeman, A. Myrick, III. *The Measurement of Environmental and Resource Values*. Second Edition. Washington, D.C.: Resources for the Future, 2003.
- Haab T and TE. McConnell (2002). *Valuing Environmental and Natural Resources: The Econometrics of Non-market Valuation*, Edward Elgar Publishers.
- Hanemann W. Michael. *Valuing the Environment Through Contingent Valuation*, *Journal of Economic Perspectives* 8(4): 19-43 (Fall 1994).
- Hannesson R., 1993. *Bioeconomic Analysis of Fisheries*. Fishing News Books Ltd.
- Hosetti BB and A Kumar "*Environmental Impact Assessment and Management*" (New Delhi: Daya Publishing House), 1998.
- http://ocw.mit.edu/courses/economics/14-42-environmental-policy-and-economics
- http://ocw.mit.edu/courses/economics/14-42-environmental-policy-and-economics-
- http://www.agecon.purdue.edu/staff/shively/courses/AGEC406/index.htm
- http://www.colorado.edu/economics/morey/4545/4545lnts.html
- http://www.economicsnetwork.ac.uk/environmental/resources
- Joy E. Hecht, "*Natural Environmental Accounting – Bridging the Gap between Ecology and Economy*" 2004.
- Myrick Freeman A, "*The Measurement of Environmental and Resource Values – Theory and Methods*" (Resource for the future press) 2003.
- Nick Hanley, Jason F. Shogran and Ben White, "*Environmental Economics in Theory and Practice*", (Delhi: Mc Millan, India), 1997.
- Pinkerton E. ed., 2011. *Co-operative Management of Local Fisheries: New Directions for Improved Management and Community Development*. UBC Press.
- Portney, Paul R. The Contingent Valuation Debate: Why Economists Should Care, *Journal of Economic Perspectives* 8(4): 3-17 (Fall 1994).
- Sathiadhas R., 1997. *Production and Marketing Management of Marine Fisheries in India*. Daya Books.
- Timothy C. Haab and Kenneth R. Mc Connell, "*Valuing Environmental and Natural Resources – The econometrics of Non-market Valuation*" (Edward Elgar Publishing Limited, UK), 2003.
- Tom Totenberg, "*Environmental and Natural Resource Economics*" (Pearson – Addision Wesley publication), 2006.
- Turner, Kerry, David prance, Ian Batsman and Johns Hopkins - *Environmental Economics: An Elementary Introduction* 1993.
- Wilson DC, Nielsen JR and Degnbol P. eds., 2003. *The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects* (Vol. 26). Springer Science & Business Media
- www.env-econ.net
- www.teebweb.org

I. **Course Title : Marketing Intelligence and Business Analysis**

II. **Course Code : FEC 505**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To give an idea about the marketing intelligence and business analysis applied in the fisheries sector.

V. **Theory**

Unit I

Research methodology: The role of marketing intelligence in the firm, The process of marketing research, The difference between exploratory and confirmatory research, Secondary and primary data, Qualitative and quantitative research methodologies, Sampling theory.

Unit II

Requirements in business analysis: Requirements in Business Analysis, Management, Communication, Tracing, Configuration and change management, quality assurance, Development, Elicitation including stakeholders and/or product requirements development, Specification.

Unit III

Business analytics: Business Analysis, Internal analysis, External analysis, Business need definition, Gap analysis, Solution proposal (including feasibility analysis), Solution delivery or maintenance program/project initiation- Business process definition, Business goals, Business needs, Business requirements, Limitations and assumptions.

Unit IV

Modelling and forecasting: Solution modelling, validation and verification, Solution evaluation and optimization, Assessing the solution options (proposals), Evaluating performance of the solution, Solution/business process optimization, Model Volatility with ARCH and GARCH for Time Series Forecasting.

Unit V

Marketing research: Definitions of the various methodological concepts -Various steps involved in designing a research plan, Data collection methods; Characteristics, Structure, Sources, Value, and use of Big Data, The relationship between digital analytics and inbound marketing strategies, Consumer information and measurement services, Rules for designing a questionnaire.

Unit VI

Data analysis in marketing research: Data sources for assessing consumer preferences, firm performance, and market condition and competition- analyze enterprise data, especially for purposes of segmentation, targeting, positioning, and evaluating consumer value- process of organizing, writing, framing, and refining analytics reports- delivering effective presentations, and aligning analytic results with stakeholder needs and preferences

VI. **Practical**

Marketing Research – ethics, standards and issues; Utilisation of Secondary Data Resources for Customer Segmentation Pricing and Elasticity; Linear Regression

Basics; Using Linear Regression to Forecast; Conjoint Analysis; Digital Marketing Metrics Customer Lifetime Value; Cluster Analysis; Finding and interpreting secondary data; Suggesting a methodology for fisheries marketing research; Tools and concepts of data visualization

VII. Suggested Reading

- Axelos, *Managing Successful Projects with PRINCE2®* 2017 Edition, Axelos, 2017 ISBN: 9780113315338
- Bens, Ingrid. *Facilitation at a Glance*! 4th Edition, Goal/QPC; 4th edition, 2016, ISBN-10: 1576811832
- Brown Tim. *Change by Design: How Design Thinking Transforms Organizations*
- Carlson C.C., Wilmot, W.W. *Innovation: The Five Disciplines for Creating What Customers Want*, New York: Crown Business, 2006, ISBN: 0307336697 Edition, ISBN 13: 978-0-13-608543-0
- eNAM – National Agricultural Market https://enam.gov.in
- Harrington H. James. *Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness*, 1991 Inspires Innovation, HarperCollins, 2009, ISBN 978-0061766084
- MPEDA – *Marine Products Export Development Agency* – mpeda.gov.in
- Naresh Malhotra. *Marketing Research: an Applied Orientation*, Sixth
- NFDB- National Fisheries Development Board – nfdb.gov.in
- Pearson Prentice Hall *Analyzing the Target Market*, Part 1: Chapter 3, Marketing Research, Harvard Business Publishing BEP 117, length 18 pages

I. Course Title : International Fisheries Trade

II. Course Code : FEC 506

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize students with basic concepts and principles of economics applied to international trade with reference to fisheries.

V. Theory

Unit I

Introduction to international economics: International Economics, Concepts and scope, Nature of international trade, Difference between domestic and Foreign trade; Theories of international trade, Absolute and comparative advantage, Modern theories of international trade, Hecksher Ohlin theorem.

Unit II

Concepts in trade: Concepts of terms of trade, Free trade, Protection, Tariffs, Quantitative restrictions and other non-tariff measures; Exchange rate; Devaluation and depreciation; Balance of payments, EXIM policy of India in relation to fish and fishery products.

Unit III

Export- Import procedures: Export- Import procedures, and certification, Growth of marine product exports – MPEDA and its development programmes.

Unit IV

Institutions and trade policies: GATT and WTO, transition from GATT to WTO, WTO provision and its agreements; Agreement on Agriculture (AoA), Agreement on SPS measures and its salient features, Role of Codex Alimentarius Commission

(CAC) and Agreement in Trade Related Intellectual Property rights (TRIPs) WTO in dispute settlement.

VI. Practical

Pattern and performance of India's seafood exports; Product and market diversification; Competitiveness of Indian fish and fish products; Exports of value added seafood products; Case study of a seafood export firm; Use of SPS / TBT measure; Non-tariff barriers in fisheries trade; Dumping and anti-dumping measures in seafood trade.

VII. Suggested Reading

- Apple yard DR & Field A. J. 2001. *International Economics*. 4th Ed. McGraw Hill.
- Bradley, T. 2008. *Essential Mathematics for Economics and Business* (2nd Ed.). New Delhi: Wiley India Pvt. Ltd
- CAC – Codex Alimentarius Commission – www.fao.org
- Charles PK. 1968. *International Economics*. Richard D. Irwin.
- Cherunilam, F. 2011. *International Economics* (5th Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- Deepti. 2011. *Foreign Direct Investment: in Different Sectors of Indian Economy*. New Delhi: Deep & Deep Publications Pvt. Ltd.
- Dennis Appleyard, *Trade Theory and Practice*. Irwin Publishers
- Ethier WJ. 1995. *Modern International Economics*. Norton International Ed.
- Francis C. 1999. *International Economics*. Tata McGraw Hill. Kemp MC. 1964. Pure Theory of International Trade. Prentice Hall.
- Walterjngo and Kaaj A. 1981. International Economics. 3rd Ed. Prentice Hall.
- Francis C. 2008. *International Economics*. Tata McGraw Hill.
- GATT – *General Agreement on Tariffs and Trade* – https://www.wto.org
- Jain, S. K. 2012. *Export Import Procedures and Documentation* (6th Ed.). Girgaon, Mumbai: Himalaya Publishing House
- Krugman PR & Obstfeld M. 1991. *International Economics*: *Theory and Policy*. Harper Collins Publ.
- Krugman, R. P. and Obstfeld, M. 2013. *International Economics: Theory and Policy* (8th Ed.). New Delhi: Pearson Education.
- Mithani. J.P *International Economics* Tata Mcgraw, Hill, New Delhi
- MPEDA – Marine Products Export Development Agency – mpeda.gov.in
- Nath, H.S. 2012. *Economics of Foreign Exchange and Global Finance*. New Delhi: Cyber Tech Publications
- Pugel, A.T. 2012. *International Economics* (13th Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- Samuelson and Nordnaus. *Economics*, Tata Mcgraw, Hill, New Delhi
- Taneja, P. 2011. *Statistics for Business and Economics*. New Delhi: Rajat Publications
- Tejpal, B.K. 2012. *Business Economics: Modern Methods & Techniques*. Jaipur: Ritu Publications
- Venkatachalam, P.V. 2012. *Text Book on International Economics*. New Delhi: Cyber Tech Publications
- WTO – World Trade Organisation - https://www.wto.org

I. Course Title : Fisheries Finance, Accounting and Control

II. Course code : FEC 507

III. Credit Hours : 2+1

IV. Aim of the course

To make aware about the innovations in the fisheries finance and accounting.

V. Theory

Unit I

Principles of finance: Importance of fisheries finance; Principles of fisheries financial management, Rural credit structure, Demand and supply, Sources and forms; Estimation of credit requirement; Cost of Credit/capital; Credit appraisal. The concept of 3C's, 7P's and 3R's of credit, District Credit Plan and lending to agriculture/priority sector Micro-Financing.

Unit II

Reforms in policies and institutions: Reforms in fisheries credit policy; Innovations in fisheries financing, Micro Finance, Role of institutions in fisheries, Finance, Public and Private sector banks; Cooperatives, Micro-finance institutions (MFIs), SHGs; Financing through Co-operatives, NABARD and Commercial Banks and RRBs International Financial Institutions; Successes and failures of co-operative sector in India; Role of co-operatives under emerging economic scenario.

Unit III

Capital and cost concepts: Sources of long-term finance and cost of capital; Concepts of components of working capital, Managing working capital, Cash management, Dividend decision; Capital budgeting, Appraisal criteria; Fish business financing system in India-money and capital markets, National, regional and global financial institutions; Insurance; Risk management; Micro-credit.

Unit IV

Project formulation and appraisal: Elements of project cycle; Identification, Preparation, appraisal, Financing and implementation of projects, Project Appraisal techniques; Undiscounted measures, ranking by inspection, Pay-back period, Average annual proceeds per unit of outlay, Time value of money, Use of discounted measures, Derivation of incremental net benefit; B-C ratio, NPV and IRR, Project management Net-work Techniques – PERT and CPM.

Unit V

Accounting types: Branches of Accounting, Internal and External Users of Accounting, Financial Accounting, Meaning, Need, Concepts and Conventions; Advantages and Limitations, Accounting Standards, The Double Entry System, Its Meaning and Scope, The Journal, Cash Book, Ledger, Trial Balance, Trading Account, Profit and Loss Account, Balance Sheet, Entries and Adjustments of different heads in different Books and Accounts, Introduction of Company Accounts.

Unit VI

Accounting management: Management Accounting, Meaning, Functions, Scope, Utility Limitations and Tools of Management Accounting, Cost Accounting, Basics, Significance, Objectives, Classification of Costs, Marginal Costing. Responsibility Accounting, meaning and significance, Budgets and Budgetary Control-Types of Budgets.

VI. Practical

Rural Lending Programmes of Commercial Banks; Lead Bank Scheme-Preparation of District Credit Plan; Preparation of financial statements using farm/firm level data; Farm credit appraisal techniques and farm financial analysis through financial statements; Different case studies on fisheries cooperative societies and their performance (marine and inland sector); Practical exercise on PERT and CPM; Ratio analysis; Valuation of project inventories; Project appraisal techniques– undiscounted and discounted measures; Company accounts format and formatting

VII. Suggested Reading

- Bhatia BS, HL Verma, Mahesh C Harg. 2001. *Encyclopaedia of Co-operative Management* (Vol. I, II, III, IV), Deep and Deep publications, New Delhi
- Chodhury, Project Management Tata McGraw Hill Publishing Company Ltd., New Delhi
- FAO. Technical Paper No.334, *Fisheries Project Formulation*, FAO, Rome.
- FAO. 1971. *Manual on Fishermen's Co-operatives*, Rome.
- Gittinger J, Price. *Economic Analysis of Agricultural Projects*, EDI Series in Economic Development, John Hopkins University Press, Baltimore and London
- NABARD – National Bank for Agriculture and Rural Development – https://www.nabard.org
- Proctor T. 2005. *Essentials of Marketing Research. Financial Times*, Prentice Hall.
- Rajagopalan R. 1997. *Rediscovering Cooperation* Vol. I, II, III, IRMA Anand.
- Ronald W Cotterill. 1998. *Competitive Strategy Analysis for Agri-marketing Co-operatives*. 5. FISHCOPFED. 1989. *Fish Co-operatives*, New Delhi.
- Shang YC. *Aquaculture Economic Analysis* – An Introduction, The World of Aquaculture Society Ltd.
- Twiner and Simister (ed.). *Project Management*, Infinity Books, New Delhi.

I. Course title : Introduction to Econometric Tools

II. Course code : FEC 508

III. Credit Hours : 1+1

IV. Aim of the course

To make students acquainted with econometric tools applied to social sciences. This course on quantitative and econometric analysis focuses on practical applications that are relevant in fields such as economics, finance, public policy, business and marketing.

V. Theory

Unit I

Nature and scope of econometrics: Definition and Scope of Econometrics; Methodology of econometrics, The nature of the econometrics Approaches, Simple regression estimation and testing procedures, Stochastic and Non-Stochastic relations, Statistical properties of least squares estimators, Confidence interval and Hypothesis testing, Goodness of fit, Reporting the results of regression Analysis; Matrix Algebra.

Unit II

Introduction to classic linear regression analysis: Two variable regression model, The basic assumptions; Application of regression model, The covariance and covariance estimator, Functional forms of regression models and methods of estimation; Cobb-Douglas Production Model, Multiple regression model, Relationship between simple and multiple regression coefficients; Auto correlation-Heteroscedasticity; Multicollinearity; Meaning and problem, Autoregressive models for univariate time series stationary data (AR), Trend (ARIMA), and Seasonal component (SARIMA).

Unit III

Regression models and forecasting techniques: Simultaneous – Equation

Models; Problems of Simultaneous equation model; Multinomial regression models Ordinal – Regression models.

Unit IV

Forecasting with regression model: Panel data regression models, Survival analysis, Parametric and non-parametric tests in Social Sciences; Adhoc procedures in Regression analysis, Estimation of Probit, Logit and Tobit Probability Models.

VI. Practical

Analysis on fitting classical linear regression models; Detection of multicollinearity; Forecasting models; Heteroscedasticity and autocorrelation for the given data sets in fisheries; Parametric and non-parametric tests; Data analysis in MS excel, SPSS and STATA; Forecasting models that can be developed for univariate time series data.

VII. Suggested Reading

- Brooks C. 2009. *RATS Handbook to Accompany: Introductory Econometrics for Finance* New York: Cambridge University Press
- Damodar Gujarati. 2006. *Basic Econometrics*. Tata McGraw-Hill Publishing Company Ltd, Delhi
- Damodar Gujarati. 2012. *Econometrics by Example*, Palgrave Macmillan, New York
- Debbie Holmes, Peter Moody & Diana Dine. 2006. *Research Methods for the Biosciences*. International Student edition, Oxford University Press.
- Deepak Chowla & Neena Sondhi.2011. *Research Methodology: Concepts and Cases*. Vikas Publishing House Pvt. Ltd, New Delhi
- Dougherty C. 2011. *Introduction to Econometrics* (4th Ed.). Oxford: Oxford University Press
- Greene HW. 2012. *Econometric Analysis* (5th Ed.). New Delhi: Pearson Education.
- Gujarati D. 2011. *Econometrics by Example*. New York: Palgrave
- Gujarati DN, Porter DC and Gunasekar S. 2012. *Basic Econometrics* (5th Ed.). New Delhi: Tata McGraw Hill Education Private Limited
- Harry H Kelejin & Wallace E Oates. 1975. *Introduction to Econometrics: Principles and Applications*, Herber International Edition, Joanna Cotler Books
- http://www.oswego.edu/
- http://www.tiesindia.net/
- https://guides.lib.monash.edu/econometrics
- https://www.amstat.org/
- https://www.rss.org.uk
- Koutsoyiannis, A. 2013. *Theory of Econometrics: An Introductory Exposition of Econometric Methods* (2nd Ed.). New York: Palgrave
- Madnani GMK. 2012. *Introduction to Econometrics: Principles and Applications* (8th Ed.).New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.
- Murray R, Spiegel & Larry J Stephers. 2000. *Theory and Problems of Statistics*, Tata McGraw-Hill edition, New Delhi
- Studenmund AH. 2015. *Using Econometrics* (6th Ed.). Chennai: Pearson
- Teresa Bradley & Paul Patton. 2008. *Essential Mathematics for Economics and Business*. John Wiley & Sons ltd. New Delhi.

I. Course Title : Management of R&D Innovations and Policy

II. Course Code : FEC 510

III. Credit Hours : 1+1

IV. Aim of the course

To give an idea about the R & D Management and fisheries policy analysis.

V. Theory

Unit I

Innovation and technology: Innovation, productivity and economic growth; Nature, process and importance of technological innovation, Role of fisheries in economic and rural development.

Unit II

Fisheries in economic development theories: Growth stage theories, Structural transportation leading sectors and dual economy models, Technology adoption, Diffusion and transfer, Theoretical models and case studies, Technology, Resources and environment.

Unit III

Fisheries research systems: Fisheries research systems, Evolution and growth, Selected case studies of major countries, Investment trends, International comparisons, Institutional details; Changing public-private roles in technology development, Institutions and fisheries development; Collective actions, property rights, Transaction cost economics.

Unit IV

Theories and policies: Need for separate/sound fisheries policy, Resource polices, Credit policies, Input and product marketing policies, Price policies, Theories of fisheries development, Conservation, Urban industrial impact and Diffusion, High-pay-off input, Science and technology policy, Regulation, Incentives; Technology and Intellectual Property Rights, selected case studies.

VI. Practical

Measurement of productivity growth; Exercise on total factor productivity; Using frontier production function; Institutional structures and national and international fisheries research systems; Ex-ante and ex-post methods of estimation of R & D impacts in fisheries.

VII. Suggested Reading

- Alston JM, Norton GW and Pardey PG. 1995. *Science Under Scarcity*. Cornell University Press, Ithaca.
- Blaug M. 1986. *Economic History and the History of Economic Thought*. Wheatsheaf Books, Brighton. Ghatak S and Ingersent K. *Agricultural Economic Development*. Select Book Service Syndicate, New Delhi.
- FAO – *Food and Agriculture Organization* – www.fao.org
- GATT – *General Agreement on Tariffs and Trade* – https://www.wto.org
- Khurana VK. 2007. *Management of Technology and Innovation*. Ane Books India, Delhi.
- Ruttan VW. 2001. *Technology, Growth and Development: An Induced Innovation Perspective*. Oxford University Press, New York.
- Schultz TW. 1964. *Transforming Traditional Agriculture*. Yale University Press, New Haven Ruttan VM. 2001. *Technology, Growth and Development*. Oxford University Press.
- WTO – World Trade Organisation - https://www.wto.org

I. Course title : Economics of Fisheries Enterprises

II. Course code : FEC 511

III. Credit Hours : 1+1

IV. Aim of the course

To make the students aware about the economics of the various culture fisheries and the post – harvest operations.

V. Theory

Unit I

Production economics: Aquaculture in economic development, Production concepts in aquaculture Production function, Cost and return concepts in aquaculture, Optimization of use of single resource, Cost of production, Short run production cost, Long run cost, Production function analysis in various aquaculture system, Preparation of financial statements-Balance Sheet, Cash Flow Statement and Profit and Loss Account, Ratio Analysis and Assessing the performance of farm/firm.

Unit II

Planning and budgeting: Farm income and budget analysis, Planning and budgeting, Aquaculture management decisions, Resource, labour and financial management, Managing risks and uncertainties, Economics of different aquaculture systems, Socio economic issues, Causes for aquaculture problems, Government support policies for inland, Coastal and marine aquaculture systems.

Unit III

Value Chain Management concept: Value Chain Management concepts, Value addition in fish marketing, Constraints and approaches to VCM in fisheries sector, Domestic and external markets for fisheries products, Export – Infrastructure development from landing to marketing.

Unit IV

Value chain analysis: Post-harvest operations in inland and marine fisheries including deep sea fishing, methodological issues in marine capture fisheries, needed measures for the constraints in post-harvest operations.

VI. Practical

Estimation of cost and returns of different aquaculture systems in India; Production trends of aquaculture in India for the past 10 years and the projected production estimates; Production function analysis; Planning and budgeting; Financial analysis in aquaculture production systems; Case studies of various aquaculture systems in India; Visit to various shrimp hatcheries or farms; Visit to various finfish farms and ornamental units; Visit to various craft and gear manufacturing units; Cost and returns of marketing establishments including export processing firms

VII. Suggested Reading

- Asche F, Roll KH and Tveteras R. 2009. Economic inefficiency and environmental impact: An application to aquaculture production. *Journal of Environmental Economics and Management*, *58*(1), pp.93-105.
- Battese GE. 1992. Frontier production functions and technical efficiency: a survey of empirical applications in agricultural economics*Agricultural economics*, *7*(3-4), pp.185-208.
- CIBA – Central Institute of Brackish water Aquaculture – www.ciba.res.in
- CIFRI – Central Inland Fisheries Research Institute – www.cifri.ernet.in
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- Engle, Carole R et *al*. 2017. "Economics of sustainable intensification of aquaculture: evidence from shrimp farms in Vietnam and Thailand." *Journal of the World Aquaculture society*48(2), 227-239.
- Hatch U and Tai CF. 1997. A survey of aquaculture production economics and management. *Aquaculture Economics & Management*, *1*(1-2), pp.13-27.

- Jolly CM & Clonts HA. 1993. *Economics of aquaculture*. CRC Press.
- Knapp G & Rubino MC. 2016. The political economics of marine aquaculture in the United States. *Reviews in Fisheries Science & Aquaculture*, *24*(3), 213-229.
- Ngoc PTA, Meuwissen MP, Cong Tru L, Bosma RH, Verreth J & Lansink AO. 2016. Economic feasibility of recirculating aquaculture systems in pangasius farming. *Aquaculture Economics & Management*, *20*(2), 185-200.
- Ìlayide SÌ and Heady EO. 1982. *Introduction to agricultural production economics*. Ibadan University Press, University of Ibadan.
- Shang YC. 1990. *Aquaculture economic analysis: an introduction*. World Aquaculture Society.
- Subba Reddy S and Raghu Ram P. 1996. *Agricultural finance and management*. Oxford & IBH Pub. Co.

I. Course Title : Fisheries Development Planning and Policy

II. Course Code : FEC 512

III. Credit Hours : 2+0

IV. Aim of the course

To understand fisheries policy of different states and plans for development

V. Theory

Unit I

Planning: Planning Commission era, Organisation, role and functions, Planning in India, Objectives, Strategy, Allocation, Achievements and Bottlenecks, Types of planning, Stages in planning process, Planning models. Impact of development plans, International co-operation programmes, NITI AYOG; Planning under NITI AYOG; Planning and development in China and Russia; Planning and Free Market economies.

Unit II

Fisheries development schemes and policies: Fisheries Development and policy under the plans, Fisheries schemes; NFDB; NABARD schemes, State and center sector schemes and centrally sponsored schemes, Central Department of Fisheries; Agriculture policies, Need for a separate fishery policy, National Marine Fisheries Policy; Leasing policies for inland and brackish water bodies in different states, National Mariculture Policy; National Inland Fisheries and Aquaculture policy, Inputs Policy, Financing and Credit Policy, marketing and pricing policy, Export -Import Policy.

Unit III

Importance of fisheries in rural and economic development: Importance of Fisheries in rural and economic development, Centre and state level policies for fisheries, Fisheries policy issues, Fisheries sector strategy, Various resource policies, Fisheries policy and Legislation, Development of Fisheries during the Five-Year Plans, Fisheries credit and marketing policies.

Unit IV

Planning and cooperation: Fisheries planning, Economic factors influencing development and co-operation in fisheries, Fisheries management, Role of fisheries in rural development and Policy initiatives, Economic planning in fisheries, Problems of development Planning, Fishing policies and economic growth, Panning and policy analysis, Fisheries project planning.

Unit V

Fisheries legislation: Fisheries legislation in India, background, Indian Fisheries Act of 1897 and Subsequent amendments; Marine capture fisheries, Comparative study of Marine Fishery Regulation, Acts of coastal Indian States – licensing/ registration of vessels and mechanization, Declaration of closed season, Protection of endangered species, Prohibition of destructive fishing methods, Regulation of mesh size, Filing of return on fish catch and income, Features of MPEDA Act and Rules, 1972.

Unit VI

Legislative policies: Guidelines for operation of Indian deep sea fishing vessels in Indian EEZ, Maritime Zone of India (regulation of fishing by foreign vessels) Act 1981, Aquatic exotics and quarantine regulations, Marine Fisheries Policy, 2004. Coastal Aquaculture authority; Aquaculture Guidelines under CRZ notification of 1991 and its Amendments, Land leasing policies, Regulations on use of chemicals and antibiotics, Features of Central/state legislative provisions of Environmental, Wildlife, Water, Biodiversity: (riverine, reservoir and aquaculture), Processing in different States.

VI. Suggested Reading

- Bailey C and Jentoft S. 1990. *Hard Choices in Fisheries Development*. Marine policy, 14(4), pp.333-344.
- Chakaravathi RM. 1986. *Under Development and Choices in Agriculture*. Heritage Publ., New Delhi.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- Dewett KK. 2002. *Modern Economic Theory*. S. Chand & Co.
- Diana Tussie and David Glover. 2000. *The Developing Countries in World Trade- Policies and Bargaining Strategies*, Lynne Rienner/ IDRC, Washington.
- Dutta and Sundaram Indian economy
- FAO – Food and Agriculture Organization –www.fao.org
- Gillis M, Perkins DH, Roemer M and Snodgrass DR. 1992. *Economics of Development* (No. Ed. 3). WW Norton & Company, Inc.
- Green D and Griffith M. 2002. *Dumping on the Poor: The Common Agricultural Policy*, the WTO and International Development, CAFOD, London.
- HL Ahuja *Indian Economy*
- Higgins Benjamin. *Economic Development, Problems, Principles and Policies*. Universal Book Stall, New Delhi.
- Holden M and Garrod D. 1996. *The Common Fisheries Policy: Origin, Evaluation and Future* (No. Ed. 2). Fishing News Books Ltd.
- James D Gaisford & William A Kerr 2001. *Economic Analysis for International Trade Negotiations*, John Wiley and Sons.
- Kindleberger, Charles P. *Economic Development*. McGraw-Hill, New Delhi.
- ML Jhingan *Economics of Development and Planning*
- Meier, Gerald M. *Leading Issue in Economic Development*. Oxford University Press,Delhi.
- Michael L Weber. 2001. *From Abundance to Scarcity: A History of U.S. Marine Fisheries Policy*, Island Press, New York.
- MPEDA – Marine Products Export Development-www.mpeda.org.in
- NFDB- National Fisheries Development Board – nfdb.gov.in
- Panayotou T. 1982. *Management Concepts for Small-Scale Fisheries: Economic and Social Aspects* (p. 53). Rome: FAO.
- Runge CF. 1986. *Common Property and Collective Action in Economic Development*. World Development, 14(5), pp.623-635.
- Soley N. 1999. *Development Planning: a Perspective for the Fisheries Sector*. Centre for the

Economics and Management of Aquatic Resources, University of Portsmouth.
- Soumyen Sikder. 2001. *Contemporary Issues in Globalisation- an Introduction to Theory and Policy in India*, OUP, New Delhi
- Todaro Machael P. *Economic Development in the Third World*. Orient Longman, NewDelhi

I. Course Title : Fisheries Project Management
II. Course Code : FEC 513
III. Credit Hours : 1+1

IV. Aim of the course

To highlight the different institutions financing fisheries projects

V. Theory

Unit I

Finance and management: Sources of long term finance and cost of capital; Concepts of components of working capital, Managing working capital, Cash management, dividend decision; Capital budgeting, Appraisal criteria.

Unit II

Financing system in India: Financing system in India, Money and capital markets, national, Regional and global financial institutions; Insurance; Risk management; Micro-credit.

Unit III

Project formulation: Elements of project cycle, Identification, Preparation, Appraisal, Financing and implementation of projects, Project Appraisal techniques, Undiscounted measures, Ranking by inspection, Pay-back period, Average annual proceeds per unit of outlay, Time value of money.

Unit IV

Project Evaluation: Identification, Preparation, Appraisal, Financing and Implementation of projects, Project Appraisal technique, Undiscounted Measures, Time value of money, Use of discounted measures, B-C ratio, NPV and IRR, Agreements, Supervision, Monitoring and Evaluation phases in appraising fisheries investment projects, Net worth Techniques–PERT and CPM.

VI. Practical

Rural Lending Programmes of Commercial Banks, Lead Bank Scheme; Insight on District Credit Plan; Preparation of financial statements using farm/firm level data; Farm credit appraisal techniques and farm financial analysis through financial statements; Different case studies on fisheries cooperative societies in India; Visit to marine and inland cooperatives to analyse performance; Practical and Case studies: Ratio analysis, valuation of project inventories; Project appraisal techniques–undiscounted and discounted measures.

VI. Suggested Reading

- Chodhury, *Project Management* Tata McGraw Hill Publishing Company Ltd., New Delhi
- Dhubashi PR. 1986. *Policy and Performance - Agricultural and Rural Development in Post Independent India*. Sage Publ.
- FAO Technical Paper No.334, *Fisheries Project Formulation*, FAO, Roam.
- Gittinger JP. 1982. *Economic Analysis of Agricultural Projects***.** The Johns Hopkins Univ. Press. Gupta SC. 1987. *Development Banking for Rural Development.* Deep & Deep Publ.

- Gittinger J Price. *Economic Analysis of Agricultural Projects*, EDI Series in Economic Development, John Hopkins University Press, Baltimore and London
- Little IMD & Mirlees JA. 1974. *Project Appraisal and Planning for Developing Countries.* Oxford & IBH Publ.
- Muniraj R. 1987. *Farm Finance for Development*. Oxford & IBH Publication.
- Shang YC. *Aquaculture Economic Analysis – An Introduction*, The World of Aquaculture Society Ltd.
- Twiner and Simister (ed.). *Project Management*, Infinity Books, New Delhi.

Course Title with Credit Load
Ph.D. in Fisheries Economics

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FEC 601	Fisheries Production and Sustainability	1+1
FEC 602	Applied Econometrics	2+1
FEC 604	Fishery Resource Evaluation and Governance	1+1
FEC 605	Institutional and Legal Environment for Fish Business	2+0
FST 601	Advanced Statistical Methods	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a student's major subject)	
FEC 603	Economics of Development and Planning	2+0
FEC 606	Indian Fisheries Trade and International Scenario	1+1
FST 602	Software for Fisheries Data Analysis and Management	0+2
	Supporting courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Total Course Work Credits	**23 Credits**
	Seminar	**2 Credits**
FEC 691	Seminar-I	0+1
FEC 692	Seminar-II	0+1
	Ph.D. Research	**75 Credits**
FEC 699	Doctoral Research (Semester II)	0+15
FEC 699	Doctoral Research (Semester III)	0+15
FEC 699	Doctoral Research (Semester IV)	0+15
FEC 699	Doctoral Research (Semester V)	0+15
FEC 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fisheries Economics

I. Course Title : Fisheries Production and Sustainability

II. Course Code : FEC 601

III. Credit Hours : 1+1

IV. Aim of the course

To impart skill of fish production and sustainability in the different culture systems

V. Theory

Unit I

Introduction: Fishery resources of India, Capture and culture fisheries- Status and prospects, Production function in culture and capture fisheries of India- Inland fisheries in India, Marine fisheries in India, Mariculture, Present status and future potential.

Unit II

Production economics: Fish catch and fishing effort, Catch per unit effort, Fishing costs and returns, Estimation of economics of fisheries, Dynamic economic models of fishing, Sustainable yield, Sustainable yield curves, Open access equilibrium, Maximum economic yield, Maximum sustainable yield, Change in open access equilibrium yield, Free and open access equilibrium, Total revenue, costs and sustainable yield with respect to effort.

Unit III

Fisheries management: Fisheries Management Theories, Objectives and techniques of fisheries management, Criteria for fisheries management, Need for management, Implementation of management Measures.

Unit IV

Fisheries regulations: Objectives of fisheries regulation, Need and types of regulation in Indian Fisheries, Overfishing- Problems of overfishing, Reasons for overfishing, Measures adopted to minimize overfishing.

VI. Practical

Production status of fishery resources in India; Analysis in the production of marine fisheries in India; Analysis in the production of maritime states in east coast of India; Analysis in the production of maritime states in west coast of India; Analysis in the production of inland fisheries in India; Analysis in the production of inland states in India; Catch and effort surveys; Estimation of cost and returns of different capture fisheries methods; Estimation of cost and returns of different culture fisheries methods; Case studies on various sectors of fisheries.

VII. Suggested Reading

- Charles AT. 2008. *Sustainable Fishery Systems*. John Wiley & Sons.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in

- Evenson RE and Pingali P. 2010. *Handbook of Agricultural Economics*, vol. 4. Amsterdam, London: Elsevier
- FAO – Food and Agriculture Organization – www.fao.org
- Johl SS. 2007. *Fundamentals of Farm Business Management*. New Delhi: Kalyani Publishers
- Munro GR and Scott AD. 1985. *The economics of fisheries management*. In Handbook of natural resource and energy economics (Vol. 2, pp. 623-676). Elsevier.
- Pearce D, Barbier E and Markandya A. 2013. *Sustainable Development: Economics and Environment in the Third World*. Routledge.
- Schaefer MB. 1957. *Some Considerations of Population Dynamics and Economics in Relation to the Management of the Commercial Marine Fisheries*. Journal of the Fisheries Board of Canada, 14(5), pp.669-681.
- Sutinen JG and Andersen P. 1985. The economics of fisheries law enforcement. *Land Economics*, 61(4), pp.387-397.
- WWF- World Wide Fund for nature - htpps: //www.worldwildlife.org

I. Course Title : Applied Econometrics

II. Course Code : FEC 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge of advanced econometric tools for better understanding of economic problems.

V. Theory

Unit I

Model specifications: Econometric model specification criteria, Specification errors, Measurement errors of dependent and explanatory variables, Different model specification criteria.

Unit II

Instrumental variables: Review of classical regression model, Hypothesis testing, Estimation subject to linear restriction, Mixed estimation, Use of instrumental variables in regression analysis.

Unit III

Qualitative regression tools: Use of Dummy variables, Models for qualitative dependent variable-LPM, Multinomial logit models.

Unit IV

Simultaneous equations: Simultaneous equation systems; Basic rationale, identification problems, Single equation methods of estimation, Indirect least squares, Two stage least squares and K-class estimators, Limited information maximum likelihood, Three-stage least squares and Full information maximum likelihood; Relative merits of these methods and their small and large sample properties, SURE estimates.

Unit V

Time series analysis: Introduction to time series analysis, Trend, cycle and seasonality, Time series models, Basic ideas in fitting non-linear regression models.

Unit VI

Time series modelling: Distributed lag models, Analysis of economic time series, Stationarity and unit root test, ARIMA, ARCH group of models and co-integration, Neural Network Models, Pooling of cross-section and time series data.

VI. Practical

Estimation of multiple regression model; Estimation of LPM; Logit and Probit models – comparing two regressions; Chow test - Indirect least squares 2SLS, SURE, 3SLS; Estimation of simultaneous equation models; unit root tests for stationarity, fitting of ARIMA and ARCH group of models; Co integration. Model selection; Hands on using econometric packages like SPSS and SAS.

VII. Suggested Reading

- Greene WH. 2002. *Econometric Analysis*. Pearson Edu.
- Gujarati, Damodar, *Econometrics*, McGraw Hill, latest edition
- http://www.oswego.edu/
- http://www.tiesindia.net/
- https://guides.lib.monash.edu/econometrics
- https://www.amstat.org/
- https://www.oecd.org
- https://www.rss.org.uk
- Johnston, J. and Dinardo, J. 2000. *Econometric Methods*. McGraw-Hill.
- Maddala, G.S. 2002. *Econometrics*. McGraw Hill.
- Spyros Makidakis, Steven Wheelwright and Hyndman, Wiley *Forecasting Methods and Applications*.

I. Course Title : Economics of Development and Planning

II. Course Code : FEC 603

III. Credit Hours : 2+0

IV. Aim of the course

To provide orientation to the concepts and measures of economic development and planning.

V. Theory

Unit I

Economic development and growth: Development Economics, Scope and Importance, Economic development and economic growth, Divergence in concept and approach, Theories of development; Indicators and Measurement of Economic Development – GNP as a measure of economic growth – Green GNP, Criteria for under development, Obstacles to economic development, Economic and Non-Economic factors of economic growth.

Unit II

Theories of development: Role of fisheries in economic development, Characteristics of developing and developed economies; Theories of development; Role of economic, Technological, Social, Cultural, Political and Environmental factors; Interdependence between fisheries and industrial development.

Unit III

Growth models: Growth models – Harrod - Domar, Neo-classical, Von Neumann; Development strategies in India; Five-year plans and fisheries, Growth analysis, Determinants of growth and their measurements.

Unit IV

Planning: Planning models, Features of planning in capitalist, Socialist, Neosocialist and Mixed economies; Types of planning, micro level, Regional, Sectoral, Agro eco regional development.

Unit V

Institutions and policies: Role of Non-Government Organizations (NGOs) and Self-Help Groups (SHGs) in agriculture and fisheries development; Characterizing fisheries growth, Changes in fishing and farming pattern, Decomposition analysis and sources of output growth; Transfer of technology, Constraints to technology adoption, Yield gap analysis and research planning; Fisheries information system, Fisheries policy analysis and reforms.

Unit VI

Food and nutritional security: Concepts of food and nutritional security, Production oriented policies, Food price policies, Food subsidies, Food safety and Food quality, Measurement of poverty, Poverty alleviation programmes.

VI. Practical

VII. Suggested Reading

- Chakaravathi RM. 1986. *Under Development and Choices in Agriculture*. Heritage Publ., New Delhi.
- Dewett KK. 2002. *Modern Economic Theory*. S. Chand & Co.
- Dutta and Sundaram. *Indian Economy*
- HL Ahuja. *Indian Economy*
- ML Jhingan. *Economics of Development and Planning*

I. Course Title : Fishery Resource Evaluation and Governance

II. Course Code : FEC 604

III. Credit Hours : 1+1

IV. Aim of the course

The students will be exposed to economic evaluation techniques in the realm of resource governance in fisheries.

V. Theory

Unit I

Ecosystem valuation: Present status of Natural environmental ecosystems in India Economic Tools Markets for the Environment, Valuing the natural ecosystems in fisheries, Cost-Benefit analysis and Environmental risk, Problems in natural Fishery Resources management, Misuse of natural resources, Accountability and transparency.

Unit II

Environmental policies and tools: A History of Environmental 'Regulation, Environment, Security, Violence: The Malthusian Legacy, Problems of "Regulating" Nature, Introduction to Policy Analysis; A policy tool approach. Property Rights and Common Property Management, Payments for environmental services.

Unit III

International Environmental Agreements: Evolution in Environmental

Governance, Governance Strategies, Governance Tools, Analytical issues in assessing participation and devolution, Participatory approaches in natural resource management and policy.

Unit IV

Environmental Impact assessment: Concept and principles of EIA; Methodologies for EIA in fisheries and aquaculture sector; Institutional (International/National/Stale/Local) arrangements and strategies for estimation, Amelioration and compensation for impacts; Aquaculture Authority Bill and AAI, Environment related conflicts and dispute resolution; Coasian theorem and stakeholder decision making process.

VI. Practical

Environmental Policy Analysis; Developing Criteria for Evaluating Environmental Policies; Frameworks for environmental governance analysis; Common Property and Community-Based Resource Management; Case studies on environmental economics of shrimp farming (intensive/semi-intensive/extensive) and poly culture farms; Application of Extended Domestic Resource; Cost Ratio and Policy Analysis Matrix for aquaculture; Case studies on the sustainability of various capture fishery systems; Exercise on global warming and fisheries development concepts in valuing environment; Productivity change method, substitute cost method, Hedonic price method, Travel cost method, Contingent valuation methods.

VII. Suggested Reading

- Donald Kettl. *Introduction: Environmental Governance: A Report on the Next Generation of Environmental Policy*, Brookings Institute 2001.
- E.Ostrom. 2000. *Private and Common Property Rights*, http://allserv.rug.ac.be/~gdegeest/2000book.pdf (pp. 332-352)
- Forsyth T. 2009. *Democratizing Environmental Expertise About Forests and Climate*. In Kütting, G and Lupshutz (eds) *Environmental Governance: Power and Knowledge in a Local-Global World*. Routledge: London and NY. Pp170-185.
- Lemos MC and A Agrawal. 2006. Environmental Governance. *Annual Review of Environmental Resources*, 31: 297-325.
- Paluso NL. 2004. *Coercing Conservation*. In Conka, K & Dabelko, G.D. Green Planet Blues: *Environmental Politics from Stockholm to Johannesburg*. Westview Press. Third Edition. Pp 346-357
- Pretty and Ward. Social Capital and the Environment. *World Development* (29) 2: 209-229
- Cortner HJ and MA Moote. 1999. *Collaborative Stewardship in Action: Building a Civic Society*. *The Politics of Ecosystem Management*. Washington, D.C.: Island Press.
- Ridley M and B Low. 1993. "Can Selfishness Save the Environment" *The Atlantic Monthly* 272 (3): 76-86.
- Scott JC. 1998. *Nature and Space*. In Scott, J.C.: Seeing like a State. New Haven, Yale University Press, pp. 11-52.
- Vatn AE, Krogh F, Gundersen and P Vedeld. 2002. Environmental Taxes and Politics - The Dispute over Nitrogen taxes in Agriculture. *European Environment*, 12: 224-240.
- Vedung E. 1998. *Policy Instruments: Typologies and Theories*. In Bemelmans-Videc, ML RC Rist and E. Vedung (eds) Carrots, Sticks and Sermons. *Policy Instruments and their Evaluation*. New Brunswick, Transaction Publishers, pp. 28-53.

I. Course Title : Institutional and Legal Environment for Fish Business

II. Course Code : FEC 605

III. Credit Hours : 2+0

IV. Aim of the course

To provide an insight into the legal and institutional aspects that impact the efficiency and performance of fish business organizations.

V. Theory

Unit I

Legal system and business: The Indian legal system an overview, The Indian Contract Act (1872); Meaning, nature, and scope; Types of contracts; Essentials of a valid contract, Offer and acceptance, capacity to contract, Free consent, Performance of contract, Issues in international business transactions; International Sale of Goods, The Sales Contract, Letters of Credit, Foreign Direct Investment, Protection of intellectual property, Dispute Resolution.

Unit II

Acts and laws: Companies Act (1956); Incorporation, Commencement of business, types of companies, Management, Winding up of companies; Negotiable Instruments Act, Factory Act, Labour laws, Industrial dispute Act.

Unit III

Management systems for food quality and safety: Management systems for food quality and safety; Regulatory provisions and acts; Essential Commodities Act, APMC Act, Consumer Protection Act, RTI Act, MRTP Act, Regulations related to food safety, Hygiene and quality; National FPO (1955).

Unit IV

Acts and laws for food quality and safety: Food Safety and Standards Act (2006), and other Acts related to fish, fruits, meat, milk, grading and standardization (AGMARK) and international (sanitary and phyto-sanitary requirements, Codex, ISO, HACCP, Good Manufacturing Practices (GMP) and Good Agricultural Practices (GAP)) (BMPs in Aquaculture and Fisheries).

Unit V

Institutional environment: Role of institutions in fish business; Ministry of Food Processing Industries, Ministry of Food and Consumer Affairs, Product Boards, Export Promotion Council, Food Safety and Standards Authority, India, etc. International institutions facilitating fish business, Provisions related to FDI in agriculture and food production and distribution.

Unit VI

Corporate social responsibility: Nature and importance of ethics and moral standards; Corporations and social responsibilities, Scope and Purpose of business ethics; Ethics in business functional areas; Industrial espionage; Solving ethical problems; governance mechanism.

VI. Suggested Reading

- Bare Acts: Indian Contract Act. 1972. *The Sale of Goods Act* 1930. Essential Commodities Act, 1955, Consumer protection Act, 1986. The companies Act, 1956.
- Chow, Daniel CK and Schoenbaum TJ. 2005. *International Business Transactions: Problems,*

Cases and Material. Aspen Publishers Gulshan, S.S. and Kapoor, G.K. 2003. *Business Law including Company Law.* 10thed. New Age Publications.

- http://www.fao.org
- https://www.fisheries.noaa.gov
- https://www.iied.org
- https://www.wto.org
- Kapoor ND. 2005. *Business Law*. S. Chand & Sons. Tulsain PC. 2006. *Business Law*. Tata McGraw Hill.
- Tuteja SK. 2005. *Business Law for Managers*. S. Chand & Sons.

I. Course Title : Indian Fisheries Trade and International Scenario

II. Course Code : FEC 606

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the student with the evolution, growth and performance of Indian fisheries trade in international context.

V. Theory

Unit I

Evolution of Indian fisheries industry: Growth and evolution of Indian fisheries industry; Size, Organisation, structure, Export promotion measures in India, Duty draw back, Deemed exports –ASIDE-MDA-MAI-EPGC, Innovations and productivity in Indian fisheries industry.

Unit II

Trade theories and policies: International trade; Nature of international trade, Theories of international trade, Modern theories of international trade.

Unit III

Concepts of terms of trade: Free trade, Protection, Tariffs, Quantitative restrictions and other non-tariff measures, Globalisation and changing facets of global and Indian fisheries industry.

Unit IV

Institutional frame work: Growth of global fisheries industry, Fresh, Frozen, Cured, Canned and other types, Fisheries industry in US, Japan, European Union, Australia, Asian and African countries, Institutional frame work in India for foreign trade, Internalization of Indian fisheries trade.

VI. Practical

Pattern and Performance of India's Seafood Exports; Export Composition and destination of Indian seafood products; Product and market diversification; Competitiveness of Indian fish and fish products; Exports of value added seafood products; Case studies on non-tariff barriers in fisheries trade; Case studies on dumping and anti-dumping measures in seafood trade; Studies on world shrimp, tuna and cephalopod industries; Analysis of International price trends and volatility; WTO and trade dispute settlement.

VII. Suggested Reading

- Appleyard DR & Field AJ. 2001. *International Economics*. 4th Ed.
- FAO. Fisheries Statistics. Rome (Various years).

- FAO. Globefish Commodity Updates. Rome (Various years).
- Francis C. 2008. *International Economics*. Tata McGraw Hill.
- Henry Thompson. 2010. *International Economics*. World Scientific Publishing Co,Pte.Ltd
- Jain Khushpat S. 2012. *Export Import Procedures and Documentation*. Himalaya Publishing House
- Krugman PR & Obstfeld M. 1991. *International Economics: Theory and Policy*. Harper Collins Publ.
- McGraw Hill.Dennis A. 2001. *Trade Theory and Practice*. Irwin Publ.
- Ministry of Agriculture. *Handbook of Fisheries Statistics*. New Delhi (Various years).
- Mithani JP.1998. *International Economics*. Tata McGraw Hill.
- Oscar JB. 1999. *Export Competitiveness in South-East Asia: Policy Initiatives and Corporate Actions in Marine Products Industry*. Wheeler Publ.
- Porter G. 1998. *Fisheries Subsidies* – Over fishing and Trade. Geneva.

List of suggested Journals

- *Agricultural Economics*
- *Agricultural Economics Research Review*
- *American Journal of Agricultural Economics*
- *Applied Economic Perspectives and Policy (Review of Agricultural Economics)*
- *Aquaculture Economics and Management*
- *Arthshastra: Indian Journal of Economics & Research*
- *Asian Journal of Agricultural Extension, Economics & Sociology*
- *Australian Journal of Agricultural and Resource Economics*
- *Canadian Journal of Agricultural Economics*
- *Ecological Economics*
- *Economic Affairs*
- *Economic Systems*
- *Economic and Political Weekly*
- *Economics-The Open Access Open-Assessment E-Journal*
- *Environment and Development Economics*
- *European Review of Agricultural Economics*
- *Forest Policy and Economics*
- *Indian Journal of Agricultural Economics*
- *Indian Journal of Agricultural Marketing*
- *Indian Journal of Economics and Development (Indian Journal of Industrial Economics and Development)*
- *International Journal of Economics, Commerce and Business Management*
- *International Journal of Economics, Commerce and Research*
- *International Research Journal of Agricultural Economics and Statistics*
- *Journal of Agricultural Economics*
- *Journal of Agricultural and Food Economics*
- *Journal of Economics*
- *Journal of Economics, Management and Trade (British Journal of Economics, Management and Trade)*
- *Journal of Fisheries Economics and Development*
- *Journal of Global Economics, Management and Business Research*
- *Maharashtra Journal of Agricultural Economics*
- *Shanlax International Journal of Economics*

List of suggested e-Resources

- Fisheries economics and policy related publication and tools including resilience- http://www.ifpri.org/publications?keyword=Fisheries+economics & ss_search_author=& sm_content_subtype_to_terms=All & sort_by=ds_year &f%5B0%5D=sm_research%3Anode%3A9838
- OECD Data for fisheries production statistics - https://data.oecd.org/fish/fish-landings.htm

- World bank: climate change, macroeconomics, competiveness, trade, poverty, gender, income inequality - https://www.worldbank.org/en/topic
- PROFISH- marine fisheries, aquaculture and climate changehttps://www.worldbank.org/en/topic/environment/brief/global-program-on-fisheries-profish
- Fisheries economics and policy; ecosystem valuation; cost benefit analysis; and conservation of ecosystem - https://www.youtube.com/channel/UCSUx8XzYbinaF0whJYXHU8Q
- Fisheries statistics details state wise - https://data.gov.in/sector/fishery
- Fisheries Economics related publications -http://www.seaaroundus.org/articles/
- National agricultural marketing related schemes - http://sfacindia.com/Nam.aspx
- National Marketing - https://enam.gov.in/web/
- Entrepreneurship, Gender and Climate change - https://www.worldfishcenter.org/publications-resources
- Policies, Institutions, and Markets - https://www.cgiar.org/research/program-platform/policies-institutions-and-markets/
- Climate Change, Agriculture and Food Security - https://www.cgiar.org/research/program-platform/climate-change-agriculture-and-food-security/
- Fisheries Economics related Indian Publications - http://eprints.cmfri.org.in/view/subjects/economics.html
- Fish Marketing - http://eprints.cmfri.org.in/view/subjects/Sub26.html
- Theses including fisheries economics - http://eprints.cmfri.org.in/view/subjects/theses.html
- FAOSTAT http://www.fao.org/faostat/en/#home
- Indiastathttps://www.indiastat.com/
- Marine Products Export Development Authority (MPEDA) https://mpeda.gov.in/MPEDA/#
- Ministry of Statistics and Programme Implementation http://mospi.nic.in/sustainable-development-goalssdgs
- Economic Survey 2018-19 https://www.indiabudget.gov.in/economicsurvey/
- ICAR-NCAP http://www.ncap.res.in/#

Suggested Broad Areas for Master's and Doctoral Research

- Profitability and comparative performance of different aquaculture systems
- Investment pattern and capital flow in fisheries sector over the years
- Price spread/consumer surplus, and marketing efficiency of different marketing channels in fisheries marketing
- Opportunities and challenges for organised fish retail markets
- Impact of mechanization/modernization in coastal fisheries on productivity, sustainability and livelihood
- Cost benefit analysis of different aquaculture production systems
- Cost benefit analysis of advanced aquaculture production systems like RAS
- Capital formation and fisheries development in different plans
- Social and ecological impact of coastal aquaculture
- Conservation economics
- Social and ecological benefit of waste water based aquaculture systems
- Preparation of model commercial project proposals
- Economic and financial analysis of fisheries project proposals
- Export performance and potential of fish and fish products
- WTO and its implications on the fisheries trade
- Forecasting of the structure and pattern of Indian seafood trade
- Export competitiveness of Indian fish and fish products
- Status and performance of fisheries co-operatives in marine and inland fisheries sector
- Financial appraisal of the different co-operatives
- Estimation of credit requirement of Indian fishing community
- Economic evaluation of the fisheries cooperatives -case studies
- Contribution of agriculture and fisheries to Indian economy over the years
- Capital formation In Indian Agriculture and allied sectors
- Demand and supply projections for fish and fish products

- Consumer preference and market segmentation in domestic and export markets for fish products
- Policy gaps and anomalies in Indian fisheries and aquaculture
- Science and politics of monsoon ban in coastal fisheries
- Production constraints in different aquaculture production systems
- Yield gap analysis of the different aquaculture production systems
- Impact of trade and environment with respect to high value export oriented fisheries
- Analysing the MSY, MEY and SOY of the different marine resources
- Comparative advantage and competitiveness of Indian fish products in relation to major exporting countries
- Impact of anti-dumping and subsidies on Indian fish exports
- Comparative study of land leasing policies for fish/shrimp farming in different States
- Financial advantage of formation of exclusive ministry/council for fisheries

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fisheries Extension

Preamble
(Fisheries Extension)

Fisheries Extension is the conscious provisions of information and communication support to fishermen and fish farmers who use marine, inland and backwaters. A great scope is seen in fisheries extension in various areas of fisheries sector like aquaculture, conservation, post-harvest technologies, fishery information and forecasting, community development, etc. Marine and Inland resources are yet to be exploited fully, which requires greater attention from the fisheries extension system. The Indian coastal zone is dynamic and diverse with a great potential for feeding the increasing human population. India has a coastal line of 8129 km with encouraging and massive infrastructure facilities such as 2.4 lakh fishing crafts operating along the coast, 7 major fishing harbours, 75 minor fishing harbours and 1,537 landing centres are functioning to cater to the needs of over 14.0 million fisherfolk. However, there are several problems facing the fishing industry today. The main consensus about the fishery industry is about the over exploitation of inshore fishery which is stagnating and heavy scope to exploit the offshore and deep sea fishery resources. Secondly, the socioeconomic status of fishermen, fish farmers is still substandard. About 25% of the population live in and around the coastal zone. Keeping all these in mind, the extension needs of the fishermen and fish farmers are the most serious concern in the fishing industry. The major task for extension, thus, becomes to collect the desired information, inform and convince the people about the value of new and better technology packages, make further refinement to suit them and motivate them to adopt it and draw benefit from it. The role of fisheries extension in the development of fisheries is, therefore, immense and considering this the Government of India has created a new Department of Fisheries under the Ministry of Fisheries, Animal Husbandry and Dairying.

Fisheries extension has to play a major role in exploiting offshore and deep-sea fishery opportunities with the help of government policies. Research in various thrust areas of fisheries extension, therefore, provides planners and policy makers with information for the growth of fisheries in India. Considering the vital part of the production of fisheries, the PG degree programme in the fisheries extension is important, and indeed unavoidable.

According to the National marine fisheries policy 2020, the Fisheries extension personnel with higher education on fisheries aspects focusing on fisheries extension only fulfil the mission and objectives of this policy.The unique human resources generated from the fisheries extension would also contribute to the creation of data-based fisheries management, market-led fisheries extension and fisheries advisory services that will be different from crops and livestock.

In view of the above, the present PG degree programme in Fisheries extension has been thoroughly updated and several new courses in M.F.Sc. and Ph.D. levels have been added. In the M.F.Sc. degree programme, courses such as Global Extension Landscape, Knowledge and Innovation Systems, Monitoring, Evaluation and Impact Assessment, Aquapreneurship Promotion and Value Chain Development, Risk Management and Climate Change Adaptation and Capacity Development have been introduced taking into account of the national and global scenario. Moreover, the existing courses are also updated to a great extent.

Courses such as Extension Service System Management, Technology Commercialization and Intellectual Property Management, Policy Engagement and Extension have been added as new courses in the Ph.D. degree programme. Considering the country's existing extension needs, the existing courses are also greatly modified.

Course Title with Credit Load
M.F.Sc. in Fisheries Extension

Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FEX 501	Global Extension Landscape	2+1
FEX 502	Communication and Journalism	2+1
FEX 503	Knowledge and Innovation Systems	2+1
FEX 504	Organizational Behaviour and Development	2+1
FEX 505	ICT for Development	2+1
FEX 506	Monitoring, Evaluation and Impact Assessment	2+1
FEX 507	Aquapreneurship Promotion and Value Chain Development	1+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
FEX 508	Sociology, Psychology and Community Organisation	2+1
FEX 509	Risk Management and Climate Change Adaptation	2+1
FEX 510	Capacity Development	1+1
	Supporting Courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common Courses	**5 Credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**

Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FEX 591	Master's seminar	0+1
	Masters' Research	**30 Credits**
FEX 599	Master's Research	0+15
FEX 599	Master's Research	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fisheries Extension

I. Course Title : Global Extension Landscape
II. Course Code : FEX 501
III. Credit Hours : 2+1

IV. Aim of the course

To help the students to appreciate the process and the impact of extension reforms implemented in many countries, the new approaches that are evolving globally in different regions and the policy challenges in managing a pluralistic extension system.

V. Theory

Unit I

Basics of extension & advisory services: Genesis and Evolution of Extension; Understanding education, Extension education, Extension research and Extension service; Formal, Informal and Non-formal education; Principles and Philosophy of Extension Education; Meaning and Importance of Extension and Advisory services (EAS); Core competencies of an extension professional beyond ToT, Performing new functions to deal with new challenges.

Unit II

Extension systems and approaches: Public Extension Systems in India, Historical as well as current systems at state (DoF), national (NAREES) and international levels (WF, NACA, FAO, ICSF, WAS, AFS); Extension systems in different regions: South Asia (Bangladesh and Sri Lanka), South East Asia (Japan, China, Thailand, Indonesia and Vietnam), USA, and Europe, Extension approaches (General extension approach, commodity specialized approach, T & V approach, Participatory approach, Project approach, Farming systems approach Cost-sharing Approach, Educational institution approach); Paradigms of agricultural extension (Technology transfer, advisory work, Human resource development, Facilitation for empowerment); RRA and PRA, Participatory Learning and Action (PLA), Participatory technology development (PTD); Fisheries Co-management; ATMA; Marianad model, BENFISH, Matsyafed model.

Unit III

Extension delivery: Pluralism in Extension Delivery, Private sector (input firms, aqua-business companies, consultants); Non-Governmental Organisations (National/ international)/Civil Society Organisations (CSOs)/SHGs in providing extension; Farmer Producer Organisations - Scope, Strength and Weaknesses-experiences; Media and ICT based extension services; Managing pluralism in EAS - challenges and experiences.

Unit IV

Extension programs and institutions development: Meaning, Concept and

Major paradigms / models; Agriculture and rural Development programs; Important pre-independent extension programs; Extension/ToT programs: NES, ND, ORP, KVK, LLP, FSR & E, TAR-IVLP, NATP, NAIP, NMAET; Fisheries policies and programs: FFDA, BFDA, Blue revolution schemes; Institutions: NFDB, MPEDA-NETFISH, NaCSA, CAA, ICAR-FIs, NITIAayog, MANAGE, EEI.

Unit V

Challenges before extension and advisory services (EAS): New Challenges before farmers/fishers and extension professionals; Supporting fishers/farmers to manage the declining aquatic resources/CPRs; Gender Mainstreaming, How extension can enhance access to knowledge/resources among women & men fishers/ farmers; Nutrition- Role of extension in promoting fish as healthy food; Linking fishers/farmers to markets; Adaptation to climate changes- How extension can contribute to up-scaling climate smart fisheries/aquaculture.

Unit VI

Supporting family farms: Doubling fishers/farmers income; In and out Migration in inland and marine fisheries; Attracting and Retaining Youth in Fisheries/ Aquaculture; Fisher/Farmer distress; Facilitating access to credit, Inputs and services; Networking and partnership development including GFRAS (Global Forum for Rural Advisory Services) and its regional networks; Extension and Sustainable Development Goals (SDGs); Financing Extension; Mobilizing resources for extension; Strengthening extension policy interface, Generating evidence on impact of extension and policy relevant communication.

VI. Practical

Visits to formal, informal and non-formal educational organization and familiarizes their functional activities, Technology of transfer, advisory work, and Human resource development in fisheries programmes, ToT models of ATMA, Marianad, BENFISH, Matsyafed, etc., Public and private extension services of aqua-business companies, consultants, SHGs, KVK, NATP, NAIP, FFDA, BFDA, MPEDA-NETFISH, NaCSA, CAA, etc., Global and national ICT based fisheries extension services, Gender Mainstreaming in fisheries for poverty reduction, Climate resilient fisheries/ aquaculture, Review of national, state and regional extension networks and policies.

VII. Suggested Reading

- Adhikarya R. 1994. *Strategic Extension Campaign – A Participatory-Oriented Method of Agricultural Extension*. Food and Agriculture Organization. Agricultural Education and Extension Service.
- Human Resources, Institutions and Agrarian Reform Division. Rome: FAO.
- Alex G *et al*. 2000. *Decentralizing Agricultural Extension: Lessons and Good Practices*. Washington, DC: The World Bank.
- Antholt C & Zijp W. 1994. *Participation in Agricultural Extension*. Washington, DC: The World Bank.
- Bathrick DD. 1997. *Fostering Global Well-Being: A New Paradigm to Revitalize Agricultural and Rural Development. Food, Agriculture, and the Environment discussion paper* 26. Washington, DC: IFPRI.
- Berdegué JA & Escobar G. 2001. *Agricultural Knowledge and Information Systems and Poverty Reduction*. AKIS Discussion Paper. Washington, DC: The World Bank.
- Birner R & Anderson JR. 2007. *How to Make Agricultural Extension Demand Driven–The Case of India's Agricultural Extension Policy*. IFPRI Discussion Paper. International Food Policy Research Institute. Washington, DC: IFPRI.

- Kaimowitz D. 1991. *The Evolution of Links Between Research and Extension in Developing Countries*. In WM Rivera & D.J. Gustafson, eds. Agricultural extension: institutional evolution and forces for change. Amsterdam: Elsevier.
- Rondinelli D. 1987. *Administrative Decentralization of Agricultural and Rural Development Programs in Asia*. In W.M. Rivera & S.G. Schram, eds. Agricultural extension worldwide: issue, practices and emerging priorities; New York.
- Rondot P & Collion MH. 2001. *Agricultural Producer Organizations: Their Contribution.*
- Schuh GE. 1987. The policy environment necessary to make extension effective. In W.M. Rivera & SG. Schram, eds. Agricultural Extension Worldwide: issues, practices and emerging priorities. London & NY: Croom Helm.
- Schware R & Shibata K. 2003. *Engendering ICT: Ensuring Gender Equality in ICT for Development*. PowerPoint presentation. Washington, DC: The World Bank.

I. Course Title : Communication and Journalism
II. Course Code : FEX 502
III. Credit Hours : 2+1

IV. Aim of the course

To orient the students towards the basics, approaches and applications of communication for facilitation and development.

V. Theory

Unit I

Communication: Meaning and importance, Perspectives, Characteristics, Elements, process, Types (Individual, group and mass communication), Directions(Upward, downward and horizontal) and Levels of communication; Verbal and non-verbal communication; Message - meaning and dimensions; Message distortion types; Barriers to Communication; Noise; Key Communicator, Homophily and Heterophily, Credibility, Fidelity, Empathy and feedback in communication; Communication skills & Competence, Communication effectiveness; Theories and Models of communication.

Unit II

Media and development communication: Audio Visual aids; Classification and selection; Traditional Media and Methods for communication and development programmes; Extension teaching methods; Extension & Development Communication- concept, importance and approaches; Organizational communication; Modularized communication, Business communication-concept, methods and processes; Use of social media in communication; Media mix.

Unit III

Understanding the structure and construction of news: Language and principles of writing; Basic differences between the print, electronic and online news, Organising a news story, 5W's and 1H, Inverted pyramid Criteria for news worthiness, Principles of news selection, Use of archives, Sources of news, Use of internet.

Unit IV

Journalism: Journalism – Meaning, scope and importance, principles, theories; Development journalism – meaning, scope and importance, principles, theories; Growth of and challenges for development/ farm journalism in India.

Unit V

Facets of Journalism: Basics of Writing – News stories, Feature articles, Magazine articles, Farm bulletins and folders; Art of clear writing: Readability and comprehension testing procedures; Script development and Story board preparation; Magazine journalism - profile and feature writing; Radio and television journalism - principles and practices of gathering, writing and producing news for radio and television; Photo journalism - visual language, skills and techniques; Photography; principles and use in extension; New media journalism – websites, blogs, social media; Responsible journalism - fairness and balance, libel, and the commercial nature of the media, Constructive criticism; Advertisements – principles and practice.

Unit VI

Media role: Role in democracy, Responsibility to society, Press and democracy, Contemporary debates and various issues relating to media, Ethics in journalism.

VI. Practicals

Communication skill development and public speaking; Developing extension materials: folders, leaflets, booklets, newsletters, popular and scientific articles, blogging, etc.; News writing and success stories writing; Digital photography and image editing; video production; Visit to news channels/ printing press/fishing villages; Organization of content - choice of media, categorization of photographs, queuing of audio and video clips, logical sequencing, text entry; Identification, articulation and analysis of major issues related to fisheries; Critical analysis of fisheries related news stories and feature articles from development magazines / newspapers; Designing, editing and publishing campus newsletters; Interface with editors of journals and magazines; Critical analysis of fisheries related radio news stories; Producing radio news items for broadcast; Digital photography and image editing; Study and practice of various kinds of video editing systems; Practice and use of digital photography.

VII. Suggested Reading

- Van Den Ban AW. *Communication for Rural Innovation: Rethinking Agricultural Extension*, Blackwell Pub.
- Harry A Carey *Food & Agriculture Org., Communication in Extension: A Teaching and Learning Guide 1999*.
- Francis Xavier Moakley. *Handbook of Audio-Visual Aids*, Publisher: Harcourt Brace Jovanovich. 1973.
- RK Samanta. 1990. *Development Communication for Agriculture*. D.K. publishers. New Delhi
- KB Mathur. 1994. *Communication for Development and Social Change*. Allied Publishers Limited, New Delhi
- Lesiskar RV and Pettit JD. *Business Communication*, Tata Mc Graw- Hill 7.
- Locker, K.O. & Kaczmark. *Business Communication-Building Critical Skills*, Tata McGraw Hill
- Bond FF – *An Introduction to Journalism*, Mac-million, Company, New York.
- Wainwright David – *Journalism Made Simple*. Rupa & Heinemani, London.
- Kamat MV – *Professional Journalism*, Vikas, New Delhi.
- Wolenloy Roland – *Journalism in Modern India*, Asia Publishing, House, London.
- Aggarwal VirBala, Gupta VS. – *Handbook of Journalism & Mass Communication*, Concept Publishing Company, New Delhi.
- Ray G L. 2005. *Journalism*, Kalyani Publishers.

I. Course Title : Knowledge and Innovation Systems

II. Course Code : FEX 503

III. Credit Hours : 2+1

IV. Aim of the course

To orient the students about the various knowledge and innovation systems in fisheries

V. Theory

Unit I

Knowledge systems: Knowledge- meaning, Epistemology, Sources and types; Origins of the innovation systems concept, Innovation vs Invention; Agricultural/ Fisheries Innovation System (AIS) and AKIS; Role of different actors in AIS; Importance of interaction and knowledge flows among different farming sectors.

Unit II

Innovation systems: Innovation – definition – innovation decision process, Role of Extension in AIS, Different views to analyse AIS, Structural view, Functional view, Process view and Capacity view.

Unit III

Diffusion and adoption process: Diffusion – meaning and elements; Diffusion research and its criticism; Generation of innovations in fisheries – Innovation development process; Concept and stages of Innovation-decision process; Diffusion process, Adoption process, Models of diffusion and adoption, Adopter categories and their characteristics; Factors influencing adoption and attributes of innovations.

Unit IV

Change agents in the adoption process: Change agent – meaning, roles, factors of success; Centralized and decentralized diffusion systems; Innovation in organizations; Consequences of innovations - model and classification; Opinion leader – Meaning, Characteristics, Types, Their measurement and Role Critical mass.

Unit V

Indigenous knowledge systems: Indigenous knowledge - meaning, scope and importance, Types and systems; Indigenous vis-a-vis Scientific knowledge; Indigenous-Information, Practices and technologies; Documentation, Validation, Conservation, and Dissemination of ITK and Grassroots level innovations in fisheries; Access and use of indigenous knowledge; Peoples' Biodiversity Register; Issues in protection of traditional knowledge / ITK - understanding Indian Biological Diversity Act and National Biodiversity Authority, Limits to benefit sharing – IPR, Prior Informed Consent, TRIPS vs. CBD; Integration of Indigenous knowledge and modern technologies.

Unit VI

Enabling and scaling up innovations: Role of enabling environment; Policies and institutions in enabling innovation; Methodologies for AIS Diagnosis; Typologies of existing methodologies, strengths and limitations; Scaling Up; Definitions, Changing views on scaling up, Approaches to Scaling Up: Push, Pull, Plant, Probe; Scaling up pathways; Drivers and spaces for scaling up; Framework and Tools for

Scaling up; Planning and implementing a scaling up pathways; Scalability assessment tools; Role of policies in scaling up: Influencing policies for scaling up; Innovation Management for scaling up knowledge and implications for Extension and Advisory Services.

VI. Practicals

Documentation of ITK in fisheries; Development of Case studies of ITK in fisheries; Institutions and NGOs involved in ITK collection and validation, testing appropriateness of ITKs; Concept mapping; describing fisheries technologies; explaining case study of the diffusion process of select fisheries innovations; Identify one fisheries activity and use AIS framework to diagnose actors and their roles, patterns of interaction, institutions determining interaction and the enabling policy environment and develop an AIS Diagnosis Report (Review and Key informant interviews); Undertake a case study on a successful case of scaling up knowledge and identify factors that contributed to its success; Identify one specific knowledge (a technology, an approach) that has been recently introduced and develop an Upscaling Strategy

VII. Suggested Reading

- Rogers Everett M. 2003. *Diffusion of Innovation*, Fifth Edition. New York, NY: Free Press. ISBN 0-7432-2209-1
- Davies Stephen. 1979. *The Diffusion of Process Innovations*. Cambridge University Press. Cambridge.
- Grenier Louise. 1998. '*Working with Indigenous Knowledge*', International Development Research Centre, Canada
- Warren Michael D and others. 1995. '*The Cultural Dimension of Development: Indigenous Knowledge Systems*', Intermediate Technology Publications, London.
- Warren Michael D, vonLiebenstein GW and Slikkerveer. 1993. Networking for indigenous knowledge. *In Indigenous Knowledge and Development Monitor*. Vol. 1 (1) pp 2-4.
- JulianInglis. 1993. *Traditional Ecological Knowledge: Concepts and Cases*, published by DRC, ISBN 0889366837.
- Berkes Fikret. 2001. *Managing Small-Scale Fisheries: Alternative Directions and Methods*, IDRC, ISBN 0889369437
- Anon. 1998. *Aquatic Sciences and Fisheries Abstracts*, By United Nations Dept. of Economic and Social Affairs, Information Retrieval Limited, Cambridge Communications Corporation, v.28No.8001-10000 1998
- Robert S Pomeroy Rebecca Rivera-Guieb *Fishery Co-Management: A Practical Handbook*, published by IDRC, ISBN 1552501841

I. Course Title : Organisational Behaviour and Development

II. Course Code : FEX 504

III. Credit Hours : 2+1

IV. Aim of the course

To orient students on the importance of knowledge and skills on various management functions, as applicable to extension organizations

V. Theory

Unit I

Basics of organizational behaviour: Introduction to organizations-Concept and Characteristics of organizations; Typology of organizations; Theories of organizations; Nature of organizational theory, Classical theories, Modern management theories, System Theory, Criticisms and lessons learnt/analysis; Organization Behaviour-Concepts, Scope, Importance, Models of OB.

Unit II

Group behaviour in organization (organizational system): Foundations of group, Group behaviour and Group dynamics, Group Development and Cohesiveness, Group Performance and Decision Making, Intergroup Relations; Teams in Organisations-Team building experiential exercises, Interpersonal Communication and Group; Leadership, Meaning, types, Theories and Perspectives on Effective Leadership, Power and Influence, Leadership styles; Motivation-Concept & Theories, Managing motivation in organizations.

Unit III

Organizational conflict management: Conflict Management and Negotiation skills, Problem-solving techniques; Job analysis, Job performance and Job- stress management; Occupational stress – Meaning, sources, Effects, Coping mechanism, Effects and management; Occupational stress in farming, Farmer groups/ organizations, research and Extension organizations, Organizations Structure- Need and Types, Line & staff, functional, Committee, Project structure organizations, Centralization & decentralization; Organizational Culture vs Climate; Organizational Change; Organizational Learning and Transformation.

Unit IV

Organizational development and interventions: Organizational development-Concept and process; Meaning, Importance, Characteristics and types of Organization development, Interventions; OD consultant Types of OD consultants and their advantages, Qualifications, Comparison of traditional consultants vs. OD consultants.

Unit V

Management in organizations: Concept and principles of administration and management, Classical and modern theories, Schools of management thoughts, Functions of management – Planning, Organizing, Staffing, Directing and Leading, Controlling, Coordinating, Reporting and Budgeting; Managerial skills, Concept of HRM and methods, Job satisfaction and morale; Performance appraisal – Meaning, Concept and Methods. Authority and responsibility, Delegation and decentralization, line and staff relations; Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision; Coordination at different levels of extension management, Methods of coordination.

Unit VI

Management techniques: Management by Objectives (MBO) and Total Quality Management (TQM); Time management; Critical analysis of organizational set up of extension administration at various levels; Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organizations.

VI. Practicals

Simulated exercises on techniques of decision making / problem solving; Study the structure and function of fisheries enterprises, Designing organizational structure/ organograms; Group activity on leadership development skills, Field visit to extension organizations (MANAGE, ATARI, KVKs, ATMA, NGOs, etc.), FPOs, fisheries cooperatives to understand the functions of management, Study of organizational structure of development departments, study of departmentalization, span of control, delegation of authority, decision-making patterns; Exercise on OD interventions (Interpersonal, Team, Structural, Comprehensive) with its procedure to conduct in an organization, Case studies/ success stories on performance of SHGs in fisheries, Case Analysis of organization in terms of process – attitudes and values, motivation, leadership, Study of individual and group behaviour at work in an organization; Conflicts and their management in an organization, Documenting occupational stress in farming, farmer groups/ organizations, Exercises on stress management and time management; Exercises on team building and negotiation skill development Understanding organizational change process tools and techniques, Case analysis on organizational change process; Stakeholder analysis mapping.

VII. Suggested Reading

- Ancona, Kochaw, Scully, Van Maanen, Westney. 1999. *Organizational Behaviour and Processes*. South Western College Publ., New York. Banerjee M. 1984. Organizational Behaviour. Allied Publ.
- Deka GC. 1999. *Organizational Behaviour - A Conceptual Application Approach*. Kanishka Publ.
- Dwivedi RS. 2006. *Human Relations and Organization Behaviour- A Global Perspective*. 5th Ed. Macmillan.
- Kumar A. 2000. *Organizational Behaviour Theory and Practice*. Anmol Publ.
- Luthans F. 1998. *Organizational Behaviour*. Tata McGraw Hill.
- Luthans F. 2001. *Organizational Behaviour*. McGraw Hill. NewstromJW & Davis K. 1997. Human Behaviour at Work. Tata McGraw Hill.
- Robbins SP. 2007. *Organizational Behaviour*. Prentice Hall.
- Shaun T and Jackson T. 2003. *The Essence of Organizational Behaviour*. Practice Hall of India.
- Stephen RR. 1999. *Organizational Behaviour*. 5th Ed. Practice Hall of India.

II. Course Title : ICT for Development

I. Course Code : FEX 505

III. Credit Hours : 2+1

IV. Aim of the course

To orient students on advances in ICT initiatives, knowledge management process smart/ disruptive technologies and data analytics.

V. Theory

Unit I

ICTs - concepts, roles and initiatives: ICTs- meaning, concepts, basics of ICTs, Global and National status, Types and functions of ICTs, Meaning of e-Governance, e-learning, m-Learning, Advantages and Limitations of ICTs.

Unit II

Knowledge management: Meaning, Approaches and Tools, Role of ICTs in Agricultural Knowledge Management, e-Extension, overview on Global and national e-Extension initiatives, Inventory of e-Extension initiatives in Agriculture and allied sectors from Central and State governments, ICAR, SAUs, private sector and NGOs in India.

Unit III

ICT applications: Knowledge centres (tele centres), CSC, Digital kiosks, Web portals, Community radio, Internet radio, Kisan call centres, Mobile based applications, INCOIS-PFZ advisories; Self-learning CDs on Package of practices, Augmented Learning, Virtual Learning, social media, Market Intelligence and Information Systems-e-NAM, Agmarknet, etc. Expert System/ Decision Support System/ Management Information Systems, Farm Health Management & Intelligence System for Plant /Animal/ Soil Health, Fishery, Water, Weather, etc., National e-Governance Plan in Agriculture (NeGP-A).

Unit IV

Networks and policies: Global and regional knowledge networks, international information management systems, e-Learning platforms (MOOCS, Coursera, EduEx, etc.); Digital networks among extension personnel, Farmer Producers Organisations (FPOs) / SHGs/ Farmers Groups, Video conference, Live streaming and Webinars, types and functions of social media applications, Guidelines for preparing social media content, Engaging audience, Data- analytics and Info graphics.

Unit V

Smart technologies for extension: Open technology computing facilities, System for data analytics/ mining/ modelling/ Development of Agricultural simulations; Remote Sensing, GIS, GPS, Information Utility (AIU).

Unit VI

Disruptive technologies for extension: Disruptive technologies Analysis; Internet of Things (IoTs), Drones, Artificial intelligence (AI), Block chain technology, Social media and Big Data analytics for extension.

VI. Practical

Content and client engagement analysis
Case studies and exercises on ICT based interventions in fisheries and agriculture
Designing extension content for ICTs; Creating and designing web portals, blogs, social media pages
Development and use of online and offline e-learning modules in fisheries
Live streaming extension programmes and organizing webinars
Visit to KCC; Exercises on developing mobile based applications;
Developing social media pages for disseminating fisheries related information;
Writing for digital media
Developing video content related to fisheries
Conducting exercise on remote sensing and GIS.

VII. Suggested Reading

- August E Grant and Jennifer H. Meadows (Ed.). 2012. *Communication Technology Update and Fundamentals*, Focal Press, USA.
- Batcheloret all. 2003. *ICT for Development: Contributing to the Millennium Development Goals: Lessons Learned from Seventeen ICT Development Projects*, World Bank.
- ICTs for Development (http://ict4dblog.wordpress.com/).
- Donner J and Parikh T. (eds). 2013. ICTD2013. *Proceedings of the Sixth International Conference on Information and Communication Technologies and Development* held in Cape Town, South Africa.
- Elder L, Emdon H, Fuchs R and Petrazzini B. (eds). 2013. *Connecting ICTs to Development*, Anthem Press, London.

- NISG 2004. *ICT for Development: Make ICT Work for People* – Compilation of ICT Cases in India, NISG, Hyderabad.
- The Internet and Poverty: Opening the Black Box, http://dirsi.net/web/files/files/Opening_the_Black_Box.pdf.

I. Course Title : Monitoring, Evaluation and Impact Assessment

II. Course Code : FEX 506

III. Credit Hours : 2+1

IV. Aim of the course

To make students' understand the concepts of participatory development planning, monitoring, evaluation and impact assessment.

V. Theory

Unit I

Introduction to monitoring: Monitoring- Definition, Objectives, Tools, Methods and Approaches; Major Components of project Monitoring; Special Diagnostic studies, Project Completion report, Project sustainability, Monitoring Standards; Past quality or performance, The quality of other systems, Desired quality, Professional standards, The quality required, Planning targets and Optimal quality.

Unit II

Concept of evaluation: Meaning and concept in different contexts; Why Evaluation is Done and When? Purpose of Evaluation; Principles of Evaluation; Types of Evaluation; Objective Oriented, Management Oriented; Context Evaluation, Input evaluation, Process Evaluation, Product Evaluation, Consumer oriented evaluation, Expertise Oriented Evaluation, Adversary Oriented Evaluation, Naturalistic and Principal oriented evaluation, Goal free evaluation and meta evaluation; Process of Evaluation, Evaluation at the beginning, Evaluation during the programme, Evaluation at the end; Use of evaluation findings; Statistical Tools for evaluation; Evaluation theories, Three broad categories of theories that evaluators use in their works, Programme theory, Social science theory, and Evaluation theory (other theories/ approaches - Utilization-Focused Evaluation & Utilization-Focused Evaluation (U-FE) Checklist, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation).

Unit III

Programme planning: Steps, Analyse programme effectiveness, AAccountability; Objectives, Types, Criteria and Approaches of programme evaluation; The context of program evaluation in agricultural extension; Competency and credibility of evaluator; Integration between theory and practice of evaluation; Evaluation forums, Workshops, Conferences and Apprenticeship / internship, Ten Steps in programme evaluation; SWOT Analysis; Bar Charts (Gantt Charts and Milestone Charts); Networks, Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM); Bennett's Hierarchy of Evaluation; LFA.

Unit IV

Impact assessment indicators and approaches: Meaning, Need, Features, Benefits, Concepts; Indicators for Impact Assessment, Direct indicators, Indirect or proxy indicators, Quantitative indicators, Qualitative indicators, Result chain/

hierarchy of indicators; Methods of Impact Evaluation, Learning retention of participants (KOSA), Impact on the job performance, Impact on organizational effectiveness, Impact on stakeholder's competency.

Unit V

Impact assessment framework: Meaning of inputs, Outputs, Outcomes, Impacts and their relation with monitoring, Evaluation and impact assessment; Indicators for impact assessment – meaning and concept; Selecting impact indicators; Types of impact indicators for technology and Extension advisory services, Social and behavioural indicators, Socio-cultural indicators, Technology level indicators, Environmental impact assessment indicators and Institutional impact assessment indicators; SDGs, Yield-related Public participation models; Crisis management, Conventional participation, Participation in project-cycle, Concurrent participation, dedicated participation framework; Social auditing: concept, elements, steps, potential problems, benefits.

Unit VI

Impact assessment approaches – Quantitative, Qualitative, Participatory and Mixed methods with their advantages and disadvantages; Quantitative Impact Assessment Types – Based on Time of Assessment (Ex-ante and ex-post), Based on Research Design (Experimental, quasi experimental, Non-experimental), Econometric Impact Assessment; (Partial Budgeting Technique, Net Present Value, Benefit Cost Ratio, Internal Rate of Return, Adoption Quotient etc.), Qualitative and Participatory Impact Assessment Methods, Quantitative and qualitative techniques for impact assessment, Social impact analysis; Economic impact analysis cost, Benefit analysis, Social-cost Benefit analysis, Partial budget analysis; Environmental impact analysis; Institutional impact analysis; Sustainability analysis, Human impact assessment methods.

VI. Practical

Search the literature using web / printed resources and identify evaluation indicators for the following: Utilization-Focused Evaluation, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation, Visit to Directorate of Extension in anuniversity and enquire about extension programmes being implemented / coordinated by Directorate, Developing an evaluation proposal of any one programme using 'Ten Steps in Programme Evaluation', Field studies for identification and ranking of criteria/indicators for impact assessment, Identifying a fisheries development programmes and their objectives being implemented in your state, Strengths, Weaknesses, Opportunities and Threats related to the identified programme objectives in the SWOT grid, Visit a nearby KVKs / ATIC. Select any agriculture technology with package of practices and extension advisory services promoted by KVK / ATIC, Identifying impact assessment indicators for social and behavioural indicators, socio-cultural indicators, technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators, Exercises on evaluation of fisheries development programmes using the techniques of evaluation; Exercises on CPM and PERT.

VII. Suggested Reading

- Capturing Experience: Evaluation, Evaluation and Impact Assessment Methods, http://web.mit.edu/urbanupgrading/upgrading/resources/bibliography/Evaluati on-Impact.html
- Equality Impact Assessment, http://www.scotland.gov.uk/Resource/

- *Evaluating Development Operations: Methods for Judging Outcomes and Impacts. Operations Evaluation Department*, The World Bank. Lessons & Practice Number 10, July 1997.
- John Pearch, Peter Raynard and Simon Zadek. *Social Auditing for Small Organizations: The Workbook. New Economics*: London. 1995.
- Louisa and Mike Edwards. *Toolkits: A Practical Guide to Assessment, Monitoring*. Review and Evaluation
- *Resources on Impact Assessment*. http://www.gdrc.org/ uem/eia/define.html

I. Course Title : Aquapreneurship Promotion and Value Chain Development

II. Course Code : FEX 507

III. Credit Hours : 1+1

IV. Aim of the course

To orient students on the importance of aquapreneurship, fish Markets, supply chains and value chain analysis

V. Theory

Unit I

Basics of aquapreneurship and Facilitation for entrepreneurship development: Entrepreneurship - Concept, Significance and Scope, Theories and models; Entrepreneurship Development Cycle and process; Aquapreneurship – Meaning, Drivers, Characteristics, Importance, Types of entrepreneurs; Startups, Small businesses, Startups group/ community-based entrepreneurship; Entrepreneur and Manager; Approaches for assessing characteristics of entrepreneurs, Enterprising tendency, Entrepreneurship intention, Entrepreneurship orientation; Critical competencies required for entrepreneur in managing the businesses, Technical, communication, Financial, Human; Entrepreneurial university approach. Approaches for developing agricultural enterprises through extension and advisory services, Individual, Group and Community based approaches; Specific roles of extension agents in creating agricultural entrepreneurships; Pluralistic extension and extension agents working with other agents; Free and fee for extension services for business upgrading for farmers/farmer groups; Competencies of extension professionals for creating entrepreneurships.

Unit II

Basics of business planning, entrepreneurial ecosystem and Infrastructure requirement: Feasibility report, Business plan, Bankable project and Detailed project report – Similarities and differences; Elements of business plan, The team and its competencies, Business idea, Gaps, Opportunities and risks, Key products and services, Target market and Consumer segments, Marketing plan, Financial plan, Intellectual property and others, Meaning, Elements; Government policy support and Schemes for development of agricultural and allied enterprises (Start-up India, Make in India, Digital India, Atal Innovation Mission and others; Entrepreneurship policy and schemes at different states of India); Sources of funding for agripreneurship/ aquapreneurship, Debt and equity capital, grants and subsidies, Angel investor, Venture capitalist, Bank lending, NABARD and others; Entrepreneurial culture, Mentoring and handholding incubators.

Unit III

Infrastructure for supporting agricultural entrepreneurship – Warehouse, Cold storage and Transportation and Other support systems, Technology development system, Education and training, Human capital and workforce, Systems for assessing capacity requirement and Capacity building, Local and global markets and Regulatory framework; Policy approaches for women entrepreneurship development, Organisations promoting entrepreneurship in India; Emerging perspectives, Focus on startups and support mechanisms, Climate-smart technology businesses; Block chains for value chain management.

Unit IV

Extension and value chain: Supply chains – Meaning, Structure, Value chains – Meaning, Importance, Types; Supply chains vs value chains; Value chain development and Value Chain extension; Steps in a value chain analysis; Three dimensions of the value chain process; Participatory tools used in a value chain analysis, Focus groups, Ranking and weighting, Historical calendars, Market mapping, Evaluation of Business development services, Market visits, Learning journeys, Semi-structured interview, Structured interviews, Direct observation; Extension toolkits and Approaches for value chain development; Value chain upgrading strategies on farmer and extension agent level.

VI. Practical

Field visit to any entrepreneurship promotion agency of Govt. of India (e.g. Small farmer agribusiness consortium, EDI etc.); Business plan preparation and presentation – covers all aspects of choosing the business idea, financial estimates, market planning and others and presentation; Assessing the entrepreneurship potential of a prospective entrepreneur – enterprising tendency, entrepreneurship intention and entrepreneurship orientation scales administration and explain the processes Field visit to market support system – warehouse, cold storage unit, regulatory market etc. Field visit to Banks and Venture capitalist/ angel investors or other private investing agencies; Value chain mapping using participatory approaches. Field visit to successful aquapreneurs –startup, Farmer Producer Organization, SHG business, large business to orient themselves with different types of aquapreneurship; Field visit to technology business incubator.

VII. Suggested Reading

- N. Mukherjee. 1997. *Participatory Rural Appraisal, Methodology and Applications*, Concept Publishing Company, New Delhi.
- R Chambers, P Arnold and Thrupp. 1989. *Farmers First: Farmer Innovation and Agricultural Research*. Intermediate Technology.
- Roger L Martin & Sally Osberg. 2007. *Social Entrepreneurship: The Case for Definition, Stanford Social Innovation Review*.
- http://www.ngobiz.org/picture/File/Social%20EnterpeuneurThe%20Case%20of%20Definition.pdf

II. Course Title : Sociology, Psychology and Community Organisation

I. Course Code : FEX 508

III. Credit Hours : 2+1

IV. Aim of the course

To orient the students towards basics in sociology, psychology and cognitive processes.

V. Theory

Unit I

Overview of sociology: Basic Concepts in Sociology, Society, Understanding of basic rural institutions, Social structure, Community, Social institution, Culture, Social change, Cultural change, Social system, Social process, Social conflict, Social values, Norms, Folkways, Mores, Customs; Cultural relativism, Cultural integration, Cultural lag, Acculturation; Family, Kin and Clan – its relationship with group behaviour and rural development; Social Stratification, Class and caste system, Their impact on rural development; Social Process and Social Interaction – Concepts, types; Competition, Conflict, Cooperation Accommodation and Assimilation, and change in social process due to developmental programmes, Community Organization (CO): Meaning and Models.

Unit II

Dynamics of change: Concept, Types and importance in rural community; Typology of change, Planned, Indoctrinational, Technocratic, Coercive, Emulative, etc. Theories of social change, Immanency, Functionalism, Economic, Technological, Historical, Ideological, Evolutionary and Field Theory; Factors affecting change under rural settings; Stimulants and Barriers to change, Social Capital, Collectivism, Interdependence in larger groups, Conformity and functional analysis of roles.

Unit III

Preamble to Psychology: Psychology as a science and its importance in extension education, Perception- Nature, Selectivity & Laws, Importance of perception in extension work, Sensation vs Perception; Attitudes - Meaning, Characteristics, Assumptions, Types, Theories and Models of attitude formation; Methods of changing attitudes, Stereotypes and Prejudices, Factors in attitude change, Liking / affect – meaning, Types and theories; Attraction – meaning, Types and theories; Persuasion – Meaning, theories and techniques; Social influence and groups – Conformity, Compliance and Obedience.

Unit IV

Information processing: Meaning, Principles; Basic assumption, Models of information processing, Waugh and Norman model of primary and secondary memory; Atkinson and Shiffrin's stage model of memory; Sensory memory- Working, Short and Long term memory, Other models including blooms taxonomy and Sternberg's Information Processing Approach, Computer- mind analogy, Teaching-Learning process.

Unit V

Attention and perception: Meaning, types, Theories and models; Consciousness; Motivation, Nature, Characteristics and types of motives, Techniques of motivating farm people, Measuring motivation, TAT, Sentence completion, etc., Emotion- its nature, Types of emotional response, Theories of emotion, Self-motivation; Harnessing emotions productively, Empathy and its theories, Reading emotions, Role of emotion in regulating human behaviour, Psychosocial distress and coping mechanisms in farming situations, Personality, Individual differences and theories of personality, Multiple Intelligences- IQ, Emotional intelligence, Social intelligence, Managing emotions; Relationship between IQ and EQ, Handling relationships; Social skills, Defence mechanisms- types and importance.

Unit VI

Cognitive processes and learning: Cognitive processes, Attention, Perception, Remembering and Forgetting, Knowledge and Expertise, Ffoundations and Theories; Principles and processes of perception; Consciousness, Meaning, Types, Sleep and Dreams; Learning and Memory, meaning, Learning, Foundations, Approaches, Styles and theories; Cognitive approaches of learning – Meaning, Principles theories and models; Memory, Foundations, types; Behavioural approaches of learning, Foundations and theories, Classical conditioning, Operant conditioning, Applied behaviour analysis; Social cognitive and constructivist approaches to learning, Foundations and theories, Social cognitive theory, Self-regulated learning; Learning styles, Meaning, Types and applications in learning.

VI. Practical

Learning - Classical conditioning and operant conditioning; Assessment of emotional intelligence; Exercises in problem solving; Exercises in visual perception; Measuring self-concept using psychometric tools; Experiment on factors influencing information processing; Assessment of attitudes; Visit to a village to study rural institutions; Focus group discussions to identify stimulants and barriers to changes existing in rural community; Understanding perception - Attentional Blink and Repetition Blindness exercise; Understanding attention -Testing selective attention capacity and skills and processing speed ability through Stroop test; Hands-on experience in the techniques for assessing creative thinking – divergent and convergent thinking; Assessing learning styles through Barsch and Kolb inventories; Practical experience in building self-esteem; Hands on experience in methods of persuasion; Field experience in assessing social judgement; Simulation exercise to understand decision-making under different situations; Exercise in rational decision-making.

VII. Suggested Reading

- Coon D and Mitterer J. 2007. *Introduction to Psychology: Gateways to Mind and Behaviour* (11th Edition). Belmont, California: Thomson Wadsworth.
- Dodgen L and Rapp A. 2000. *Sociology: Looking Through the Window of the World* (3rd edition). Iowa: Kendall Hunt. (Includes basic terms in sociology.)
- Germov, John and Poole, Marilyn eds. 2010. *Public Sociology: An Introduction to Australian Society* (2nd Edition). Crows Nest, NSW: Allen & Unwin. (Please note this is a Level 3 Sociology textbook.)
- Holmes D, Hughes K and Julian R. 2012. *Australian Sociology: A Changing Society*. Pearson Australia.
- Mulcahy, Cutinelli, Warne and Woodruff. 2009. *Psyched: Psychology* for Year Ten. Sydney: Cambridge University Press.

II. Course Title : Risk Management and Climate Change Adaptation

I. Course Code : FEX 509

III. Credit Hours : 2+1

IV. Aim of the course

To equip students to identify, evaluate and evolve ways to address (mitigate and manage) risks and climate change.

V. Theory

Unit I

Understanding risk and distress: Introduction to risk, Risk management, Uncertainty, Sensitivity and Distress, General risk theory, Risk analysis methods, Risk perception and decision making, Indicators of risk and distress in agriculture, Identification, Selection and Assessment, Understanding the agrarian distress in Indian agriculture, Sources of distress in Indian farming, Changing farm size, Land use, Cropping patterns, Pricing policy, Markets and terms of trade, Typology of crisis in agriculture; Droughts, Floods and Indian agriculture, Distress and farmer suicides, Causes and socio-economic consequences

Unit II

Managing risk and distress: Ways to reducing/managing risk and distress in Indian agriculture/fisheries; Crop and life insurance; Developing support systems; Planning, Implementation and evaluation of risk/distress management programs; Institutional frameworks for risk and disaster management – NDMA & SDMAs; Developing District Agriculture Contingency Plans; Risk management by diversification; Good practices and lessons from other countries; Responses of government, Non-government and extension system to agrarian crisis; National Farmers Policy.

Unit III

Extension professionals and risk management: Understanding social-Psychological and behavioural dimensions of farmers under risk/distress; Risk perception and communication; Helping farmers manage farm level risks, Mobilising resources, Linking with markets, Strengthening capacities; Working with village level risk management committees; Operational skills for preparing contingency and disaster management plans; Institutional and extension innovations in managing risk and distress; Policy and technological preferences for dealing with drought and flood.

Unit IV

Introduction to climate change science: Basic concepts of and terms in climate change science; Impacts of climate change; Anthropogenic drivers of climate change, Climate change and Indian agriculture; Climate adaptation vs. Disaster risk reduction; Anticipated costs of adaptation; Climate change and poor; Overview of UNFCCC framework and institutions, Kyoto Protocol and beyond; India's National Action Plan on Climate Change and National Mission on Strategic Knowledge on Climate Change; National Coastal Mission, Institutional arrangements for managing climate change agenda.

Unit V

Introduction to climate change adaptation and mitigation: Introduction to Climate Change Adaptation, Conducting a vulnerability assessment (CVI and SEVI frameworks), Identifying and selecting adaptation options; Global, national and state level initiatives and plans to support climate change adaptation, Private sector and civil society initiatives and activities; Mainstreaming climate change adaptation into development planning, Financing climate adaptation and budgetary allocations for programmes, Gender and climate change adaptation, Agricultural development programmes and strategies towards climate change adaptation and mitigation, Community based and Ecosystem based adaptation strategies, Preparing evidence based intervention plans for vulnerability reduction at micro and macro-levels.

Unit VI

Climate Smart Agriculture (CSA) and extension & advisory services: Climate smart agriculture; Developing climate smart and climate resilient villages; Stakeholders and determinants involved in climate smart agriculture; Climate smart agriculture and EAS; Innovative extension approaches used in CSA; Climate information services, Farmers perceptions about climate change; Farm and household level manifestations and adaptation strategies; Barriers and limits to adaptation; Farmers feedback on performance of extension methods; Skills, competencies and tools required for extension professionals at different levels and development departments in up scaling CSA.

VI. Practical

Hands-on practice in using risk assessment/analysis tools; Case studies on risk / distress assessment in agriculture -Indian and global lessons / Experiences from NICRA Project in agriculture and allied sectors; Developing criteria, indicators and indices for assessment of risk, vulnerability and resilience; Hands on practice on use of vulnerability and risk assessment tools and techniques; Case studies on success stories of climate change adaptation and community based initiatives; Developing district and village level intervention plans for climate change adaptation; Field Visits to State Disaster Management Authority; Case studies on climate smart agriculture / villages from India and world; Case studies on impact assessment of crop insurance programs, disaster management programs; Capstone project on documenting ITKs and local practices related to reducing risk / climate resilience agriculture

VII. Suggested Reading

- Bruce James P, Egener ID and Black RA. 2011. *Adapting to Climate Change: A Guide for Ontario Municipalities* (in press).
- Bruce James P, Egener ID. Mark and Noble David. 2006. *Adapting to Climate Change: A Risk-based Guide for Ontario Municipalities*. Accessed from: http://www.nrcan.gc.ca/earthsciences/projdb/pdf/176a_e.pdf
- Health Canada. 2011. *Communicating the Health Risks of Extreme Heat Events*. Accessed from: http://www.hc-sc.gc. ca/ewh-semt/climat/index-eng.php
- ICLEI. *Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation*. Accessed from: http://www.iclei.org/index.php?id=8708
- Insurance Bureau of Canada. Municipal Risk Assessment Tool. Accessed from: http://www.ibc.ca/en/Natural_Disasters/Mu nicipal_Risk_Assessment_Tool.asp
- Insurance Bureau of Canada. 2011. Insurance in Ontario: What you need to know. Accessed from: http://www.ibc.ca/en/ Need_More_Info/documents/ Industry_Updates/ Industry_Up date_ON.pdf
- Insurance Bureau of Canada. 2011. *Municipal Storm and Sanitary Infrastructure Risk Assessment Tool Project*. Accessed from: http://www.ibc.ca/en/Natural_Disasters/do cuments/MRAT%20Leavebehind_EN_Jun3-11.pdf
- Mabey N, Gulledge J, Finel B and Silverthorne K. 2011. *Degrees of Risk: Defining a Risk Management Framework for Climate Security*. Accessed from: http://www.e3g.org
- Ontario Ministry of the Environment. 2011. *Climate Ready: Ontario's Adaptation Strategy and Action Plan*. Accessed from: http://www.ene.gov.on.ca/stdprodconsume/groups/lr/ @ene/@resources/documents/resource/stdprod_085423.pdf
- Ontario Ministry of the Environment. 2012. *Climate Ready: Ontario's Adaptation Strategy and Action Plan* (2011-2014). Presentation at Adaptation Planning in Eastern Ontario

I. Course Title : Capacity Development

II. Course Code : FEX 510

III. Credit Hours : 1+1

IV. Aim of the course

To make students' understand the concepts of training, capacity building, capacity development and human resource development in the context of roles and responsibilities of extension professionals

V. Theory

Unit I

Capacity development- an overview: Training, Capacity building, Capacity development and HRD, Meaning and differences; Training principles and Phases of training; Need and principles of Capacity development; Types and levels of capacities, Institutional capacities (include the rules, regulations and practices that set the overarching contextual environment), Organizational capacities (how various actors come together to perform given tasks), Individual capacities (technical, functional and leadership skills)

Unit II

Capacity building: Types of capacity building, Based on structure (structured, semi-structured & unstructured), Based on context (orientation, induction and refresher), and other categories (online, Webinar, distance etc.); Components of capacity development; Capacity development cycle; Approaches in Capacity Development, Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach Steps in Designing and Planning of Capacity Development- Step 1. Select the participants, Step 2. Determine the participants' needs, Step 3. Formulate goal and objectives, Step 4. Outline the content, Step 5. Develop instructional activities, Step 6. Prepare the design, Step 7. Prepare evaluation form, Step 8. Determine follow-up activities; Evaluation of training: types and techniques of training evaluation

Unit III

Capacity assessment and development methods: Concept of Need Assessment; Approaches in Need Analysis- Performance Analysis, Task Analysis, Competency Study; Needs Survey; Data Collection Methods in Identifying Needs, Rational Methods (Observation, Informal talks, Complaints, Comparison, Analysis of report, Opinion poll, Buzz session, Analysis of the new programme), Empirical Methods (Job analysis, Performance evaluation, Checklist or Questionnaire Method, Tests, Critical Incident Technique, Card Sort Method, Focus Group Discussion, Interview, SWOT Analysis); Information and Skills required in Need Analysis; Identification of Needs through Task Analysis, Task identification, Task Analysis, Gap Analysis.

Unit IV

Capacity development methods: Lecture, Discussion, Syndicate, Seminars, Conference, Symposium, Role Play, Case study, Programmed Instruction, T - group/ Laboratory methods, Brain storming; Delphi technique, Johari window; Factors Determining Selection of Methods, Capacity development objectives, Subject matter, Categories of participants, and the available resources like time, Location, Budget; Capacity Development Aids; Capacity Developer (Trainer), Meaning and concept;

Types of Capacity Developers (regular, *ad-hoc*, part time, guest and consultants); Roles of Capacity Developer (explainer, clarifier, supporter, confronter, role model, linker, motivator, translator/interpreter, change agent); Good Capacity Developer, Qualities, Skills and Roles. Human resource development; Meaning, Importance and Benefits; Types of HRD Systems & Sub-systems, Career system; Components of HRD System, Performance Appraisal, Potential Appraisal, Task System, Development System, Socialisation System, Governance; Functions of HRD-Organisational Development, Career Development, Capacity Development.

VI. Practical

Capacity development needs assessment exercise; Planning organizing and conducting an extension capacity development programme; Designing a programme; Writing learning objectives; Developing objectives into curriculum; Training plan; Organizing capacity development workshop; Evaluation with pre & post training tests; Exercise on business games, simulation exercises, in-basket exercise; Activities on programmed instruction, experiential learning techniques; Exercises on Transactional analysis and Fish bowl Technique; Preparing questionnaires using Delphi technique; Conducting brain storming and buzz sessions on topics related to fisheries; Organizing FGDs in fishing villages/institutions; Conducting SWOT analysis of any institutions or any fisheries technologies; Preparation of checklist/ questionnaires on capacity development related to fisheries department officers / fish farmers; Role plays on fisheries related problems; Conducting exercises on need assessment; Practicing facilitation techniques; Self-discovery exercises

VII. Suggested Reading

- Agochiya D. 2002. *Every Trainer's Handbook*. Sage Publ. David Gross. 1997. Human Resource Management - The Basics. TR Publ.
- Davis Keth & Newston W John 1989. *Human Behaviour at Work*. 8th Ed. McGraw-Hill.
- Hersey Paul & Balanchard H Kenneth. 1992. *Management of Organizational Behaviour Utilizing Human Resource*. 5th Ed. Prentice-Hall of Post Graduate Syllabus, Department of Agril. Extension, UBKV [10] India.
- Kalyani Publ. Rao TV. 2003. *Readings in Human Resource Development*. Oxford Publ. Co.
- Knoontz Harold & Weihhrich Heinz 1990. *Essentials of Management*. 5th Ed. McGraw-Hill.
- Lynton RP & Pareek U. 1993. *Training for Development. DB*. Taraporewale Sons & Co.
- Punna Rao P & Sudarshan Reddy M. 2001. *Human Resource Development Mechanisms for Extension Organization*.
- Silberman Mel. 1995. Active Training. Press Johnston Publ. Co., New Delhi. Singh RP. 2000. *Management of Training Programmes*. Anmol Publ.
- Subba Rao P. 2005. *Management & Organizational Behaviour*. Himalaya Publ. House.
- Sundaram RM, Gupta V, George SS. 2006. *Case Studies in Human Resource Management*. ICFAI, Hyderabad.
- Tripati & Reddy. 2004. *Principles of Management*. Tata McGraw-Hill.
- Wayne MR & Robert MN. 2005. *Human Resource Management*. International Ed. Pearson Prentice Hall.

Course Title with Credit Load
Ph.D. in Fisheries Extension

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FEX 601	Methodologies in Extension Research	2+1
FEX 602	Educational Technology and Instructional Design	2+1
FEX 603	Gender Mainstreaming and Livelihood Development	2+1
FEX 604	Extension Service System Management	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
FEX 605	Technology Commercialisation and Intellectual Property Management	2+1
FEX 606	Policy Engagement and Extension	2+1
FEX 607	Participatory Approaches in Fisheries Extension	1+1
	Supporting Courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctorial Seminar	**2 Credits**
FEX 691	Doctoral Seminar-I	0+1
FEX 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 Credits**
FEX 699	Doctoral Research (Semester II)	0+15
FEX 699	Doctoral Research (Semester III)	0+15
FEX 699	Doctoral Research (Semester IV)	0+15
FEX 699	Doctoral Research (Semester V)	0+15
FEX 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fisheries Extension

I Course Title : Methodologies in Extension Research

II. Course Code : FEX 601

III. Credit Hours : 2+1

IV. Aim of the course

To cater the need of equipping the scholars with essential skills in conducting high quality research which helps them to design working strategies, processes and models for professional development.

V. Theory

Unit I

Measurement properties of research instruments: Measurement properties: Dimensionality, Reliability and Validity; Dimensionality – Unidimensionality and multidimensionality, Methods of assessing dimensionality, Formative and reflective constructs; Validity, Importance, Internal validity - face validity; Content validity, Substantive Validity, Structural Validity; External validity, Convergent and Discriminant Validity, Known-group validity, Criterion-Related Validity, Consequential Validity, Nomological validity; Methods of assessing various forms of validities, Judges rating, Lawshe's Content Validity Ratio, Item-objective congruence index; Latent variable method; Reliability - Internal consistency reliability – Split-Half, Cronbach alpha; Temporal Stability reliability - test-retest method; Interrater Consistency and Consensus - interrater reliability and interrater agreement; Alternative Forms or parallel forms reliability – Reliability of difference - Factors Affecting the Validity and Reliability of Test Scores; Generalizability Theory.

Unit II

Errors in management: Errors – Meaning and sources; Types - Sampling error, Non-sampling or measurement error and Processing error – Meaning, causes; Effects of errors and biases on data quality; Bias in behavioural research – Meaning, causes, Types – Respondent and researcher biases; Methods of reducing errors and biases in surveys, Questionnaires, Personal interviews, Focus groups and Online methods.

Unit III

Scales, indices and tests: Approaches to measurement and scale development - Classical test theory, Formative or index models, The C–OAR–SE approach and Item Response Theory; Item analysis in Classical test theory, Item difficulty and item discrimination; Scoring performance in scales and tests, Meaning, types and methods; Scale development strategies, Deductive and empirical; Stimulus-centred scales, Method of equally appearing intervals, Paired comparison, Person scaling – Q methodology; Subject-centre scales, The Likert scale and Semantic Differential; Steps in constructing a multi-dimensional scale using confirmatory factor analysis, Response scales, Guttman'sscalogram analysis and The Rasch method.

Unit IV

Indices and tests: Indexes –Meaning, types, Importance; Similarities and differences with scales, Methods of constructing indexes; Common indexes used in extension, Measurement invariance, Meaning, types, Methods of assessing measurement invariance, Tests – meaning, types, importance; Steps in conducting various tests, knowledge test.

Unit V

Qualitative research methods and emerging approaches: Qualitative methods – Meaning; Types – Ethnography, Grounded theory, Phenomenology, Ecological psychology, Discourse Analysis; Observational research; Case study research – Sampling and sample size; Data collection methods, In-depth interviews, Focus groups, Direct observation, Record review; Content analysis; Unobtrusive Measures; Projective and semi-projective techniques; Selecting right qualitative method – Strengths and limitations of qualitative research; Analysis and interpretation of qualitative research data; Research synthesis – meaning, importance, methods; Systematic reviews and meta-analysis – meaning, steps, and applications; Policy research. Mixed methods research – meaning, purpose, types and applications; Participatory research – Meaning, importance, types, methods and tools and applications; Action research – Meaning, importance, Principles, Types, Steps in conducting action research, application in behavioural sciences. Social Network Analysis – Meaning, importance, types, steps in social network analysis, applications; Advanced methods of measuring perception and beliefs. Multi criteria decision making, analytical hierarchy approach.

Unit VI

Ethics in extension research: Research reports – Meaning, types, contents; Presentations – Meaning, types, principles of good presentation - Tell 'Em" and KISS 'Em" principles; Research publications – meaning, importance, types; Guidelines for preparing research papers - Peer review process, citation styles; Open access publishing; Publishing in social media, Software's in academic writing, Ethics in conducting behavioural research; Human subject research – Meaning, history, and ethical guidelines; Ethical aspects of collecting and using Indigenous knowledge and farmers technologies; Ethical practices in publishing; Plagiarism – meaning, sources, Identifying and correcting plagiarism in a research paper using anti-plagiarism software.

VI. Practical

Practice in developing research instruments; Methods of assessing measurement properties of research instruments - dimensionality, reliability and validity; Hands-on experience in constructing tests, scale and indexes; Practice in summated scale development using confirmatory factor analysis; Hands on experience in assessing measurement invariance; Practicing and collecting data using participatory tools and techniques, analysing and interpreting qualitative data; Hands-on experience in writing systematic review using meta-analysis; Field practice in conducting action research; Practical experience in writing research paper; Hands on exercises using software for qualitative data analysis; Practice in detecting and correcting plagiarism using software.

VII. Suggested Reading

- Burns RB. 2000. *Introduction to Research Methods*. Sage Publ. Chandrakandan K & Karthikeyan C. 2004. *Behavioural Research Methodology*. Classical Publ.
- Daivadeenam P. 2002. *Research Methodology in Extension Education*. Agro-Tech Publ. Academy.
- Kerlinger N Fred. 2002. *Foundations of Behavioural Research*. Surjeet Publ.
- Kothari CR. 2000. *Research Methodology Methods & Techniques*. 2nd Ed. Wishwa Prakasham.
- Ray GL and Mondal S. 1999. *Research Methods in Social Science and Extension Education*. Naya Prokash.
- Roger L and Domino WSK. 1980. *Research Methods*. Prentice Hall.
- Sadhu AM and Singh A. 2003 *Research Methodology in Social Science*. Himalaya Publ. House. Sarantakos S. 1998. Social Research. 2nd Ed. Macmillan.
- Sinha SC and Dhiman AK. 2002. *Research Methodology*. ESS Publ.
- Verma RK and Verma G. 2002. *Research Methodology*. Commonwealth Publ.

I. Course Title : Educational Technology and Instructional Design

II. Course Code : FEX 602

III. Credit Hours : 2+1

IV. Aim of the course

To develop knowledgeable, responsive and effective teachers committed to educating diverse group of learners in a dynamic extension landscape.

V. Theory

Unit I

The landscape of educational technology and instructional design: Understanding various terms, Educational technology, Instructional design, Instructional systems design, Curriculum design, Pedagogy, Andragogy; Brief overview of the origin and evolution of ET and ID as theory and practice; what is the relevance of ET and ID relevant in extension and rural advisory services? Extensional professionals as instructional designers and architects of the learning experience; Types of learning or learning domains, Bloom's taxonomy of the cognitive domain, Krathwohl and Bloom's affective domain and Simpson's psychomotor domain

Unit II

Technology enabled learning: What is the role of technology in education? Digital media, new tools and technology; Open and distance Learning (ODL); Online Education - Synchronous and Asynchronous learning models; eLearning, Massive Open Online Courses - SWAYAM, Open Education Resources (OERs), Course CERA, EduEx, CoL, RLOs; Digital education and its applications in higher agricultural education; Smart classrooms and Campuses, Web-based remote laboratory (WBRL); Integrating media and digital tools into ID; Types and implications of disruptive technologies for higher education and extension; Augmented learning; Adaptive learning; meaning, features and good practices in using open source Learning Management Systems (Moodle); Quality assurance and certification in e-learning.

Unit III

Theories and models of instruction: Howard Gardner's Theory of Multiple Intelligences, David Kolb's Experiential Learning Cycle, Albert Bandura's Social Learning Theory, Rand Spiro's Cognitive Flexibility Theory and its Application in eLearning, Wlodkowski's Motivational Framework for Culturally Responsive Adult Learning; ADDIE Model, Dick and Carey Model, SAM Model, Bloom's Taxonomy; Integrating the theories of instruction into the practice of ID in extension and RAS ecosystem.

Unit IV

Creating instruction and instructional strategies: Overview of planning, Designing and implementing the curricula and learning experiences; Needs Analysis - meaning, approaches and steps; Task and content analysis - meaning, approaches, steps and techniques (topic analysis, procedural analysis, and the critical incident method); Learner analysis – meaning, importance and approaches, Relevance of Maslow's Hierarchy of Needs and learning styles, Captive Audience vs. Willing Volunteers, Universal vs. user-centered design, Learner Analysis Procedures; Writing learning objectives: Meaning of Learning Goal and Learning Objectives; ABCDs of well-stated objectives; Setting goals, translating goals into objectives; Contextualising ADDIE process within the Extension learning environment; Organizing content and learning activities, scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, Programmed instruction, Synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies.

Unit V

Organizing content and learning activities: Scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, programmed instruction, synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies.

Unit VI

Trends in instructional design and evaluating instruction: Alternatives to ADDIE (Analysis, Design, Development, Implementation and Evaluation) model - Rapid prototyping and constructivist ID, Reflections on instructional design as science and as an art; Relating ID models and process in extension learning environment; Research in education and instructional design, Meaning of Assessment, Measurement and Evaluation; Developing learner evaluations and their reliability & validity; Assessment techniques for measuring change in knowledge, Skill and attitude of learners, Objective Test Items, Constructed-Response Tests, Direct Testing, Performance Ratings, Observations and Anecdotal Records, Rubrics, Portfolios, Surveys and Questionnaires, Self-Reporting Inventories, Interviews; Conducting learner evaluation pre, during and post-instruction; Formative and Summative Evaluation- meaning, approaches and steps; Evaluating Learner Achievement and the Instructional Design Process; Evaluating the success of instruction; Performance appraisal of teachers.

VI. Practical

Preparation of the analysis report that includes the task/content analysis and learner analysis and the design plan includes learning objectives and corresponding instructional strategies and assessment items; Prepare course outline and lesson plan with an appreciation for diverse learning styles based on temperament, gender, and cultural/ethnic differences and deliver a lecture for UG/PG students; Assessing learning styles through Barsch and Kolb inventories; Development and testing of survey instruments for evaluating learning outcomes/ competencies of students; Development and testing of survey instruments for performance appraisal / competency assessment of teachers; Design an online e-learning module on a topic of interest as a capstone project, Integrate and apply the knowledge and skills gained from the course for creating an effective learning experience for a target audience; Designing and developing a theme based knowledge portals; Exercises on designing an online course using open source LMS like Moodle or EdX; Select and evaluate or design for social al media; Prepare a short research paper on recent theories and models of instructional design; Interview an instructional designer of your choice and prepare a synthesis report about what job roles he/she perform, What ID processes does he or she use, Challenges faced; Develop a prototype for one of the lessons in your design plan using PowerPoint or a website builder such as Weebly to create the screens integrating multimedia content and various functionalities; Field visit to a virtual learning/augmented learning lab, e-learning labs, distance learning centres, etc; Hands-on practice with video-editing software, web conferencing and video conferencing solutions.

VII. Suggested Reading

- Agarwal JC. 2007. *Essentials of Educational Technology Innovations in Teaching – Learning*. 2nd Ed. Vikas Publ. House.
- Agarwal R. 2000. *Educational Technology and Conceptual Understanding*. Anmol Publ.
- Dayal BK. 2005. *Educational Planning and Development*. Dominant Publ.
- Grover I, Kaushik S, Yadav L and Varma SK. 2002. *Communication and Instructional Technology*. Agro Tech Publ. Academy.
- Jacobsen D, Eggen P and Kauchak D. 1985. *Methods for Teaching - A Skills Approach*. 2nd Ed. Charles E. Merrill Publ.
- Joyee B and Well M. 1980. *Models of Teaching*. 2nd Ed. Prentice Hall.
- Khan PM. 2002. *Text Book of Extension Education*. Himanshu Publ.
- Rush N. 1987. *Technology Based Learning - Selected Readings*. London Publ. Co., New York.
- Tara Chand. 1999. *Educational Technology*. Anmol Publ.

I. Course Title : Gender Mainstreaming and Livelihood Development

II. Course Code : FEX 603

III. Credit Hours : 2+1

IV. Aim of the course

To orient students on the importance of "Gender mainstreaming" as well as the other concepts related to gender. The students will be able to understand the gender roles and responsibilities and how in the present times, the roles may be shifting

V. Theory

Unit I

Gender related concepts and divides: Historical perspective of gender; Feminism and emergence of gender as a concept, Scope of gender studies in agriculture and rural development; Agrarian Importance of Gender; Understanding the importance of gender in national and global agriculture, Key gender issues and challenges in agriculture/fisheries, Gender and value chain, Global actions to address gender, Needs and strategies to address gender and women empowerment, Gender related concepts and divides; Understanding of the concepts of gender, Gender equality and equity, Gender balance, Gender blind, Gender relations, Gender neutrality, Gender bias and Discrimination, Gender rights, Gender roles and responsibilities, Gender budgeting, Gender divides and their implications such as gender digital divide, gender access to resources and inputs divide, gender mobility divide, gender wage divide, Gender needs; Practical and Strategic.

Unit II

Gender analysis: Gender analysis, Importance, usage, prerequisites, Tools for gender analysis, Gender sensitive indicators: HDI, GDI, GEM; Gender and technology, How gender and technology impact each other, Gender neutral technology, Gender sensitive technology, Gender supportive assistance in technology adoption-Gender in fisheries research and extension.

Unit III

Gender mainstreaming, women empowerment and policies for women: Gender mainstreaming: Importance of gender mainstreaming in agriculture, Extension strategies to address gender issues such as gender and health, Nutrition, Gender in agricultural / fisheries value chains, Gender and climate change adaptation, Gender and globalization & liberalization for mainstreaming gender concerns into the national programmes and policies, Women Empowerment; Importance of women empowerment, Current national women empowerment and gender indices, Women empowerment approaches (technological, organizational, political, financial, social, legal and psychological), Global Best Practices, Policies and Frameworks, Global best practices, Women empowerment and Gender mainstreaming models and Frameworks for addressing gender concerns in agriculture/fisheries, approaches of various organizations; Gender mainstreaming and special women focused programmes in agriculture and rural development.

Unit IV

Livelihoods and its challenges: Basic concepts of livelihood and development, Types of development-Immanent/inherent and interventionist/ intentional; Why promote livelihood; Livelihood intervention: Definition, types, Spatial, segmental, sector, sub-sector; Systemic view of Livelihoods, Understanding Rural Livelihoods, Farm, Non-Farm, and off farm; Linkages with Farm and Off-farm Livelihoods; Economic Models; Livelihood Challenge, Political economy of Livelihoods, Issues of access to farm and non-farm livelihoods; Livelihoods from a Gender Perspective, Feminization of agriculture/ poverty, Women in the unorganized sector, The issue of unpaid and informal work; Livelihood Coping Mechanism, Climate Change and Livelihoods; Livelihoods and Disasters.

Unit V

Livelihood frameworks, intervention and promotion approaches: Sustainable Livelihoods Approaches (SLAs)-Definition and origins of SLA; Assets or capitals and capabilities in SLA and its linkage to the other capitals; Vulnerability Assessment- Shocks, trends, seasonality; Policies, institutional context and processes; Conceptual Frameworks-DFID, CARE, UNDP, OXFAM, BASIX livelihood triad, Nine square Mandala or Rural Livelihood System's Framework, etc; Past, Present and Possibilities for the future of the SLA, critiques of the approach.

Unit VI

Livelihood promotion approaches: Approaches and programs in India; Livelihood and a Rights Based Approach-MGNREGA and its critique; Livelihood and a Social Capital based approach: NRLM; Livelihood Augmentation (LA)- Basic concepts; Pathways: a) Entrepreneurial strategies for LA; b) NRM based intervention; c) Market based interventions including Value-chain analysis; d) ICT based interventions; e) Livelihood and allied agriculture based livelihood; f) Forest based Livelihoods vis a vis Livelihood Protection and Promotion: Contribution of NTFP in supporting rural livelihoods.

VI. Practical

Visit to a village for understanding gender roles and for capturing shifts in gender roles in fisheries; Conducting gender analysis in a village using gender analysis tool; Exercise for identification and prioritization of issues affecting/needs for men and women in fisheries; Village visit to understand the livelihood pattern of villagers and how the other socio-economic factors affect the livelihood of people; Application of participatory rural appraisal skills for understanding village context; Engagement of working with rural communities and their grass-root institutions, understanding dynamics of working in a group; Visit to different agri-business models as mentioned in the Block 'C'. Group assignments may be given to document the field experience in the form of case study of an enterprise/ entrepreneur/ members and other related stakeholders; Visit to agencies supporting women empowerment followed by report presentation. Each student to visit a different organization such as State Rural Livelihood Mission, Women Development Corporation, Department of Agriculture, Important NGOs working for women empowerment; Interaction with a successful women entrepreneur/ SHG; Case studies based on livelihood promotion and rural development. Case studies on Livelihood augmentation and gender related issues in fisheries sector.

VII. Suggested Reading

- Agarwal B. 1986. *Women, Poverty and Agricultural Growth in India*, JPS, New Delhi.
- Agarwal Bina. 1994. *A Field of One's Own: Gender and Land Rights in South Asia*, Cambridge: Cambridge University Press.
- Bhasin K. *Understanding Gender*, New Delhi, Kali for Women, 2000
- Menon Nivedita. 1999. *Gender and Politics in India*, New Delhi: Oxford.
- Patricia Uberoi. 2009. *Freedom and Destiny: Gender, Family, and Popular Culture in India*, Oxford University Press, New Delhi
- *Report on Conditions of Work And Promotion of Livelihoods In The Unorganized Sector* by National Commission For Enterprises In The Unorganized Sector, GoI, Academic Foundation, Delhi, 2008.

I. Course Title : Extension Service System Management

II. Course Code : FEX 604

III. Credit Hours : 2+1

IV. Aim of the course

To make students' understand extension administration and management, and the functions associated with management.

V. Theory

Unit I

Extension service system: Meaning and scope of extension service system and its management; Public administration and bureaucracy - concepts, origin and development; Marxian, Weberian and Gandhian thoughts on bureaucracy; bureaucratic vs. developmental organisation.

Unit II

Processes of management: POSDCORB; Structure, Organisation, Function, Working and management of public extension service agencies like DoFs, FFDA, BFDA, MPEDA, NFDB, NABARD, Fisheries Development Corporations, State Fish Seed Development Corporations, KVKs, SAUs, Fisheries Co-operatives, international agencies, corporate sector, private organizations and MNCs.

Unit III

Organisational conflicts: Delegation of power, Autonomy and Organisational communication and Conflicts in governmental, UN agencies, Non-governmental and Private extension service organisations; Conflicting roles and responsibilities of extension agents.

Unit IV

Organisational communication: Meaning, methods, types and techniques; Functions and importance in motivation and control; Formal and informal communication networks in GOs, NGOs and POs; Behaviour of individuals in organisations; Organisational change and communication; Patterns of communication of organisational communication; Managing organizational communication in fisheries sector.

Unit V

Research, extension and client systems linkages: Linkages and coordination between Dept. of Fisheries and other line Depts. like Irrigation / Water Resources, Environment, Forestry, Agriculture at grassroots, District, State and Central levels; HRD policy in governmental, Non-governmental and Private extension service organizations, Strengthening governance - Transparency, Accountability and People's participation.

Unit VI

Strengthening extension service system: Strengthening the Human Resources of Extension System, Strengthening the Information and Communications Technology (ICT) Capacity, Decentralize the existing extension system, Developing Participatory Public Extension System: PRA, RRA, etc., Investments needed to strengthen extension systems, Civil Works, Equipment, Vehicles, Technical Assistance and Operational Expenses, Supervising, Monitoring, and Evaluating extension projects.

VI. Practical

Case study and analysis of State Departments of Fisheries in selected States; Case studies in structure organization, staffing, career advancement, quality of service delivery at grassroots level in governmental, nongovernmental and private extension service organisations like DoFs, FFDA, NABARD, State Fish Seed Development Corporations, KVKs, Fisheries Co-operatives, NGOs, and private sector organisations; Study of patterns of communication and effectiveness of Fisheries Development Organisation; Study visit to DoF, NGOs, NABARD, private sector agencies involved in fisheries extension.

VII. Suggested Reading

- Dillinger B. 1995. *Decentralization, Politics and Public Services*. In A. Estache, ed. *Decentralizing Infrastructure: Advantages and Limitations*. Discussion Paper. Washington, DC: The World Bank.
- Garfield E, Guadagni M & Moreau D. 1997. Colombia: *Decentralisation of Agricultural Extension Services*, World Bank Extension. Washington, DC: The World Bank.
- KaleelFMH & Krisnamurthy J. 2007. *Market Led Extension Dimensions and Tools*. Agro Tech Publ. Academy.
- Parker AN. 1995. *Decentralization: the Way Forward for Rural Development? Agriculture and Natural Resources Department*. Washington, DC: The World Bank.
- Rajmanohar TP & Kumaravel KS. 2006. *Contract Farming in India*. ICFAI Univ. Press, Hyderabad.
- Rivera WM. 1996. *Agricultural Extension in Transition Worldwide: Structural, Financial and Managerial Strategies*. Public Admin. Develop. (UK), 16: 151–161.
- Smith LD. 1997. *Decentralization and Rural Development: The Role of the Public and Private Sector in the Provision of Agricultural Services*. Technical Consultation on Decentralization. Food and Agriculture Organization. Rome: FAO.
- Subbalakshmi V. 2005. *Globalization - Indian Experience*. ICFAI Univ. Press, Hyderabad.
- Suresh K. 2005. *Rural Markets - Emerging Opportunities*. ICFAI Univ. Press.

I. Course Title : Technology Commercialisation and Intellectual Property Management

II. Course Code : FEX 605

III. Credit Hours : 2+1

IV. Aim of the course

To develop a critical understanding among extension students about how the technology commercialization process is linked to IPR management and entrepreneurship development.

V. Theory

Unit I

Overview of intellectual property rights: Introduction to IPR; Overview & Importance; Genesis; IPR in India and IPR abroad; Patents, Copyrights, Trademarks & Trade secrets, Geographical indication, Industrial design; Emergence of IPR Regimes and Governance Frameworks, Trade-Related Aspects of Intellectual Property Rights (TRIPS), Convention on Biological Diversity (CBD), Cartagena Protocol, International Union for Protection of New Plant Varieties (UPOV), and BIMSTEC.

Unit II

IPR protection laws and systems: National IPR Policy; and IPR laws; Procedures for filing IP protection; Systems of IP protection and management in agricultural universities and research institutions and also by stakeholders; Mechanisms of IPR Management, Institutional arrangement, IP Management processes – invention disclosure; IP portfolio management; Infringement management; National Biodiversity Act (2002); Protection of Plant Varieties and Farmers Rights Act

(2001); Guidelines for registration and transfer of biological resources; Farmers rights; Mechanisms of documenting/ collecting, protecting and commercialising farmers varieties and other biological resources; National Biodiversity Authority, PPVFRA and other agencies involved in management of biological resources in India, Access to Genetic Resources and Sharing of Benefits.

Unit III

Traditional and indigenous knowledge: Grassroots and Farmers Innovations – Meaning, forms and importance; Systems of documentation, Registration, Protection and Commercialisation, Documentation of traditional indigenous knowledge - Traditional Knowledge Digital Library (TKDL), Community Biodiversity Registers (CBRs), People's Biodiversity Registers (PBRs), Plant Biodiversity Register, and Honeybee Network.; The Global Concerns on Use of Genetically Modified Organisms in Food and Agriculture; The Cartagena Protocol on Biosafety; Regulation of GMO in India.

Unit IV

Technology commercialisation and IP valuation: Technology - Definition, functions, Process of technological advancement – Invention, Discovery, Innovation and Technology; Types of innovation, Basic research, Breakthrough innovation, Disruptive Innovation and Sustaining Innovation; Technology transfer and commercialisation, Technology transfer vs Commercialisation; Technology commercialisation process, Elements, Models, Systems and processes; Technology commercialisation strategies, Meaning, approaches for technology commercialisation, technology scaling up, technology licensing, Handholding, Agripreneur development.

Unit V

Technology assessment and refinement: Meaning; Importance; Approaches and methods of assessment and refinement of various technologies, Stakeholder oriented approaches including participatory technology assessment and refinement; Returns to investment; IP Valuation-Oxford context, IP Valuation methods, Cost approach; Income approach, Discounted Cash Flow, Risk-Adjusted Net Present Value, Net Present Value with Monte Carlo Simulation and Real Options Theory; Market approach, Industry Standards Method, Rating/Ranking Method, Rules of Thumb Approach and Auction Method; Hybrid approaches; Royalty rate method.

Unit VI

Technology incubation and promotion: Technology business incubation - Meaning, functions and types; Stakeholder-oriented incubation process, Livelihood incubation, village incubators, System of technology incubation, Incubation process; its effectiveness; Managing profit oriented and non-profit incubators; Schemes for promoting incubators in India; Technology Scouting and Innovations in technology incubation, Technology promotion: Meaning, Types, Business meetings, Scientist-industry/ Entrepreneur meets, Technology conclave, Business plan competition, Farmers fairs, Technology shows; Business Etiquette; Business networking.

VI. Practical

Understanding the technology commercialisation process – Visit to Technology Commercialisation Unit of ICAR Institute/ Agricultural University; Understanding the IPR protection practices – Visit to Patent Attorney office; Hands-on experience in drafting IPR application – Patent/Copyright/ Trademark; Documenting Traditional and indigenous knowledge – Field experience in using various protocols of using traditional and indigenous knowledge; Hands on experience in technology licensing process including drafting agreements; Understanding the Technology Business Incubation – Visit to Agri Business Incubator or Technology Business incubator; Hands on experience in planning and organising technology promotion events; Hands on experience in various techniques in business communication and Business etiquette; Protecting unique local goods through Geographical Indications – Hands on experiences in documenting and registering Geographical indications; Technology assessment/ validation of traditional and indigenous knowledge – QuIK and other methods; Hands on experience in technology valuation.

VII. Suggested Reading

- CMA / IIMA, *Implications of WTO Agreements for Indian Agriculture*, Oxford & IBH
- Fundamentals of patent law: interpretation and scope of protection. By Matthew Fisher. Hart, 2007. (KD1369. F57x 2007, Library 4 West)
- Ganguli P. *Gearing Up for Patents: The Indian Scenario*, Orient Longman
- *Guide for the Preparation of Patent Drawings*. USPTO, 2002. (C21.14/2: D79/2, Library 3 East)
- *Guide to the International Registration of Marks Under the Madrid Agreement and the Madrid Protocol*. WIPO, 2004. (K1557. G85x 2004, Reference, Library 2 East)
- *Intellectual Property: Patents, Trademarks, Copyrights, Trade Secrets*. By Catherine J. Holland. Entrepreneur Press, 2007. (KF2980. I539 2007, Library 4 West)
- *Patent, Copyright & Trademark: A Desk Reference to Intellectual Property Law*. By Stephen Elias. Nolo Press, 1996. (KF2980. E44 1996, *Microform, Library use only*, Library 2 East)
- *Patent, Trademark, and Copyright Searching on the Internet*. By Charles C. Sharpe. McFarland, 2000. (T210. S53 2000, Reference, Library 2 East)
- Sikder S. *Contemporary Issues in Globalisation- an Introduction to Theory and Policy in India*, OUP
- *Trademark: Legal Care for Your Business & Product Name*. byStepen Elias. Nolo, 2007. (KF3180.Z9E43 2007, Ready Reference, Library 1 West)

I. Course Title : Policy Engagement And Extension

II. Course Code : FEX 606

III. Credit Hours : 2+1

IV. Objective

To develop the capacities of students to successfully engage with policy actors and bringing about desirable policy changes to strengthen extension.

V. Theory

Unit I

Understanding policy, policy advocacy and tools: Why policies are important for extension? Role in providing structure, Ensure funding and Framework for providing functions-examples; Policy: definitions and types; Is policy a product or a process or both? Policies and institutions, How these influences defining organizational roles and performance in extension organizations, Role of policies in upscaling knowledge.

Unit II

Role of extension in influencing policies to enable innovation; Definition of advocacy, Approaches to policy advocacy-Advising, Media campaigning, Lobbying, Activism, Information education communication (IEC) and Behaviour change communication

(BCC); Advocacy for RAS; Policy advocacy strategy.

Unit III

Policy analysis and development process: Explain the meaning and use of policy analysis in decision making; Describe different types of policy analysis, Empirical, Evaluative or normative policy analysis, Retrospective/ prospective policy analysis, Predictive/prescriptive/descriptive policy analysis; How to do policy analysis?, Understand the process of policy analysis, Highlight the different methods and techniques used in policy analysis, Doing ethical policy analysis; Tools for policy impact- research tools, Context assessment tools, Communication tools, Policy influence tools, Who drives policy change?, National Governments, Donors, Civil Society-varied experiences.

Unit IV

Understanding the environment and key actors in policy space: Problem identification, Policy adoption, Implementation and evaluation; Stakeholder mapping, Identifying opportunities and Barriers, Mobilising financial resources; Dealing with policy incoherence: Identifying contradictions and challenges in policy implementation, Generating evidence.

Unit V

Role of policy research: Analysing the usefulness and appropriateness of the evidence; Using evidence in policy advocacy; Good practices in influencing policies Organising policy dialogues; Policy engagement strategy, Engaging with policy makers; GO and NGO experiences; Policy working groups; advisory panels; use of committees.

Unit VI

Policies in fisheries sector: Policy and regulatory environment in Marine Fisheries Sector, Inland Fisheries Sector, Brackish water Aquaculture Sector, Freshwater Aquaculture Sector, International policy and regulatory scenario in fisheries sector; FAO's CCCRF; UN's Law of the Sea and other conventions; EU's Common Fisheries Policy; Fisheries policy and regulation of select countries in Asian and American region; WTO and Fisheries; Subsidies and taxation in fisheries sector, NIFAP, Marine Policy.

VI. Practical

Analysis of country/state level fisheries/ extension policy to understand the policy intentions from strengthening EAS, Analysis of fisheries policies of other countries: policy intentions, processes adopted in development of the policy and mechanisms of policy implementation, Interaction with key policy actors in EAS arena at the state/ national level (e.g.: Secretary of fisheries, Director of fisheries, etc) to explore policy level challenges in EAS, Identifying what evidence policy makers look for from extension research (Is the evidence available? If so what form? (Reports, Briefs etc), If not, develop a plan; Explore how different stakeholders influence policies (e.g.: policy advocacy of prominent NGOs, private sector and public sector) -What mechanisms and tools they use, Identifying policy level bottlenecks that constrain effective EAS delivery at the district level- E.g.: Issues around linkages between KVK and ATMA; inter-departmental collaboration; public private partnerships; joint action etc., Case studies on sub-sectoral review of fisheries policy and legislative framework in select Indian States; Case studies on shrimp culture policy and development in Thailand and East Coast of India; Case studies on leasing policy in Bihar, Rajasthan, Tamil Nadu, Orissa, Karnataka, Maharashtra and Himachal Pradesh; Case studies on implications of WTO agreements for Indian and world fisheries.

VII. Suggested Reading

- Ananthan PS, B Nightingale Devi and Nisha Elizebeth Joshua (Compilation). 2010. *Policy and Regulatory Environment for Fisheries and Aquaculture in India: A Compendium* Vol I: Policies and Case Studies, Vol.II: Legislation, and Vol. III: Legislation-State MFRAs; CIFE, Mumbai.
- Ananthan PS, Dilip Kumar and RS Biradar. 2010. *Policy Guidelines and Framework for Fisheries and Aquaculture Development in India*-Second Draft for Discussion, CIFE.
- Dilip Kumar, Ananthan PS. *et al*. 2008. *Proceedings of Five Zonal Workshops on Fisheries Policy in North Eastern States, East Coast States, West Coast States, Central Zone States and Northern states* organised during 2006-2008 by CIFE.
- Michael L Weber, 2001. From Abundance to Scarcity: *A History of U.S. Marine Fisheries Policy*, Island Press, New York.
- Salagrama, Venkatesh, *Fish Out of Water: Story of Globalisation, Modernisation and Artisanal Fisheries of India.*

I. Course Title : Participatory Approaches in Fisheries Extension

II. Course Code : FEX 607

III. Credit Hours : 1+1

IV. Aim of the course

To make students' gain knowledge on participatory approaches in fisheries extension programmes.

V. Theory

Unit I

Participatory approaches for aquatic resources management and development: Need, Importance and guiding principles; Community mobilization methods, Farmer-First Approach; Trickle Down System, Concept, Method and processes; Knowledge Driven Extension System, Concept and method.

Unit II

Community based fisheries management and Fisheries co-management: Concept, Origin, Importance, Types, Method, Processes, Stakeholder rights, Responsibilities and participation, Institutional mechanisms, Implementation constraints, Experiences from other countries; Conflict resolution and management; Public-Private-Community Partnership.

Unit III

Participatory Learning Approach (PLA): Role-plays, Case studies, Brainstorming, and ranking of priority issues, Discovery-based experiential learning, Participatory education methods like FGD.

Unit IV

Participatory appraisal techniques: Census mapping, Resource mapping, Social mapping; Selection of participatory methods and their uses; Farmer Field Schools for Aquaculture, Strength and weakness, Constraints in PRA methods.

VI. Practical

Conducting Participatory Rural Appraisal in select villages and developing action plans; Conducting focused group discussion and developing action plan; Facilitating group formation based on the felt needs and to implement the action plans / plan of work; Reviewing national and international case studies on participatory approach to aquaculture research and development; Case studies and simulation exercises on fisheries co-management /community based fisheries management.

VII. Suggested Reading

- Adhikary. 2006. *Participatory Planning and Project Management in Extension Science*. Agrotech Publ. Academy.
- BK. 2008. *PRA/PLA and Participatory Training*. Adhyayan Publ. & Distr.
- Brown D, Derek S & Simon FS. 2005. *Mainstreaming Fisheries Co-Management in the Asia-Pacific*. Asia-Pacific Fishery Comm. Rep. Publ. 2005/24, FAO, United Nations Regional Office for Asia and the Pacific, Bangkok.
- Chambers R, Arnold P & Thrupp LA. 1989. *Farmers First: Farmer Innovation and Agricultural Research*. Intermediate Technology Publ.
- Chambers R. 1983. *Rural Development Putting the Last First*. Longman.
- Edwards P, Little DC & Demaine H. 2002. *Rural Aquaculture*. CABI.
- Kumar D. 1999. *Trickle Down System (TDS) of Aquaculture Extension for Rural Development*. RAP Publ.
- Mukharjee N. 2002. *Participatory Learning and Action*. Concept Publ. Co. Singh.
- Robert SP. 2005. *Fisheries Co-Management*: A Practical Hand Book. CABI.
- Somesh Kumar. 2002. *Methods for Community Participation*. Vistaar Publ.

List of Suggested Journals

- *Advance Research Journal of Social Science, ISSN 0976-5611*
- *Advances in Management, ISSN 0974-2611*
- *Aquaculture Economics and Management, ISSN 1365-7305*
- *Asian Journal of Agricultural Extension, Economics & Sociology, ISSN 2320-7027,*
- *Asian Journal of Extension Education (Maharashtra Journal of Extension Education), ISSN 0971-3115*
- *British Journal of Environment and Climate Change, ISSN 2231-4784*
- *Climate Change and Environmental Sustainability, ISSN 2320-6411*
- *Contemporary Social Sciences, ISSN 0302-9298*
- *Fisheries Management and Ecology, ISSN 0969-997X*
- *Gujarat Journal of Extension Education, ISSN 2322-0678*
- *Human and Ecological Risk Assessment, ISSN 1080-7039*
- *IIMS Journal of Management Science, ISSN 0976-030X*
- *Indian Journal of Agricultural Marketing, ISSN 0971-8664*
- *Indian Journal of Extension Education and Rural Development (Rajasthan Journal of Extension Education), ISSN, 0973-1113*
- *Indian Journal of Extension Education, ISSN 0537-1996*
- *Indian Journal of Marketing, ISSN 0973-8703*
- *Indian Journal of Positive Psychology, ISSN 2229-4937*
- *Indian Journal of Social Research, ISSN 0019-5626*
- *Indian Research Journal of Extension Education, ISSN 0972-2181*
- *International Journal of Applied Social Science, ISSN 2394-1405*
- *International Journal of Climate Change Strategies and Management, ISSN 1756-8692*
- *International Journal of Education and Management Studies, ISSN 2231-5632*
- *International Journal of Extension Education, ISSN 2319-7188*
- *International Journal of Home Science Extension and Communication Management, ISSN 2348-1099*
- *International Journal of Human Resource Management and Research, ISSN 2249-6874*

- *International Journal of Human Resource Management, ISSN 2319-4936*
- *International Journal of Humanities and Social Sciences, ISSN 2319-393X*
- *International Journal of Information Systems Management Research and Development, ISSN 2250-236X*
- *International Journal of Research in Applied, Natural and Social Sciences, ISSN 2347-4580*
- *International Journal of Sales & Marketing Management Research & Development, ISSN 2249-6939*
- *International Journal of Sales & Marketing Management, ISSN 2319-4898*
- *International Journal of Social Science, ISSN 2249-6637*
- *International Journal of Social Sciences Review, ISSN 2347-3797*
- *Jharkhand Journal of Development and Management Studies, ISSN 0973-8444*
- *Journal of Agricultural Extension Management, ISSN 0976-3120*
- *Journal of Community Mobilization and Sustainable Development, ISSN 2230-9047*
- *Journal of Economics, Management and Trade (British Journal of Economics, Management and Trade), ISSN 2456-9216*
- *Journal of Education, Society and Behavioural Science (British Journal of Education, Society and Behavioural Science), ISSN 2456-981X*
- *Journal of Extension Education, Bhubaneswar, ISSN 0976-8246*
- *Journal of Extension Education, Coimbatore, ISSN 0971-3123*
- *Journal of Extension Systems, ISSN 0970-2989*
- *Journal of Global Economics, Management and Business Research, ISSN 2454-2504*
- *Journal of Knowledge and Communication Management, ISSN 2277-7938*
- *Journal of Psychology, ISSN 0976-4224*
- *Journal of Social Sciences, ISSN 0971-8923*
- *Journal of Sociology and Social Anthropology, ISSN 0976-6634*
- *North American Journal of Fisheries Management, ISSN 0275-5947*
- *Prabandhan: Indian Journal of Management, ISSN 0975-2854*
- *Selp Journal of Social Science, ISSN 0975-9999*
- *SMART Journal of Business Management Studies, ISSN 0973-1598*
- *Studies on Home and Community Scienc*e, ISSN 0973-7189
- The Anthropologist, ISSN 0972-0073

List of Suggested E-resources

- Diffusion of innovations http://www.youtube.com/watch?v=B5Kx0hV6jhY
- Resources on Impact Assessment, http://www.gdrc.org/uem/eia/define.html
- Capturing Experience: Evaluation, Evaluation and Impact Assessment Methods, http://web.mit.edu/urbanupgrading/upgrading/resources/bibliography/Evaluati on-Impact.html
- Equality Impact Assessment, https://www.webarchive.org.uk/wayback/archive/20180518072937/ http://www.gov.scot/Publications/2005/02/20687/52421
- The Internet and Poverty: Opening the Black Box, http://dirsi.net/web/files/files/Opening_the_Black_Box.pdf
- ICTs for Development (http://ict4dblog.wordpress.com/)
- Bruce, James P., Egener, I.D. Mark, and Noble, David. 2006. Adapting to Climate Change: A Risk-based Guide for Ontario Municipalities. http://ww.coastalchange.ca/download_files/external_reports/Bruce_(2006)_Adaptingto Climate Change_ARisk-basedGuideforONMunicipalities.pdf
- Ontario Ministry of the Environment. (2011). Climate Ready: Ontario's Adaptation Strategy and Action Plan. https://www.ontario.ca/document/climate-ready-adaptation-strategy-and-action-plan-2011-2014-0
- Air Quality Benefit Assessment tools. http://science.gc.ca/eic/site/063.nsf/eng/h_97170.html
- Mabey, N., Gulledge, J., Finel, B., and Silverthorne, K. 2011. Degrees of Risk: Defining a Risk Management Framework for Climate Security. http://www.e3g.org
- ICLEI. Changing Climate, Changing Communities: Guide and Workbook for Municipal

Climate Adaptation. Accessed from: http://www.iclei.org/index.php?id=8708
- Insurance Bureau of Canada. Municipal Risk Assessment Tool. Accessed from: http://www.ibc.ca/en/Natural_Disasters/Mu nicipal_Risk_Assessment_Tool.asp
- International Panel of Climate Change. https://www.ipcc.ch/links/
- National Institute of Agricultural Extension Management (MANAGE) https://www.manage.gov.in/publications
- Directorate of Knowledge Management in Agriculture (https://icar.org.in/content/directorate-knowledge-management-agriculture)
- NAARMhttps://naarm.org.in/publications/

Suggested broad areas for Master's and Doctoral research

- Comparative study on performance of public, private and market led extension systems
- Performance and impact of ATMA model of service delivery/knowledge dissemination
- Communication effectiveness of different media
- Impact of social media in technology transfer
- Impact of community radio and ICT led extension systems
- Case studies on co-management and community based fisheries management experiences in India
- Training need assessment of State Department of Fisheries
- Impact of B.Voc Programmes in addressing need of skilled human resource in fisheries and aquaculture sector
- Aquapreneurship and youth
- Recruitment policy and career advancement in State Department of Fisheries (or) State Fisheries Universities
- Role and importance of PRIs and NGOs in implementing fisheries development programmes
- Critical factors in successful development of community based organisations
- Reach and impact of fisheries innovations
- Stakeholder analysis of fisheries innovations
- Developing effective interactive e-learning and multimedia products
- Reach and impact of fisheries innovations
- Socio-economic impact assessment of development programmes
- HRM practices of Various State Fisheries Departments, NGOs and private consultancies
- Division of labour and gender equity among fishing communities
- Content analysis of development oriented articles / features in print /electronic media for their reach, readability, and persuasion and conviction
- Political economy of mass media and development journalism
- Case studies on documentation and validation of ITK practices in fisheries sector Impact of Tsunami 2005 on fishers' livelihoods and fisheries
- Pattern of rehabilitation work and its impact
- Returns to investment in fisheries and aquaculture extension
- Evolving participatory result oriented monitoring and evaluation system for fisheries development programmes in developing countries. Developing appropriate scaling technique for measuring the attitude of fishers towards conservation technologies
- Professionalism in Service Delivery System Performance of public and NGO led extension systems
- Developing and field testing of effective training tools for trainers
- Conflict between small scale fishers and large scale fishers and inadequacy of the present resolution mechanism.
- Social change, mobility and integration in fishing communities
- Case studies on success stories in use of ICT for fisheries development Limiting factors in effective use of ICT for Development
- Comparative study of effectiveness performance of extension systems in India and other developing South-East Asian Countries (Indonesia / Thailand) or developing agrarian economy based countries
- Levels of workload among Fishers and their impact on health
- Administrative advantage of formation of exclusive ministry/council for fisheries

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Physiology and Biochemistry

Preamble

(Fish Physiology and Biochemistry)

Fish physiology and Biochemistry is a basic discipline in the field of fisheries science. Physiology is the scientific study of the normal function in living systems in their living environment. One of the major objectives is to know the basic function of organs and their interaction at a macro-level while biochemistry provides more basic understanding in a micro-level about the existence of life in the organism. Physiology is closely related to anatomy which is the study of form and structure. Fish physiology seeks to understand the mechanisms that work to keep the fish body alive and functioning, through scientific enquiry into the nature of mechanical, physical, and biochemical functions of fishes, their organs, and the cells of which they are composed. Biochemistry will broaden our understanding on the physiology and helps to understand the chemical aspects of biological processes. The principal level of focus of physiology is at the level of organs and systems within the body. The endocrine and nervous systems play major roles in the reception and transmission of signals that integrate function in animals. Homeostasis is a major aspect with regard to such interactions within the organisms. The biological basis of the study of physiology, integration refers to the overlap of many functions of the systems of the body, as well as its accompanied form. It is achieved through communication that occurs in a variety of ways, both electrical and chemical. Few of the most extensively researched and applied areas in fish physiology and biochemistry is the physiology of reproduction as well as the nutritional physiology. With the help of this course, students learn to find scientific answers to the problems related with the various modes of aquaculture production before attempting to solve them. This course takes a systematic approach with emphasis on the reproductive, circulatory, endocrine, muscular, nervous, metabolic, and respiratory systems. The knowledge will certainly enable students to amicably address the failure in captive reproduction, larval growth and survival issues of new aquaculture candidates, adaptation to altered habitats, growth and immunity under various salinities, mitigation strategies for alleviating stresses and identifying welfare indicator of fishes in different aquaculture systems. In addition to the basic body systems, the course also covers the deviations from normal physiology such as stress and adaptive physiology and interactions of physiology with environment in context of foreseeable climate change scenario.

The major emphases of the discipline are as follows:

How the physiological processes happen and their biochemical basis

How they might change with environment and their biochemical basis

How one process inûuences the other

How this relates to real scenario of finfish and shellfish aquaculture.

Overall, Purpose of the 'Fish Physiology and biochemistry" course, is to provide a foundation on many basic processes that keep a fish alive and how understanding biochemical and physiological processes have practical applications. Further, the understanding of physiology will help to find reasons to recurrent practical problems such as fish mortalities, low production or breeding failure and ways to help the situation. In academics the understanding of physiology and biochemistry is invaluable for interpreting data from many fields such as nutrition, immunity, and genetics. Understanding why something happen leads to new questions and therefore new research directions can be created. The course focuses on physiological processes in fish including reproduction, nutrition, respiration, circulation, acid-base balance, smotification, osmo-ionic regulation, swimming and buoyancy, sensory physiology, egg and larval physiology, digestion, energetic and growth, immunity and adaptations to adverse climate and environments.

With the background of immense importance of the 'Fish Physiology and Biochemistry", members of the BSMA committee and the invited experts from pioneer institution like IITs and industry reviewed the existing PG and Ph.D. course syllabus critically several times, incorporated the recent content learning both in theory and practical to bring it in this elevated format to groom the fish physiology and biochemistry specialists and professionals to the industry, R&D and academics. The syllabus has been made following the same pattern maintained in preparing other disciplines. Under M.F.Sc. program minor change in title of 1 course has been made with several minor changes in the contents of different courses to keep the syllabus more relevant to the needs of the day. In Ph.D. program, only course was subjected to major changes and a new course "Diagnostic Biochemistry and Physiology" has been introduced to understand and to develop new methods of identifying disturbances in fish welfare well before of sickness and outbreak of diseases. In M.F.Sc one course "Aquatic radioecology" has been excluded from the syllabus due to lack of facilities needed to run such course.

Justification for Fish Physiology and Biochemistry Disciplines in Fisheries Science

Earlier committee reports such as, Fifth Deans' Committee Report (2013) and Report of PG and Ph.D restructuring done under the Chairman ship of Dr. Keshavanath (2009) have recommended offering "Fish Physiology and Biochemistry" for the PG/Ph.D. in Fisheries Science. The new Education Policy 2020 envisages making the education system more flexible for the Higher education students. At the PG and Ph.D. level naturally, it is essential to branch out into more specialisations and there is a need to offer many courses for students to choose from. Thus, students will be offered with a wider choice of courses and they need not be restricted to a limited no. of courses. Moreover, withdrawing the already introduced Courses on "Fish Physiology and Biochemistry" after few years would certainly affect the career of those students earned degree. It would be detrimental to the settlement of those students who pursued the courses.

Course Title with Credit Load
M.F.Sc. in Fish Physiology and Biochemistry

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FPB 501	Fish Physiology	2+1
FPB 502	Reproductive Physiology and Endocrinology	2+1
FPB 503	Fish Biochemistry	2+1
FPB 504	Metabolism of Biomolecules	2+1
FPB 505	Cellular and Molecular Physiology	2+1
FPB 506	Crustacean Physiology	1+1
FPB 507	Diagnostic Biochemistry	2+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a student's major subject)	
FPB 508	Tools and Techniques in Biochemistry	1+2
FPB 509	Principles in Fish Nutrition	2+1
FPB 510	Nutraceuticals as Functional Foods	1+1
FPB 511	Fish Pathology and Immunobiology	1+1
FPB 512	Sensory Physiology	1+1
FPB 513	Physiology of Fish Behaviour	1+1
FPB 514	Pharmaco-biology of Aquaculture Drugs	1+1
FPB 515	Eco-physiology of Fishes	1+1
FPB 516	Enzymology	2+1
FPB 517	Fish Nutrigenomics	2+1
FPB 518	Feeds and Feed Technology	2+1
FPB 519	Nutritional Requirement and Feeding Management	2+1
	Supporting Courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common Courses	
	(The following courses, one credit each will be offered)	**5 Credits**
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	

Course Code	Course Title	Credit Hours
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	**1 Credit**
FPB 591	Master's seminar I	0 + 1
	Masters' Thesis Research	**30 Credits**
FPB 599	Master's Research (Semester III)	0 + 15
FPB 599	Master's Research (Semester IV)	0 + 15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fish Physiology and Biochemistry

I. Course Title : Fish Physiology

II. Course Code : FPB 501

III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic physiology of fish

V. Theory

Unit I

Cell Physiology: Structures, Membranes, Organelles and Functions; Cell cycle; Signaling and cell death; Cellular functions in aquatic environment; Extracellular matrix biology; Bioluminescence and physiology of electric organs in fishes.

Unit II

Physiology of GIT: Anatomy; Digestion, Absorption and assimilation of food salt and water; Digestive enzymes, Neural and hormonal regulation; Impact of nutrition.

Unit III

Physiology of respiration: Morphology of gills, Respiratory pigments and their functions; Mechanism of gaseous exchange, Gill ventilation countercurrent principle, CO_2 transport,; Fluid dynamics on gill functions and respiratory mechanisms.

Unit IV

Circulatory system: Structure and functions of heart, Blood circulation, Blood pressure, Composition of blood, Heart and cardiac output, Structure of blood/ haemolymph pigments; Water salinity and blood composition.

Unit V

Physiology of Osmoregulation and Respiration: Excretory and osmoregulatory organs in fish and shellfish and their functions; Mechanism of osmotic and ionic regulation; Acid base regulation, Mechanism of excretion of nitrogenous waste; mechanisms of osmoregulation against aquatic pollutants.

Unit VI

Physiology of Reproduction: Structure and functions of gonads, Gametogenesis; Vitellogenesis; Gonadal steriodogenesis; Seasonality of reproduction, and endocrine control of reproduction; Circadian rthyme in fish physiology; Aquatic pollutants and reproduction.

VI. Practical

Cell proliferation assay: Estimation of haemoglobin /haemocyanin and blood CBC; Estimation of ion transporter activity; Measuring osmolality of blood/ haemolymph; dissection and display of reproductive system, Estimation of hormones.

VII. Suggested Reading

- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: from Basic Studies to Biotechnological Applications*. Springer Publ.
- Evans DH and Claiborne JB. 2009. *Physiology of fishes*, Fourth edition, CRC press.
- Farrell AP. 2011. *Encyclopedia of fish physiology: from genome to environment*. Volume 1-3, Academic Press.
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 2 *The Endocrine System*. Academic Press.
- Hoar WS, Randall DJ and Donaldson EM. 2014. Fish Physiology Vol. 9A, *Reproduction: Endocrine Tissues and Hormones*. Academic Press.
- Hoar WS. 2014. *Fish Physiology* Vol. 9B. Academic Press
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 4 *The Nervous System, Circulation and Respiration*. Academic Press
- Johnston 2014. Fish physiology (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014: "v, 318p" ISBN: 978-93-5107-130-3 .
- Samantaray K. 2015. *Physiology of Finfish and Shellfish*. New India Publ. Agency.

- Smith Lynwood S. 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Nielsen 1983. *Animal Physiology: Adaption and Environment* New York Cambridge University Press Edition: 3rd: "xii, 619p"
- Val. 2006. *Physiology of Tropical Fishes. California* Elsevier Academic Press: "xiv, 634p"; 23cm ISBN: 0-12-350445-7.
- William O Reece and Eric W Rowe. 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5th Edition. ISBN: 978-1-119-27086-7, Wiley-Blackwell p. 576.

I. Course Title : Reproductive Physiology And Endocrinology

II. Course Code : FPB 502

III. Credit Hours : 2+1

IV. Aim of the course

Basic concepts of reproductive physiology and endocrinology.

V. Theory

Unit I

Modes of reproduction: Sex determination and differentiation; Sexual dimorphism; Primary and secondary sex characters; Bisexual reproduction; Hermaphroditism, Sex reversal; Parental care reproductive behavior and adaptations.

Unit II

Neuroendocrine regulation: Pituitary gland and hypophthalamus; Structure and functions of GnRH other neuropeptides, Gonadotropins; Gonadotropin receptors structure, Function and regulation of their secretion.

Unit III

Gonad development and maturation: Oocyte and spermatocyte growth, Vitellogenesis; Nutrient transport and incorporation into oocytes; Oocyte maturation and ovulation; Spermiation; Metabolic changes during gametogenesis; Nutrient regulation of gonad development and endocrine function; Seminal vesicle and function.

Unit IV

Reproductive Rhythm: Daily and seasonal rhythms; Environmental cues, Photo-transduction, Role of melatonin and neuropeptides, Lunar clock, Biological Clock, Time of day, reproduction; Pheromones; Migration in fish.

Unit V

Reproductive technology: Hormonal manipulation of reproduction; Cryopreservation of gametes/ germ cells; Artificial insemination, Synthetic hormones and analogues for induced spawning; Stripping and fertilization.

Unit VI

Peripheral endocrine glands and hormones: Structure and functions; Thyroid, ultimobranchial body, Corpuscles of Stannius, Adrenal homologues, and Urophysis, PTH-related peptides, Calcitriol, Pancreatic hormones; Gut hormones; Neuroendocrine hormones.

VI. Practical

Dissection and display of reproductive and endocrine organs. Assay of hormones-testosterone, estradiol, cortisol, thyroxine; histological examination of gonad, maturity; Short term preservation of milt; Cellular morphology of pituitary gland.

VII. Suggested Reading

- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea*. Biology Reviews.
- Agarwal NK. 2008. *Fish Reproduction*. APH Publ.
- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: from Basic Studies to Biotechnological Applications*. Springer Publ.
- Croom HME. 2003. *Fish Endocrinology*.
- Diwan AD, Joseph S and Ayyappan S. 2008. *Physiology of Reproduction*, Breeding and Culture of Tiger Shrimp. Narendra Publ. House.
- Hoar WS and Randall DJ. 1969. *The Endocrine System* Volume 2. Academic Press.
- Maria RJ, Augustine A and Kapoor BG. 2008. *Fish Reproduction*. Science Publ. Matty AJ. 1985.
- Norris DO and Lopez KH. 2011. *Hormones and Reproduction of Vertebrates*. Vol. I Fishes. Academic Press.
- Reinecke. 2006. *Fish Endocrinology*, Vol. 2": Enfield "Science Publishers, Inc.: "xx, 441-871pp" ISBN: 978-1-57808-415-9.
- Sherwood NM and Hew CL. 2014. *Fish Physiology* Vol. 13. *Molecular Endocrinology of Fish*. Academic Press.

I. Course Title : Metabolism of Biomolecules

II. Course Code : FPB 504

III. Credit Hours : 2+1

IV. Aim of the course

Metabolism of different biomolecules.

V. Theory

Unit I

Carbohydrate metabolism: Glycolysis, TCA cycle; Feeder pathways of carbohydrate metabolism: Pentose phosphate pathway and gluconeogenesis; Glycogen metabolism, Regulation of blood glucose level.

Unit II

Lipid metabolism: Biosynthesis of fatty acids; Oxidation of fatty acids; Ketone bodies; desaturation and Elongation mechanisms; Control of fatty acid metabolism.

Unit III

Oxidative phosphorylation: Substrate level phosphorylation; Electron Transport Chain; NADH, NADPH, and $FADH_2$. Fo-F1 ATP synthesis.

Unit IV

Protein and amino acid metabolism: Biosynthesis of protein; Degradation of amino acids; Transamination and deamination, ammonia carrier and excretion; Biosynthesis of non-essential amino acids.

Unit V

Nucleic acids metabolism: Purine and pyrimidine metabolism, Biosynthesis of deoxyribonucleotides and ribonucleotides.

Unit VI

Vitamins and mineral metabolism: Metabolomics; Basic concepts and applications, Xenobiotic metabolism.

VI. Practical

End product estimation of aerobic and anaerobic carbohydrate metabolism (pyruvate and lactate) Estimation of lipoprotein lipase, acetyl choline esterase LDH, MDH, AST, ALT, NADH, NADPH, RNAses and DNAses.

VII. Suggested Reading

- *Bios Instant Notes Molecular Biology*. 4th Edition, 2016 by Mclennan.
- David L. Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- Gupta SN. 2019. *Biochemistry of Metabolic Processes*.
- John W Pelley. 2010. *Rapid biochemistry*. Elsevier.
- Pandya A. 2015. *Biomolecules and Biochemical Metabolism of Fuels: Carbohydrate, Protein, Lipid Metabolism*.
- Sharma MK. 2013. *Biomolecules and Metabolic Activities*.

I. Course Title : Cellular and Molecular Physiology

II. Course Code : FPB 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the cellular signaling cascades and related molecular physiology.

V. Theory

Unit I

Cell structure: General organization of euaryotic and prokaryotic cell; Structure and function of cell organelles, Cell membrane, Compartments, Electrolytes and Extracellular matrix, Membrane fluidity.

Unit II

Cell cycle and division: Meiosis and Mitosis regulation of cell cycle factors affecting cell cycle; Apoptotic and necrotic pathways.

Unit III

Cell signaling: General principles; Second messenger system; Concept of ligand; Ligand and receptor interactions Mechanism of cell signaling, Intracellular and extracellular receptors (Ion channel linked, G-Protein linked and enzyme linked) mediated signaling pathways; GPCR structures and functions; Concepts of membrane bound receptors and cytoplasmic/ nuclear receptor; second messenger system; Steroid hormone actions.

Unit IV

Cellular trafficking: Endocytic and Exocytic pathways membrane transport protein sorting vesicular transport.

Unit V

Gene expression: DNA replication, transcription translation and regulation of gene expression.

Unit VI

Translation and epigenesist: Pre and Post transcriptional and post translational modifications; Gene splicing, duplication and mutation, DNA damage and repair, Pathways; Epigenetic regulations.

VI. Practical

RNA isolation and cDNA synthesis, PCR, Genomic DNA isolation, PAGE and SDS-PAGE, DNA barcoding.

VII. Suggested Reading

- Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K and Walter P. 2015. *Molecular Biology of the Cell* (6th edition), New York: Garland Science. 1464 pp.
- CIFE. 1998. *Genetics and Biotechnological Tools in Aquaculture and Fisheries*. Mumbai CIFE.
- Cooper GM and Robert EH. *The Cell: A Molecular Approach* (6th edition) Hausman RE. 2013. Sunderland, Massachusetts: Sinauer Associates. 832 pp.
- Davbre PD. 1998. *Basic Molecular Biology: Essential Technique*. John Wiley and Sons, New York. p.208
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- Henry T Yost. 1972. *Cellular Physiology*.
- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. Lewin's Genes XII. Jones & Bartlet Publishers, MA, USA 829 pp.
- Lakra WS. 2004. *Fisheries Biotechnology*. Narendra Publishing House, Delhi.
- Mordecai P, Blaustein MD, Joseph PY, Kao. 2004. *Cellular Physiology: Mosby's Physiology* Monograph Series, ie.
- Sambrook J and Russel D. 2001. Molecular Cloning. 3rd Ed. Cold Spring Harbour Laboratory
- Verma PS. 2004. *Cell Biology, Genetics, Molecular Biology: Evolution and Ecology*. 350 pp. ISBN-13: 978-8121924429 *Instant Notes in Molecular Biology*, 2000 by Turner (Author), MCLENNAN (Author), Bates (Author), WHI (Author).

I. Course Title : Crustacean Physiology

II. Course Code : FPB 506

III. Credit Hours : 1+1

IV. Aim of the course

To understand basic physiology of crustacean.

V. Theory

Unit I

Reproduction: Reproductive physiology of crustaceans, Neuroendocrine glands and their functions.

Unit II

Molting and growth: Physiology of Molting, molting cycle, Growth.

Unit III

Ion and metabolites homeostasis: Osmoregulatory and Excretory physiology of crusataceans.

Unit IV

Digestive physiology: Function and structure of different components of digestive system, Feeding and sensory appendages, Hepatopancreas, Chemoreception.

VI. Practical

Identification of different organs, morphology of gonads; Molting cycle in relation to environment; osmolality and ionic estimation of haemolymph, anatomy of digestive tract.

VII. Suggested Reading

- Mente E. 2003. *Nutrition, Physiology and Metabolism in Crustaceans*.
- Ernest S, Chang and Martin Thiel. 2015. *Physiology: Volume IV (The Natural History of the Crustacea* Book 4.
- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea. Biology Reviews*.
- Diwan AD, Joseph S and Ayyappan S. 2008. *Physiology of Reproduction, Breeding and Culture of Tiger Shrimp*. Narendra Publ. House.
- Diwan 2007. *Physiology of Marine White Shrimp: Fenneropenaeusindicus*. Delhi Narendra Publishing House: "x, 245p." ISBN: 81-85-375-93-3
- Wilder MN. 2019. *Advances in the Science of Crustacean Reproductive Physiology and Potential Applications to New Seed Production Technology*. *In:* Jithendran, K.P.; Saraswathy, R.; Balasubramanian CP, Kumaraguru Vasagam KP, Jayasankar V, Raghavan R, Alavandi SV, and Vijayan KK. (eds.)*, BRAQCON 2019: World Brackishwater Aquaculture Conference. Journal of Coastal Research,* Special Issue No. 86, pp. 6–10. Coconut Creek (Florida), ISSN 0749-0208.
- Subramoniam T. 2016. *Sexual Biology and Reproduction in Crustaceans*. Academic Press. 1st Edition.

I. Course Title : Tools and Techniques in Biochemistry

II. Course Code : FPB 508

III. Credit Hours : 1+2

IV. Aim of the course

Different experimental techniques in the fish Biochemistry.

V. Theory

Unit I

Theory and application of spectrophotometry: Beer-Lambert's law; Calibration plot; UV-visual, fluorescent, IR, CD spectroscopy, Atomic mass spectroscopy, RT-PCR and NMR, X-ray crystallography.

Unit II

Basic principles of chromatography: Theory and applications of paper, Affinity, Column, Thin layer, Ion-exchange, Size exclusion and gas chromatography, HPLC; HP-TLC; LC-MS; Factors affecting chromatographic resolutions, Resolving power and retention time.

Unit III

Radioimmunoassay (RIA) and Enzyme-linked immunosorbent assay (ELISA): Basic principle and application in quantitative estimation of biological analytes; Development of assays.

Unit IV

Electrophoresis: Theory and applications of electrophoresis; Gel electrophoresis of proteins and nucleic acids, Determination of molecular weight of proteins and nucleic acids; Electrophoretic Mobility Shift Assay (EMSA).

VI. Practical

Spectrophotometric estimation of biomolecules: Spectrum analysis, Validation of Beer-Lamberts law IR spectroscopy FTIR, NMR Isolation and purification of protein; protein isolates and concentrate preparation, chromatographic purification of proteins, Separation of amino acids by paper chromatography; TLC separation; HPLC analysis GC-MS analysis; Qualitative and quantitative estimation of fatty acids by gas chromatography; Isolation of plasmid and genomic DNA, Total RNA, PCR, RT-PCR and qPCR, Separation of proteins and nucleic acids by gel electrophoresis: Vertical and horizontal electrophoresis. RIA and ELISA.

VII. Suggested Reading

- *Encyclopaedia of Tools and Techniques in Biochemistry and Molecular Biology*, 3 Vol Set, 2015 by Darrel Crasta.
- Katoch, R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*.
- Sharma, R.K. and. Sangha, S.P.S. 2020. *Basic Techniques in Biochemistry and Molecular Biology*.
- Wilson and Walker, 2010. *Principles and Techniques of Biochemistry and Molecular Biology*.
- *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology* 8th edition, 2018 by Andreas Hofmann (Editor), Samuel Clokie (Editor).

I. Course Title : Diagonistic Biochemistry

II. Course Code : FPB 507

III. Credit Hours : 2+1

IV. Aim of the course

To understand the different aspects of biochemical diagnostic Techniques.

V. Theory

Unit I

Blood analysis: Analytes in blood, Tissues, Invasive and non-invasive techniques of blood drawing in fish, Their limitations and interpretation, Hemoglobin, Hematocrit, Plasma proteins, Glucose tolerance test.

Unit II

Enzymes and metabolic disorders: Subcellular distribution of enzymes, Isolation and purification of enzymes, General properties, Enzyme activity, Marker enzymes, Metabolic disorders related to carbohydrate, Lipid, Protein and nucleic acid metabolism in fishes.

Unit III

Enzyme markers: Enzymes and iso-enzymes of clinical significance; Acid phosphatase, Alkaline phosphatase, Amylase, angiotensin converting enzyme, Cholinesterase, Creatine phosphokinase, Gammaglutamyl transferase, Lactate dehydrogenase.

Unit IV

Vitamins and minerals: Vitamins and Minerals sub-clinical and clinical deficiencies, Electrolytes and acid-base balance**,** Regulation of electrolyte content of body fluids, Biochemical indicators for vitamin and mineral stress.

Unit V

Lipids carriers and disorders: Chylomicrons, VLDL and IDL, HDL, LDL - Implications in disease, Fatty liver, liver, kidney and bone disorders, Liver function tests, Detoxification mechanisms of gill, liver and kidney, Pesticide poisoning.

Unit VI

Immunoglobulins: Structure, Classes, Properties and functional significance of Immunoglobulins, Monoclonal antibodies.

VI. Practical

Estimation of blood glucose, albumin and globulin, gel electrophoresis of serum proteins, quantification of serum proteins, determination of A/G ratio in serum, Analysis of stress proteins; Liver and plasma enzyme assay (GOT, GPT, ALP, AchE, CPK, LDH, Urease); Blood hemoglobin, serum bilirubin, Blood calcium. Histology of vital organs. Estimation of vitamin A and D. Tests for immunoglobulins.

VII. Suggested Reading

- *Clinical Biochemistry*, Michael Murphy, Elsevier, 2018.
- *Clinical Biochemistry*, 2016 by Maheshwai Nanda
- *Manipal Manual Of Clinical Biochemistry*, 2013 by Nayak Shivananda.
- *Practical Clinical Biochemistry Methods And Interpretations*, 2020 by Ranjna Chawla

I. Course Title : Principles of Fish Nutrition

II. Course Code : FPB 509

III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic principles of fish nutrition and the role of different nutrients.

V. Theory

Unit I

Protein nutrition: Protein and amino acids, Their specific functions, Classification and evaluation criteria of dietary protein (nutrient gain, nutrient efficiency, TGC, PER, NPU, BV, EAAI, chemical score), Protein deficiency symptoms.

Unit II

Lipid nutrition: Lipids and fatty acids, Their specific functions, Classification and evaluation of lipid quality, Lipid deficiency symptoms.

Unit III

Carbohydrate nutrition: Carbohydrates, Functions, Classification and Utilization of carbohydrate in fish diets.

Unit IV

Vitamin and mineral nutrition: Specific functions, Classification, Sources of vitamins and minerals and their deficiency symptoms.

Unit V

Nutritional energetics: Definition, Different forms of energy and energy value of feed (gross energy, digestible energy, metabolizable energy, net energy), Importance of protein-energy ratio in fish diets.

Unit VI

Larval and Brood stock nutrition: Larval gut morphology, Importance of live feed and formulated feeds in larval nutrition, Nutrients required for egg and sperm quality and reproductive efficiency.

VI. Practical

Proximate analysis; moisture, crude protein, crude lipid, gross energy, ash, acid insoluble ash, crude fibre, nitrogen free extract of feed and fish tissue, analysis of fatty acids and amino acids, calcium, phosphorus, vitamin C content of feed.

VII. Suggested Reading

- *ADCP (Aquaculture Development and Co-ordination Programme)*. 1980. Fish Feed Technology, ADCP/REP/80/11.FAO, Rome.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.
- *FAO Training Manual Related to Feed Analysis*.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*, Springer Praxis Publishing, Chichester, U.K.
- Halver JE. 1989. *Fish Nutrition, Academic Press*, San Diego, Califonia.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Paulraj R. 1993. *Aquaculture Feed*. CMFRI publication, 84 pp.

I. Course Title : Nutraceuticals as Functional Foods

II. Course Code : FPB 510

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutraceuticals in the physiological wellbeing of fish and shellfish.

V. Theory

Unit I

Functional foods v/s Nutraceuticals: Definitions, Concepts and Beneficial roles, Application of functional foods in immune modulation and disease prevention.

Unit II

Characteristics of nutraceuticals and delivery systems: Nanotechnology of drug delivery system such as biocompatible polymers, Stimuli responsive polymers.

Unit III

Modes of action and benefits: Probiotics, Prebiotics, Stanols and sterols, Their immunomodulatory effects.

Unit IV

Stress mitigation and growth enhancement: Interrelationships of stress and growth in fish, Functional feed additives and role of functional foods in stress mitigation and growth enhancement.

VI. Practical

Estimation of immunomodulatory parameters (lysozyme, NBT, MPO, antibody titre), estimation of antioxidant enzymes (SOD, catalase, GPx), extraction of bioactive compounds, in vitro antioxidant assay, Pro PO.

VII. Suggested Reading

- DeFelice SL. 1995. *The Nutraceutical Revolution: Its Impact on Food Industry R & D. Trends in Food Science and Technology*, 6(2), pp.59-61.
- Luckstadt C. 2008. *Utilization of Acidifiers in Nutrition and Feeding of Tropical Fish–A Mini-Review*. Bulletin of Fish Biology Volume, 10(1/2), pp.105-109.
- Kalra EK. 2003. *Nutraceutical-Definition and Introduction*. AapsPharmsci, 5(3), pp.27-28.

I. Course Title : Fish Pathology and Immunobiology

II. Course Code : FPB 511

III. Credit Hours : 1+1

IV. Aim of the course

Different aspects of immunostimulants and their effect on fish immunity, stress and disease resistance.

V. Theory

Unit I

Basic principles of immune system: Immune system in fishes, Cell and organ involved in immunity.

Unit II

Mechanism of immunity: Different mechanisms, Humoral and cell mediated immunity, Cytokines, Interferon, Lymphokine, Chemokines, Their role in immune response.

Unit III

Immunoprophylaxis: Immunoprophylaxis in fish, Toxin, Toxoid and Vaccines, Immuno-stimulant and immunomodulation.

Unit IV

Antibodies and their function: Biosynthesis of antibody, Function of different antibodies; Interaction of Endocrine with immune system; antibody classes and genes involved.

VI. Practical

Challenge study, Lysozyme activity, Estimation of NBT and MPO Estimation of CBC. Estimation of prophenol oxidase, Estimation of superoxide dismutase, Estimation of IgM.

VII. Suggested Reading

- Anderson DP. 2003. *Textbook of Fish Immunology*. Narendra Publishing House, Delhi.
- *BIOS Instant Notes in Immunology*, 2011 by Peter Lydyard, Alex Whelan, et al.
- Delves PJ. 2017. *Roitts Essential-Immunology*. Wiley Blackwell, UK.
- Ellis AE. 1985. *Fish and Shellfish Pathology*. Academic Press, London.
- *Fish Diseases and Disorders*. CABI, Wallingford, UK 2010
- Folds JD. 1999. *Clinical Immunology*. ASM Press, U.S.A
- Leatherland JF. 1998. *Fish Diseases and Disorders*. Vol 2. CABI Publishing, Oxon.
- Richard C. 2015. *Immunology A Short Course*. Wiley Blackwell, UK.
- Roberts RJ. 2012. *Fish Pathology*. 4th Ed. W.B. Saunders.
- Sharma DK. 2015. *Immunology*. New India Publishing Agency, New Delhi.
- Sparks A. 1972. *Invertebrate Pathology: Non-ommunicable Diseases*. Academic Press, New York
- Swain P and Sahoo PK. 2006. *Fish and Shellfish Immunology* NPH, Delhi.
- Stolen JS. 1986. *Fish Immunology*. Elsevier, Amsterdam.

I. Course Title : Sensory Physiology

II. Course Code : FPB 512

III. Credit Hours : 1+1

IV. Aim of the course

To understand different sensory organs and their functional mechanism in fish.

V. Theory

Unit I

Sense organs and their functions: Electroreceptors, Chemoreceptors, Baroreceptors, Propioreceptors, Hydroreceptors and Photoreceptors.

Unit II

Olfactory and auditory organs: Physiological mechanisms; Fisheries acoustics.

Unit III

Sensory neurons: Action potential, Synapse, Neurotransmitters, Impulse transmission, Excitation-contraction coupling.

Unit IV

Luminescence: Chemoluminescence and bioluminescence; Chromatophores; electrophysiology.

VI. Practical

Practical on chemoreception using different feeding attractants. Study of chemosensor cell function in response to salinity, dissolved oxygen levels and pH changes Chromatophores function in relation to background colour light, temperature, etc.

VII. Suggested Reading

- Toshiaki Hara and Barbara Zielinski. 2006. *Fish Physiology: Sensory Systems Neuroscience*. Volume 25.
- TH Bullock, A Fessard *et al*. *Electroreceptors and Other Specialized Receptors in Lower Vertrebrates*: 3 / 3 (Handbook of Sensory Physiology).
- Joseph A Sisneros. 2011. *Fish Hearing and Bioacoustics*: An Anthology in Honor of Arthur N. Popper and Richard R. Fay: 877 (*Advances in Experimental Medicine and Biology*).
- Shaun P Collin, N Justin Marshall *et al*. 2003. *Sensory Processing in Aquatic Environments*.

I. Course Title : Physiology of Fish Behaviour

II. Course Code : FPB 513

III. Credit Hours : 1+1

IV. Aim of the course

To understand the behavioural physiology of fish.

V. Theory

Unit I

Fish behavior: Concept, types, and regulatory mechanism.

Unit II

Feeding and predation: Predatory avoidance; Feeding behavior

Unit III

Social and reproductive behavior: Sexual and aggressive behavior; Parental behavior; Endocrine control of behaviours.

Unit IV

Adaptation mechanism in altered environment: Migration, Schooling, Shoaling, bottom dwelling.

VI. Practical

Tagging studies, Audio visual recording of behavior in simulated experiment.

VII. Suggested Reading

- Katherine Sloman Sigal Balshine Rod Wilson Volume 24. *Fish Physiology: Behaviour and Physiology of Fish*.
- Margaret E. Brown. 2013. *The Physiology of Fishes: Behavior*.
- Tony J. Pitcher, 2012. *The Behaviour of Teleost Fishes*.

I. Course Title : Pharmaco-biology of Aquaculture Drugs

II. Course Code : FPB 514

III. Credit Hours : 1+1

IV. Aim of the course

To understand aquaculture drugs and their delivery mechanism.

V. Theory

Unit I

Drugs in aquaculture and fish health management: E.O., FDA and ISO standards of levels of drugs.

Unit II

Pharmacological studies: Kinetics and dynamics; Detoxification; Drug metabolic profile; Liver function tests.

Unit III

Chemotherapeutic agents: Antiprotozoal agents, Ectoparasiticide, Antihelmenthic, Anaesthetics; Dosage determination/ optimization.

Unit IV

Antimicrobial drugs: Antibacterial, Antifungal, Antiviral drugs and their delivery system.

VI. Practical

Estimation of residual level of different drugs; Minimum Inhibitory Concentration of drugs test, Pharamaco-kinetics of aquaculture drugs

VII. Suggested Reading

- Bryan LE. 1989. *Handbook of Experimental Pharmacology*. Vol 91. Springer-Verlag, Berlin.
- Brown KM. 2000. *Applied Fish Pharmacology*. Kluwer Academic Press, London.
- Herwig N. 1979. *Handbook of Drugs and Chemicals used in the Treatment of Fish Diseases*. Charles C Thomas, Springfield
- Khory RN. 1999. *Material Medica of India and their Therapeutics*. Komal Prakashan, Delhi
- Lancaster R. 1980. *Pharmacology in Clinical Practice*. William Helnemann Medical Books Ltd., London
- Pandey G. 2017. *Fish Pharmacology and Toxicology*. DPH, New Delhi.
- Riviere JE. *Veterinary Pharmacology and Therapeutics*. John Wiley and Sons, U.S.A
- Radostits M. 2000. *Veterinary Medicine*. Bookpower Publisher, China
- Singh ISB. 2003. *Aquaculture Medicine* Cochin University 2003. 336p
- Stockopf MK. 1993. *Fish Medicine*. W.B. Saunders Company, London

I. Course Title : Ecophysiology of Fishes

II. Course Code : FPB 515

III. Credit Hours : 1+1

IV. Aim of the course

To understand the physiology of fish in changing ambient environment.

V. Theory

Unit I

Fish habitats: Disruption of habitats; Pollutants, Toxicants and Radionuclides emittants.

Unit II

Climate change effectors: Impacts on ecology, Growth and reproduction; Mitigation mechanisms; Migration patterns.

Unit III

Thermal and hypoxic stress: Physiological and metabolic responses; Heat shock protein (HSP); Hypoxia Inducing Factor (HIF); cardiovascular and gill ventillatory systems.

Unit IV

Radioecology: Occurrence of radioactive substances in water and threat on food chain, Use of radioisotopes in tracer techniques for metabolic studies, International radiological limits for the export and import of aquatic products; Radioactive substances and fish physiology.

VI. Practical

Estimate threshold of thermal and hypoxia tolerance, Estimation of LC_{50} of pollutants, Estimation of stress enzymes, isozymes, Estimation of cortisol. Use of isotopes in tracer techniques for metabolic studies, Quantification of Tritium and other radioisotope levels in fish tissues.

VII. Suggested Reading

- JC Rankin, Frank B Jensen. 2020. *Fish Ecophysiology* (Fish and Fisheries Series, Volume 9) Special Indian Edition.
- T Braunbeck, W Hanke *et al*. 1991. *Fish: Ecotoxicology and Ecophysiology: Proceedings of an International Symposium*, Heidelberg, September, 1991.
- Jeffrey Richards, Anthony Farrell, Colin Brauner. 2009. *Fish Physiology: Hypoxia*. Volume 27.
- Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
- Eddy B and Handy RD. 2014. *Ecological and Environmental Physiology of Fishes*: 04 (Ecological and Environmental Physiology Series), Oxford University Press.
- Pankhurst NW, Herbert NA. 2013. *Fish Physiology and Ecology: The Contribution of the Leigh Laboratory to the collision of paradigms*. New Zealand Journal of Marine and Freshwater Research. DOI https://doi.org/10.1080/00288330.2013.80823.

I. Course Title : Enzymology

II. Course Code : FPB 516

III. Credit Hours : 2+1

IV. Aim of the course

To understand enzyme kinetics and regulation.

V. Theory

Unit I

Enzymes: Introduction; enzyme specificity; Mode of action; Nomenclature, Classification and EC numbering; Structure of enzymes, active site.

Unit II

Enzyme kinetics and equilibrium: Kinetics; Enzyme equilibrium; Single substrate enzyme kinetics and factors affecting the rates of enzyme catalyzed reactions; Michaelis- Menten equation; K_m and V_{max} values; Enzyme efficiency; Line weaver and Burke Plots; Multi-substrate enzyme kinetics.

Unit III

Enzyme inhibition: Reversible and non-reversible, Competitive, Uncompetitive and Non-competitive inhibition; Enzyme poisoning.

Unit IV

Enzyme regulation: Allosteric enzymes; Factors affecting enzyme activity, Holoenzyme and coenzyme, Zymogens, Isoenzymes, Ribozymes; Immobilized and restriction enzymes.

Unit V

Role of vitamins in enzyme reactions: Structure and biological function of coenzyme A, Thiamine pyrophosphate, Pyridoxal phosphate, NAD+, NADP+, FMN, FAD, Lipoic acid and vitamin B12; Mechanisms of reactions catalyzed by above cofenzymes.

Unit VI

Role of elements in enzyme reactions: Copper enzymes, Superoxide dismutase, Cytochrome oxidase Coenzymes; Molybdenum enzymes: Xanthine oxidase; Zinc enzymes: Carbonic anhydrase, Carboxy peptidase and Interchangeability of zinc and Cobalt in enzymes; Vitamin B12 and B12 coenzymes.

VI. Practical

Enzyme extraction and purification, specific activity, enzyme substrate reactions, mode of enzyme kinetics, assay of enzyme activity (alkaline phosphatase, transaminases, amylase, LDH, MDH, G6PD).

VII. Suggested Reading

- David L. Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- *ENZYMES: Biochemistry, Biotechnology*, Clinical Chemistry, 2/E, 2008 by Trevor Palmer and Philip Bonner.
- *Fundamentals of Enzymology: Cell and Molecular Biology of Catalytic Proteins*, 1999 by Price Nicholas C. and Lewis Stevens.

I. Course Title : Fish Nutrigenomics

II. Course Code : FPB 517

III. Credit Hours : 2+1

IV. Aim of the course

To understand the nutrient-gene interactions in fish

V. Theory

Unit I

Functional Genomics: Comparative nutrigenomics to understand the metabolic diversity; Nutritional biochemistry and Climate change.

Unit II

Nutritionally important genes: Genes regulation by protein lipid, Carbohydrates, Genes in fatty acid synthesis, Desaturases, Elongases, Genetic control of metabolic pathways.

Unit III

Omic Studies: Transcriptomics, Proteomics and Metabolomics.

Unit IV

Epigenesis: Methylation, Acetylation and Farnesylation, Nutrigenetics, Histone modifications.

Unit V

Techniques used in omic studies: RT PCR, cDNA synthesis, Realtime PCR, Gene cloning and Restriction digestion.

Unit VI

Basic bioinformatics tools: Primer designing, Softwares, Data mining and NGS data analysis. Full genome sequencing of fishes

VI. Practical

Short term nutrigenomics experiment for gene expression study; glycolytic enzymes expressions in fish liver; studies on fatty acid synthesis; Desaturases and elongases expressions.

VII. Suggested Reading

- Fingerman M, Nagabhushanam R and Thompson MF. 1997. *Recent Advances in Marine Biotechnology* (vol1-3). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Glick BR and Pasternak JJ. 1999. *Molecular Biotechnology: Principles and Applications of*

Recombinant DNA Technology, ASM Press, Washington, D.C.
- Lehninger AL. 1984. *Principles of Biochemistry*. CBS Publishing, New Delhi.
- Primrose SB. 1989. *Modern Biotechnology*. Blackwell Scientific, Oxford.
- Rodney B. 1998. *Concepts in Biochemistry*. Cole Publishing Company London.
- Kaput J, Rodriguez RL. 2006: *Nutraceutical Genomics*. Wiley Interscience Hoboken, New Jersey.
- Martin SAM, Król E. *Nutrigenomics and Immune function in Fish: New Insights from Omics Technologies*. Dev Comp Immunol. 2017; 75(Suppl C): 86–98.
- Afman L, Müller M. 2006. *Nutrigenomics: from Molecular Nutrition to Prevention of Disease*. J Am Diet Assoc 106: 569-576.
- Fenech M, El-Sohemy A, Cahill L, Ferguson LR, French TA *et al*. 2011. *Nutrigenetics and Nutrigenomics: Viewpoints on the Current Status and Applications in Nutrition Research and Practice*. J NutrigenetNutrigenomics 4: 69-89.
- Pedro M.Rodrigues, Tomé S.Silva, Jorge Dias and Flemming Jessen. 2012. *Proteomics in aquaculture: Applications and trends. Journal of Proteomics*. 75: 4325-4345
- Panserat S, Kaushik S. 2010. *Regulation of Gene Expression by Nutritional Factors in Fish*. Aquacult Res 41: 751–762.
- Panserat S, Kirchner S, Kaushik S. 2007. *Nutrigenomics*. In: Nakagawa H, Sato M, Gatlin D III (eds) *Dietary Supplements for the Health and Quality of Cultured Fish*. CAB International North America, USA, pp 210–229.

I. Course Title : Feeds and Feed Technology

II. Course Code : FPB 518

III. Credit Hours : 2+1

IV. Aim of the course

To learn basic concept of feed formulation and different feed processing techniques

V. Theory

Unit I

Feed formulation: General principles and criterions, Different methods of feed formulation; Pearson's square method and least cost formulation (quadratic equation, solver function, graphic solution, Linear programming and software assisted formulations), Limitations of formulation methods.

Unit II

Types of feed: Wet, Moist and Dry (pellets – steam compressed, extruded and crumbled, flakes, powdered/ mash, micro-encapsulated, micro-bound and micro-coated diets), Farm made feeds, experimental diets; Reference diet, purified and semi-purified diet, Compact pellet, Floating and slow sinking pellet feeds; Starter, grower, Finisher and Broodstock feeds, High energy eco-friendly and medicated feed.

Unit III

Feed processing technology: Receiving of raw materials, Equipments used in feed manufacture and processing; Grinder/pulverizer, mixer, Pelletizer/extruder, Crumbler, drier, Vacuum coater/ fat sprayer, Automatic bagging and sealing, Role of pre-conditioning in feed preparation, Effects of processing on the nutritional value and availability of nutrients.

Unit IV

Feed storage: Hydro-stability of feed and their storage; Prevention of spoilage from rancidity, Fungus and associated toxins; Vectors of fish disease in feed and quality control; Nutritional value in relation to feed storage.

Unit V

Feed additives and supplements: Binders, carotenoids, Attractants, Antioxidants, probiotics, Prebiotics, Synbiotics, Immunostimulants, Nutraceuticals, Acidifiers and preservatives, Bile acids, Herbal additives and Vitamins, minerals, Limiting amino acids, Essential fatty acids, Phospholipids, and cholesterol.

Unit VI

Quality control in fish feed manufacturing: Quality control procedures, Raw materials, Finished products; Safety of farm fish products, Harmful residues (pesticides, antibiotics, and pollutants), Geometrical, and physical feature; Mechanical characteristics in air, Behavioural characteristics in water, Feed economics and evaluation.

VI. Practical

Feed formulation: Preparation of mineral and vitamin premix. Feed additives, binders, water stability test, and available lysine. Determination of feed particle size. Development of feed dispensers both for laboratory and pond feeding as part of project assignment. Visit to feed processing industries.

VII. Suggested Reading

- *ADCP (Aquaculture Development and Co-ordination Programme)*. 1980. Fish Feed Technology, ADCP/REP/80/11.F.A.O., Rome.
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture Chapman and Hall Aquaculture Series*, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver JE. 2002. *Fish Nutrition*. Academic Press, San Deigo, C.A.
- ICAR-IRRI Outreach programme
- Muir JF and Robert D. (Eds.). 1998. *Recent Advances in Aquaculture* Vol.II., Blackwell Science
- New MB. 1987. Feed and Feeding of Fish and Shrimp. *A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture*. ADCP/REP/87/26 F.A.O., Rome.

I. Course Title : Nutritional Requirement and Feeding Management

II. Course Code : FPB 519

III. Credit Hours : 2+1

IV. Aim of the course

To learn nutritional requirements, feeding methods and feed management of commercially important fish and shellfish

V. Theory

Unit I

Nutritional requirements of finfish and shell fish: Nutritional requirements of larvae, Growout and Broodstock of commercially important finfish and shellfish,

–Methods of studying nutritional requirements; Qualitative and quantitative methods; Nutrients deficiency symptoms.

Unit II

Nutritive value of live food: Algae, Artemia, Cladocerans, Ostracods, Rotifers and Copepods, Bio enrichment of artemia and zooplankton, Experimental diets; Reference diet, Purified and semi-purified diet.

Unit III

Response indices for nutrient requirement studies: Weight gain, Specific growth rate (SGR)/ Daily growth coefficient (DGC), Thermal growth coefficient (TGC) and, Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER), Net Protein Utilization (NPU), Physiometabolic parameters, Dose response curves, Gonadosomatic Index (GSI).

Unit IV

Body composition of fish and shellfish: Influence of nutrients on body composition and flesh quality; Effect of rations on fecundity and egg quality.

Unit V

Feeding methods and devices: Broadcasting, bag feeding, tray feeding, Raft feeding, Demand feeder, Mechanical automatic feeder, Blower feeder, Check tray feed monitoring, Ration size/ feeding rate and feeding frequency, Restricted feeding and mixed feeding.

Unit VI

Feeding management: Application of research findings to farming situations, Record keeping, growth prediction and feeding management.

VI. Practical

Determination of feed intake in fry and fingerlings; Determination of nutrient requirements of fish/prawn using purified diet; Analysis of experimental data from growth study; Measures of protein quality (PER, NPU, BV); Exercise on feeding.

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva, SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver, J. E, andTiews, K. T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II, Heenemann, Berlin.
- Halver, J. E. 1989. *Fish Nutrition*. Academic Press, San Diego, CA.
- Halver, J. E. and Hardy, R. W. 2002. *Fish Nutrition*. Academic Press, London.
- Cho, C.H. and Kaushik, S.J.1990. *Nutritional Energetics in Fish: Energy and Protein Utilization in Rainbow Trout*. World Review on Nutrition and Dietetics.61: 132-172.
- Houlihan, D., Boujard, T. and Jobling, M. 2001. *Food Intake in Fish*. Blackwell Science Ltd., London.
- Kaushik, S.J. 1998. *Nutritional Bioenergetics and Estimation of Waste Production in Non-Salmonids*. Aquat living resour 11(4): 211-217
- New, M. B. 1987. Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.
- NRC.2011. *Nutrient Requirements of Fish*.

Course Title with Credit Load
Ph.D in Fish Physiology and Biochemistry

Course Code	Course Title	Credit Hours
	Major Course	**12 Credits**
FPB 601*	Advances in Fish Physiology	2+1
FPB 602*	Advances in Fish Biochemistry	2+1
FPB 603*	Climate change and adaptive physiology	2+1
FPB 604*	Analytical Biochemistry and Instrumentation	1+2
	Minor Courses	**6 Credits**
	(From the subjects closely related to a student's major subject)	
FPB 605	Endocrinology	2+1
FPB 606	Intermediary Metabolism	2+1
FPB 607	Proteomics and metabolomics	1+1
FPB 608	Diagnostic biochemistry and physiology	1+2
FPB 609	Macro and Micronutrient Nutrition	2+1
FPB 610	Feed Technology and Feed Mill Management	2+1
FPB 611	Larval and Brood stock Nutrition	1+2
	Supporting Courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Total Course Work Credits	**23 credits**
	Doctoral Seminar	2 Credits
FPB 691	Doctoral Seminar-I	0+1
FPB 692	Doctoral Seminar - I	0+1
	Doctoral Research	**75 Credits**
FPB 699	Doctoral Research (Semester II)	0 + 15
FPB 699	Doctoral Research (Semester III)	0 + 15
FPB 699	Doctoral Research (Semester IV)	0 + 15
FPB 699	Doctoral Research (Semester V)	0 + 15
FPB 699	Doctoral Research (Semester VI)	0 + 15
	Total Ph.D. Program Credit Hours	**100 Credits**

*Major compulsory subjects

Course Contents
Ph.D in Fish Physiology and Biochemistry

I. Course Title : Advances in Fish Physiology
II. Course Code : FPB 601
III. Credit Hours : 2+1

IV. Aim of the course

To understand the advances in fish Physiology

V. Theory

Unit I

Cardio-vascular Physiology: Laws of Thermodynamics; Raoult's law; Partial pressure of oxygen and carbon dioxide in gas and blood; Blood pressure; Cardiac morphology and output; ECG; Environmental influences of fish Cardiovascular physiology; Cardiac plasticity in fish.

Unit II

Physiology of bimodal gas exchanges: Haemoglobin; structure and functions; Carbonic anhydrase and respiration; Oxygen sensing; Respiratory control, Concept of fluid dynamics across respiratory structures; Mechanism of gaseous exchange.

Unit III

Physiology of ion transport and excretion: Functional morphology of branchial ionocytes; Mechanism of ion transport and water balance, Osmo-sensing, Role of gut and Kidney in osmoregulation, Nitrogen excretion.

Unit IV

Understanding growth in fish: Myogenic cells and growth; Muscle satellite cells; muscle fibre dynamics, Genetic and environmental factors regulating muscle growth; Diversity and plasticity in muscle fiber.

Unit V

Reproduction and Fertility: Formation of eggs and spermatozoa; Vitellogenin: structure, Synthesis and transportation to oocytes; Egg envelop proteins; Gonadal steriodogenesis; Physiology of Fertilization; Mechanism of egg activation and endocrine disruption.

Unit VI

Reproductive biotechnology: Cryopreservation of milts/germ cells, Process of sex reversal; Development of surrogate brooders, Growth hormone, transgenesis in fish.

VI. Practical

Measurement of heart rate, ECG; Measurement of Osmolality of plasma and muscle, Techniques for examining of channel proteins under environmental conditions, Assay of reproductive steroids; Examination of progress of gonad maturity in fish; DNA/RNA ratio measurement as an indicator of growth parameter.

VII. Suggested Reading

- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: from Basic Studies to Biotechnological Applications*. Springer Publ.
- Dietmar Kültz. 2012. *The Combinatorial Nature of Osmosensing in Fishes.* Physiology (Bethesda), 27(4): 259-75. doi: 10.1152/physiol.00014.2012. PH
- Evans DH and Claiborne JB. 2009. *Physiology of Fishes*, Fourth edition, CRC press.
- Farrell AP. 2011. *Encyclopedia of fish physiology: from genome to environment*. Volume 1-3, Academic Press.
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 2 The Endocrine System. Academic Press
- Hoar WS, Randall DJ and Donaldson EM. 2014. Fish Physiology Vol. 9A, *Reproduction: Endocrine Tissues and Hormones*. Academic Press.
- Hoar WS. 2014. Fish Physiology Vol. 9B. Academic Press
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 4 The Nervous System, Circulation and Respiration. Academic Press
- Johnston 2014. Fish physiology (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014: "v, 318p" ISBN: 978-93-5107-130-3
- Lee CS and Donaldson EM. eds. 2012. *Reproductive Biotechnology in Finfish Aquaculture*. Elsevier.
- Nielsen 1983. Animal Physiology: adaption and environment New York Cambridge University Press Edition: 3rd: "xii, 619p"
- Samantaray K. 2015. *Physiology of Finfish and Shellfish*. New India Publ. Agency.
- Smith Lynwood S. 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Smith Lynwood S. 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Val. 2006. Physiology of tropical fishes. California Elsevier Academic Press: "xiv, 634p"; 23cm ISBN: 0-12-350445-7.
- William O. Reece, Eric W. Rowe. 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5th Edition. ISBN: 978-1-119-27086-7, Wiley-Blackwell p. 576.
- Yoshida, Manabu, Asturiano, Juan F. (Eds.) 2020. *Reproduction in Aquatic Animals: From Basic Biology to Aquaculture Technology*. SPRINGER.

I. Course Title : Advances in Fish Biochemistry

II. Course Code : FPB 602

III. Credit Hours : 2+1

IV. Aim of the course

To understand advances in fish biochemistry.

V. Theory

Unit I

Saccharide chemistry: Significance of monosaccharides; Amino sugars, Acidic sugars, Glycosides, Sulfonated sugars; Oligosaccharides; Mannan oligosaccharide, Fructose oligosaccharide, Galactose oligosaccharide, Polysaccharides; Glycans, Glycogen, Mannan, Levan, Alginates, Chitin, Heparin, Keratin sulphate, Chitosan and hyaluronic acid, Carbohydrates of immunological importance.

Unit II

Lipid chemistry: Simple and complex lipids; Classification; Significance of fatty acid derivatives, Prostaglandins, Thromboxanes, Leukotrienes; Plasmalogens, Gangliosides, Sphingomyelin, Cerebrosides, Liposomes, Glycero-phospholipid metabolism, Lipids of clinical significance; Distribution patterns of lipids.

Unit III

Protein chemistry: Classification; Significance of glycoproteins, Lipoproteins, Protein folding, Trafficking and protein sequencing, Bioactive peptides; Chaperones, Heat shock proteins; Antifreeze proteins, Cytochrome P450, Metallothionenes, Immunoglobulins, Clinical proteomics, Proteins of clinical significance.

Unit IV

Nucleic acid chemistry: Classification; Types of DNA and RNA, Metabolic functions of nucleotides, Sense and antisense RNA, RNA interference; Cistron, Operon and transposon; RNA splicing, miRNA and lnRNA.

Unit V

Enzyme chemistry: Classification, Types of enzymes, Mechanisms of enzyme action, Enzyme kinetics, units of enzyme activity, Coenzymes, Co-factors and prosthetic groups, Enzymes of clinical significance.

Unit VI

Vitamin and mineral chemistry: Classification, Active forms of vitamins, Types of vitamins and essential minerals; Deficiency syndromes of vitamins and minerals; Clinical significance of vitamins and essential minerals.

VI. Practical

Extraction, purification and quantification of specific proteins by SDS-PAGE; Estimation of phytic acid, Estimation of fatty acids by GC-MS; Assay of metabolic enzymes. DNA and RNA isolation, Restriction digestion, amplification of DNA by PCR, analysis of amino acids and steroids. Assays of vitamins A and C.

VII. Suggested Reading

- David L Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- David Hames and Nigel Hooper. 2011. *BIOS Instant Notes in Biochemistry*.
- David Bender and Kathleen Botham (Eds.) 2018. *Harper's Illustrated Biochemistry* 31st Edition, Victor Rodwell.
- Gupta SN. 2019. *Biochemistry of Metabolic Processes*.
- John W Pelley. 2010. *Rapid Biochemistry*. Elsevier.
- Kasturi Samantaray. 2012. *Principles of Biochemistry with Special Reference to Fishes*.

I. Course Title : Climate Change and Physiology of Adaptation

II. Course Code : FPB 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand environmental factors affecting fish physiology leading to adaptation.

V. Theory

Unit I

Basic concepts of global warming and climate change; concept of carbon credit

Unit II

Interaction of climate change with multiple stressors (Pesticides, salinity, starvation, hypoxia, disease, pH, water hardness, turbidity; microbial load) and its impacts on fish.

Unit III

Stress responses: Primary, Secondary and tertiary stress responses; General Adaptive Syndrome, Genetically based adaptation, Modulation of intermediary metabolic pathways.

Unit IV

Thermal adaptation mechanisms: Types of heat shock proteins, Anti-freeze proteins and their roles, Enzyme variants (Isozymes), Thermal limits; Thermal optima; Mechanism of thermal adaptations, Oxygen and capacity limited thermal tolerance; Adaptive changes in proteins.

Unit V

Global warming impacts: Habitat, reproductive performance; Embryonic and larval development; Growth; Osmoregulation; Cardiovascular functions, Thermal death, DNA decay.

Unit VI

Mitigation strategies: Cross protection through behavioural, Adaptational, Nutritional and Genetic intervention.

VI. Practical

Evaluation of stress markers; plasma cortisol level, glucose, HSP expression, HIF expression; Determination of oxygen consumption rates; Determination of temperature, salinity and hypoxia tolerance in fish.

VII. Suggested Reading

- Eddy B and Handy RD. 2014. *Ecological and Environmental Physiology of Fishes*: 04 (Ecological and Environmental Physiology Series), Oxford University Press.
- JC Rankin, Frank B, Jensen. 2020. *Fish Ecophysiology* (Fish and Fisheries Series, Volume 9) [Special Indian Edition.
- Jeffrey Richards, Anthony Farrell, Colin Brauner. 2009 Fish Physiology: Hypoxia. Volume 27.
- Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
- Pankhurst NW, Herbert NA. 2013. *Fish Physiology and Ecology*: *The Contribution of the Leigh Laboratory to the Collision of Paradigms*. New Zealand Journal of Marine and Freshwater Research. DOI https://doi.org/10.1080/00288330.2013.80823.
- Pecl GT, Araújo MB, Bell JD, Blanchard J, Bonebrake TC, Chen IC, Clark TD, Colwell RK, Danielsen F, Evengård B and Falconi L. 2017. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, 355(6332), p.eaai9214.
- Schmutter K, Nash M and Dovey L. 2017. Ocean acidification: assessing the vulnerability of socioeconomic systems in Small Island Developing States. Regional Environmental Change, 17(4), pp.973-987.
- T Braunbeck, W Hanke *et al*. 1991. *Fish: Ecotoxicology and Ecophysiology: Proceedings of an International Symposium*, Heidelberg, September, 1991.

I. Course Title : Analytical Biochemistry and Instrumentation

II. Course Code : FPB 604

III. Credit Hours : 1+2

IV. Aim of the course

To understand the principles and application of analytical instruments.

V. Theory

Unit I

Spectrophotometry: UV-visual, Fluorescent spectrophotometer, Infra-red, mass spectroscopy MALDI-TOF, ESI_TOF CD spectroscopy, NMR spectroscopy, X-ray crystallography, Atomic absorption spectroscopy, ICP-MS.

Unit II

Electrophoresis: Capillary, Vertical slab and horizontal electrophoresis, Immuno-electrophoresis, 2-D electrophoresis, Imaging: SEM, TEM.

Unit III

Chromatography: Paper, TLC; HP-TLC; LC-MS ion exchange, Molecular sieving, Affinity, FPLC, HPLC and Gas Chromatography, Sonication, Centrifugation techniques, ultracentrifugation.

Unit IV

Molecular techniques: Blotting (Southern, Northern, Western) techniques; Plasmid isolation and cloning; qRT-PCR.

VI. Practical

Quantitative estimation of metabolites and enzymes, purification of proteins from tissue samples, chromatographic separation and fractionation of proteins, characterization of proteins by Native PAGE, SDS- PAGE and 2D electrophoresis, Spectrophotometric estimation of fish protein, nucleic acids and glycogen; Enzyme assay from fish tissues; Molecular weight determination of fish protein by PAGE; Isolation of plasmid and genomic DNA, and amplification by PCR, cloning of gene in vectors, selection of recombinant and non –recombinant clones, Agarose gel electrophoresis; Southern and dot blotting; Fatty acid analysis by GCMS.

VII. Suggested Reading

- Darrel Crasta. 2015. *Encyclopaedia of Tools and Techniques in Biochemistry and Molecular Biology*, 3 vol set.
- Katoch. R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*.
- Sharma RK and Sangha SPS. 2020. *Basic Techniques in Biochemistry and Molecular Biology*.
- Wilson and Walker. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*.

I. Course Title : Endocrinology

II. Course Code : FPB 605

III. Credit Hours : 2+1

IV. Aim of the course

To understand the endocrine functions in fish.

V. Theory

Unit I

Endocrine glands: Structure and functions of pituitary, Pineal, Thyroid, Ultimobranchial body, Corpuscles of Stannius, Gonads, Kidney, Adrenals, Urophysis.

Unit II

Mechanism of hormone action: Hormone receptors and signaling pathways.

Unit III

Hormones in calcium and Phosphorus homeostasis: Calcitonin, Stanniocalcin, Calcitriol, PTH- related peptide, Mechanism and interaction of PTH, Calcitonin and vitamin-D on Ca^{++} metabolism.

Unit IV

Hormones in growth, Digestion and colour change.

Unit V

Role of hormones in osmotic, Ionic regulation and adaptation, The Renin; angitensin system.

Unit VI

Reproductive hormones: Neuropeptides and hormones in regulating gonadotropins; Gonadal steroids and peptides, Prostaglandins, Adrenal steroids; Steroidogenesis

VI. Practical

Histological study of endocrine glands; *in vivo* demonstration of endocrine glands; estimation of vitamin D3; assay of steroid hormones; quantification of vitellogenin by ELISA. Analysis of expression of insulin growth factor-1 and IGFBP.

VII. Suggested Reading

- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea*. Biology Reviews.
- Greenwood MP, Flik G and Balment RJ. 2009. The Corpuscles of Stannius, Calcium-Sensing Receptor, and Stanniocalcin: *Responses to Calcimimetics and Physiological Challenges. Endocrinology*, 150(7): 3002–3010.
- Agarwal NK. 2008. *Fish Reproduction*. APH Publ.
- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: From Basic Studies to Biotechnological Applications*. Springer Publ.
- Croom HME. 2003. *Fish Endocrinology*.
- Diwan AD, Joseph S and Ayyappan S. 2008. *Physiology of Reproduction, Breeding and Culture of Tiger Shrimp*. Narendra Publ. House.
- Hoar WS and Randall DJ. 1969. The Endocrine System Volume 2. Academic Press.
- Maria RJ, Augustine A and Kapoor BG. 2008. *Fish Reproduction*.
- Norris DO and Lopez KH. 2011. *Hormones and Reproduction of Vertebrates*. Vol. I Fishes. Academic Press.
- Reinecke. 2006. *Fish Endocrinology*, Vol. 2": Enfield "Science Publishers, Inc.: "xx, 441-871pp" ISBN: 978-1-57808-415-9
- Sherwood NM and Hew CL. 2014. Fish Physiology Vol. 13. *Molecular Endocrinology of Fish*. Academic Press.
- Yonathan Zohar, José Antonio Muñoz-Cueto, Abigail Elizur, Olivier Kah 2010. *Neuroendocrinology of Reproduction in Teleost Fish*. General and Comparative Endocrinology 165 (2010) 438–455.

I. Course Title : Intermediary Metabolism

II. Course Code : FPB 606

III. Credit Hours : 2+1

IV. Aim of the course

To understand the intermediary metabolism of biomolecules.

V. Theory

Unit I

Scope and significance: Integration and regulation of lipid, Carbohydrate and protein metabolism in fishes.

Unit II

Lipid metabolism: Oxidation of fatty acids (SFA, MUFA, PUFA, HUFA); Biosynthesis of n-3 and n-6 fatty acids; Desaturases and elongases in freshwater fish; Biosynthesis of triglycerides, Phospholipids, Sphingolipids and cholesterol.

Unit III

Carbohydrate metabolism: Coordinated regulation of glycogen synthesis and breakdown; Enzymatic control of glycolysis; Feeder pathways for glycolysis; TCA cycle; Gluconeogenesis; pentose phosphate pathway; Electron transport chain.

Unit IV

Protein metabolism: Oxidative degradation of amino acids; Transamination and deamination; Biosynthesis of amino acids.

Unit V

Nucleic acid metabolism: Synthesis of deoxy and ribonucleotides; Uric acid production; Derivation of nucleotide groups of CoA, NAD, FAD from ATP.

Unit VI

Metabolomics, Proteomics, Transcriptomics; Nutrigenomics; Environmental metabolomics.

VI. Practical

Assay of mitochondrial and cytoplasmic enzymes, quantification of genes of metabolic pathways.

VII. Suggested Reading

- *Bios Instant Notes Molecular Biology*. 4th Edition, 2016 by Mclennan.
- David L Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- John W Pelley. 2010. *Rapid Biochemistry*. Elsevier
- Pandya A. *Biomolecules and Biochemical Metabolism of Fuels: Carbohydrate, Protein, Lipid Metablism* by Gupta SN 2019. Biochemistry of Metabolic Processes.
- Sharma MK. 2013. *Biomolecules and Metabolic Activities*.

I. Course Title : Proteomics and Metabolomics

II. Course Code : FPB 607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the emerging field of metabolomics.

V. Theory

Unit I

Introduction to Metabolomics and Proteomics: Functional and Structural Proteomics.

Unit II

Analytical methods: Separation and detection methods of proteins and metabolites; 2D-electrophoresis, mass spectrometry, Protein arrays HPLC, GC-MS.

Unit III

Experimental and computational methods: Databases, Genevestigator and OncoMine – browsing microarray-derived gene expression profiles.

Unit IV

Environmental Metabolomics: Nutrigenomics and metabolic health; Future challenges.

VI. Practical

Gene expression study of metabolic pathways, Cross feeding mechanism, 2D-electrophoresis, mass spectrometry, bio-informatics tools.

VII. Suggested Reading

- Afman L, Müller M. 2006. Nutrigenomics: from molecular nutrition to prevention of disease. *J Am Diet Assoc* 106: 569-576.
- Attwood TK and Smith DJP. 1999. *Introduction to Bioinformatics*. Addison Wesley Longman.
- Brown SM. 2000. *Bioinformatics: A Biologist's Guide to Biocomputing and the Internet*. Eaton Publ.
- Fenech M, El-Sohemy A, Cahill L, Ferguson LR, French TA *et al*. 2011. *Nutrigenetics and Nutrigenomics: Viewpoints on the Current Status and Applications in Nutrition Research and Practice*. *J NutrigenetNutrigenomics* 4: 69-89.
- Kaput J, Rodriguez RL. 2006. *Nutraceutical Genomics*. Wiley Interscience Hoboken, New Jersey.
- Lesk AM. 2008**.** *Introduction to Bioinformatics*. Oxford University Press.
- Martin SAM, Król E. *Nutrigenomics and Immune Function in Fish: New Insights From Omics Technologies. Dev Comp Immunol*. 2017; 75(Suppl C): 86–98.
- Mount DW. 2001. *Bioinformatics: Sequence and Genome Analysis*. ColdSpring Harbor Press.
- Overturf K. 2009. *Molecular Research in Aquaculture*. Blackwell Publishing, 395 pp.
- Panserat S, Kaushik S. 2010. *Regulation of Gene Expression by Nutritional Factors in Fish. Aquacult Res* 41: 751–762
- Panserat S, Kirchner S, Kaushik S. 2007. *Nutrigenomics*. In: Nakagawa H, Sato M, Gatlin D III (eds) Dietary supplements for the health and quality of cultured fish. CAB International North America, USA, pp 210–229
- Pedro M Rodrigues, Tomé S Silva, Jorge Dias and Flemming Jessen. 2012. *Proteomics in Aquaculture: Applications and Trends. Journal of Proteomics*. 75: 4325-4345
- Schlena M. 1999. *DNA Microarrays: A Practical Approach*, Oxford University Press, London, UK, 232 pp.

I. Course Title : Diagnostic Biochemistry and Physiology

II. Course Code : FPB 608

III. Credit Hours : 1+2

IV. Aim of the course

To monitor the systems that keep body functioning.

V. Theory

Unit I

Clinical Signs and sample collection: History, Clinical signs, Environmental conditions, Site history, Handling of animals, Sample collection, Methods of processing and preservation of samples; Fish Welfare Management; Fish welfare and emotions- functional aspects; Behavioural responsiveness; Fear; pain; Appetite, Satiety, Exercise, Metabolic shifts; Diet-gene interaction for fish welfare.

Unit II

Evaluation of cardiovascular and respiratory disorders: Partial pressures in gill and blood; Hb estimation, Blood CBC, RBC morphology, pH, Carbonic anhydrase, Blood gases: O_2, CO_2, HCO_3, H+; ECG; Doppler test; C-reactive protein; Gill morphology/pathology; oxygen exercise; Cardiovascular monitoring.

Unit III

Evaluation of homeostasis and Acid-base: Respiratory and metabolic acids, Their elimination; Blood osmolality, Chloride, Carbonic anhydrase, pH, Lactate, Ammonia; Kidney morphology.

Unit IV

Growth, reproductive and immunity disorders: Tissue DNA/RNA ratio; Metabolic enzyme profiles; Liver function tests; Appetite estimation; Hormone assay: Gonadotropins, Sex-steroids, cortisol, Blood enzymes: GOP, GPT, ALP, Glucose, CPK, LDH, Lactate, Albumin, Immunoglobin, AChE, Blood ammonia, Urea and creatinine; NH_4, NBT, Ovarian/liver biopsy, Blood CBC; Ultrasonography.

VI. Practical

Handling an sample collection; Tissue DNA/RNA; Hb estimation, RBC morphology, Blood pH and Carbonic anhydrase; Blodd gas analysis: O2, CO2, HCO3, H+; ECG; Ultra-sound, Blood osmolality, Chloride, lactate, ammonia, urea; Glycolytic enzymes; Liver function test, Blood enzymes: GOT, GPT, ALP, CPK, LDH, AChE, NBT, Immunoglobin, blood CBC, liver/ovary biopsy; ultrasonography.

VII. Suggested Reading

- *Clinical Biochemistry*, Michael Murphy, Elsevier 2018.
- *Clinical Biochemistry*. 2016 by Maheshwai Nanda
- *Manipal Manual Of Clinical Biochemistry*. 2013 by Nayak Shivananda.
- *Practical Clinical Biochemistry Methods and Interpretations*. 2020 by Ranjna Chawla
- Walker P 2005. *DNA-based Molecular Diagnostic Techniques*. Daya, Delhi 2005.

I. Course Title : Macro and Micronutrient Nutrition

II. Course Code : FPB 609

III. Credit Hours : 2+1

IV. Aim of the course

To understand recent developments in macro and micro nutrient nutrition for fish and shellfish.

V. Theory

Unit I

Protein and aminoacids: Requirements, functional roles of aminoacids, Ideal protein concept, Nitrogen excretion, Aminoacidantagonism, Improving nitrogen retention, Dietary supply of synthetic aminoacids in different forms.

Unit II

Lipid and essential fatty acids: Functions and deficiencies, Fatty acid oxidation, Antioxidants, Role of phospholipids and steroids.

Unit III

Optimization of carbohydrates in diets: Strategies for improving carbohydrate utilization; Potential of exogenous enzymes, Solid state fermentation (SSF).

Unit IV

Micronutrients: Physiological roles and functions of vitamins and minerals; Forms of supply of minerals and vitamins, Deficiency symptoms.

Unit V

Recent developments in energy nutrition and feed additives: Recent advances in nutritional energetics and feed additives, Medicated feeds (farm-made and commercial), Regulations and certification of feed additives.

Unit VI

Designer fish production: Tailoring flesh quality, Food safety, Roles of nutrients and additives (fatty acids, antioxidants, drugs etc.), Flesh quality evaluation (colour, texture and sensory), Estimation of fatty acids, Aminoacids and minerals in ingredients, feeds and Flesh of fish and shrimp; Dietary effects on nitrogen excretion.

VI. Practical

Protein quality estimation (PER, NPU), Digestibility studies. Estimation of fatty acids and amino acids.

VI. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*. ADCP/REP/80/11.F.A.O., Rome.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish*.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

I. Course Title : Feed Technology and Feed Mill Mangement

II. Course Code : FPB 610

III. Credit Hours : 2+1

IV. Aim of the course

To study the feed formulation techniques; design of feed mill and feed manufacturing; feed quality assurance and regulations.

V. Theory

Unit I

National and global scenario of feed ingredients and feed industry: Availability demand and supply; types of feeds, BIS and international standards for fish feed, overview of feed mill business.

Unit II

Feed formulation: Different methods of feed formulation, Use of feed formulation softwares; Nutritional and physical quality of feed ingredients; Importance of additives formulation of nutritionally balanced diet (amino acid, micronutrients).

Unit IV

Feed manufacturing process and control: Receiving of raw material, Grinding, Mixing, Conditioning, Pelleting /extrusion, Drying and cooling. coating/top dressing, Packaging and labelling, Factors affecting feed manufacture and stability of nutrients, Effects of processing on the nutritional value of feeds, Processing methods for non-compacting feed; Economics of feed manufacturing.

Unit III

Emerging new feed ingredients: Scope and exploration of new feed ingredients, Anti-nutritional factors and methods of detoxification (e-beam irradiation, solvent extractions, SSF, Protein concentrates/isolates, genetic improvement of plants etc.).

Unit V

Storage and quality control: Ingredient quality assurance, Feed processing quality assurance and processed feed quality assurance, Miscellaneous adventitious toxins and effect on feed safety; Storage of feed and quality deterioration, CGMPs and HACCP feed regulation, Feed transmitted bioterrorism and its implications.

Unit VI

Design of a feed mill unit: Layout, Feed mill design and safety of operation, Maintenance and record keeping.

VI. Practical

Analysis of anti-nutritional and toxic substances in feed ingredients and feed; Formulation of diets using software. Preparation of different types of feed and their quality evaluation; Effect of feed storage on nutritional value of feed, preparation of farm made feeds.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome.
- D'Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Heijden PGM van der. 2016. *The aquaculture sector of Zambezi Valley, Mozambique: Description of the current situation and emerging opportunities*.Centre for advance Innovation. Wageningenuniversity.
- ICAR-IRRI Outreach programme reports
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*, Kluwer Academic Publishers.
- Muir JF and Robert D. (Eds.). 1968. *Recent Advances in Aquaculture* Vol.II. Blackwell Science.

- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.

I. Course Title : Larval and Broodstock Nutrition

II. Course Code : FPB 611

III. Credit Hours : 2+1

IV. Aim of the course

To understand the role of nutrition in reproductive performance and larval development of fish and shellfish

V. Theory

Unit I

Embryonic and larval development: Nutritional profile of egg yolk and mechanism of egg yolk utilization, Degradation of egg yolk platelets and granules, Utilization of egg protein, Amino acid and lipid, Influence of abiotic factors on yolk absorption; Criteria for evaluation of early larval development.

Unit II

Larval digestive system: Ontogenesis of digestive systems, Digestion and absorption of protein and lipid, Mechanism of transition from endogenous to exogenous nutrition.

Unit III

Larval nutrition: Importance of live foods, Weaning diets and their importance in larval nutrition; Nutritional requirements and deficiency symptom, Nutritional status of larvae

Unit IV

Broodstock nutrition: Effect of nutrition on fecundity, Fertilization, Embryonic development and larval quality.

Unit V

Improving brood-stock performance: Special ingredients and specific nutrients for improving gonadal development and reproductive performance; Effective feeding periods for optimum brood-stock performance.

Unit VI

Feeding strategies: Manual, mechanical and automatic Feeding; feeding devices and strategies, Larval feeding behaviour and feed management.

VI. Practical

Preparation of larval feed, Nutritional profiling of egg yolk and larvae. Nutritional analysis of live food organisms, Estimation of proteases in larvae, Estimation of gonado-somatic index and fecundity.

VII. Suggested Reading

- CIFE. 1993. *Training Manual on Culture of Live Food Organisms for Aqua Hatcheries.* Central Institute of Fisheries Education, Versova, Mumbai.
- De Silva, SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and*

Crustaceans. Springer Praxis Publishing, Chichester, U. K.
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer Academic Publishers, London.
- Holt JG. 2011. *Larval Nutrition*. John Wiley & Sons, Inc.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

List of suggested Journals

- *Advances in Marine Biology*
- *Fish Physiology and Biochemistry*
- *General and Comparative Endocrinology*
- *Frontiers in Aquatic Physiology*
- *Frontiers of Physiology*
- *American Journal of Physiology*
- *Scientific Reports*
- *Plos One*
- *Journal of Experimental Biology*
- *Journal of Comparative Physiology*
- *Comparative Biochemistry and Physiology*
- *Endocrinology*
- *Journal of Endocrinology*
- *Reproduction*
- *Biology of Reproduction*
- *Reproductive Sciences*
- *Journal of Endocrinology*
- *Animal Reproduction Science*
- *Molecular Reproduction and Development*
- *Reproduction Fertility and Development*
- *Journal of Fish Biology*
- *Canadian Journal of Aquatic Science*
- *Journal of Physiology and Biochemistry*
- *Current Research in Physiology*
- *Journal of Physiology and Pathophysiology*
- *Indian Journal of Physiology and Pathophysiology*
- *Journal of Cellular Physiology*
- *Cellular Physiology and Biochemistry*
- *Histology and Histopathology*
- *American Journal of Physiology - Endocrinology and Metabolism*
- *Annual Review of Cell and Developmental Biology*
- *Aquaculture*
- *Climate Change*
- *Climate Change and Environmental Sustainability*
- *Developmental Biology*
- *International Journal for Vitamin and Nutrition Research*
- *International Journal of Food Sciences and Nutrition*
- *Journal of Animal Physiology and Animal Nutrition*
- *Journal of Nutritional Biochemistry (Nutrition Reports International)*
- *Journal of Nutritional Science and Vitaminology*
- *Aquaculture Nutrition*
- *Aquaculture Research*
- *Fish and Fisheries*
- *Fish and Shellfish Immunology*
- *Fisheries and Fisheries*
- *Fisheries management and ecology*
- *Fisheries Research*

- *Indian Journal of Fisheries*
- *Journal of Biology*
- *Journal of Comparative Neurology*
- *Journal of Environment and Bio-sciences*
- *Journal of Environmental Biology*
- *Journal of Fish Behaviour*
- *Molecular Marine Biology and Biotechnology*

List of suggested e-resources

- https://oregonstate.edu/
- https://www.dtu.dk/english
- https://www.utas.edu.au/
- http://cifa.nic.in/node/47
- http://people.tamu.edu/~tdewitt/wfsc448/index.html
- https://www.ufl.edu/academics/programs/
- https://www.nord.no/en
- https://www.uib.no/en
- http://www.fish.kagoshima-u.ac.jp/efish/field/aqu.html
- https://www.ccac.ca/en/training/modules/fish-stream.html
- https://www.u-tokyo.ac.jp/en/
- https://www.bio.mie-u.ac.jp/en/
- https://www.ntu.edu.tw/english/
- https://en.ctu.edu.vn/
- https://en.uit.no/startsida
- http://www.ncbi.nlm.nih.gov/
- http://www.genome.gov
- http://web.utk.edu/~rstrange/wfs550/html-con-pages/l-heart.html
- Fish Pathology Edition 4 by Ronald J. Roberts https://www.barnesandnoble.com › fish-pathology-ronald-j-roberts
- Fish Vaccines By Alexandra Adams https://www.springer.com › book
- Fish models in behavioural toxicology: Automated techniques, updates and perspectives. semanticscholar.org
- Physiological Methods in Fish Toxicology: Laboratory and Field Studies springer.com
- http://bioinfo.ut.ee/primer3-0.4.0/
- https://all-about-molecular-biology.jimdo.com/
- https://www.molbiolcell.org/
- http://www.web-books.com/MoBio/
- https://npsa-prabi.ibcp.fr/cgi-bin/npsa_automat.pl?page=/NPSA/npsa_sopma.html
- http://www.bioinformatics.nl/cgi-bin/primer3plus/primer3plus.cgi
- https://www.sciencedaily.com/terms/molecular_biology.htm
- https://plato.stanford.edu/entries/molecular-biology/#toc
- https://molbiol-tools.ca/Alignments.htm
- https://molbiol-tools.ca/Phylogeny.htm
- http://evolution.genetics.washington.edu/phylip/software.html
- https://www.addgene.org

Suggested Broad Areas for Master's and Doctoral Research

- Functional significance and mechanism of action of nutraceuticals /micronutrients
- Mechanistic studies with respect to drug delivery
- Pharmacokinetics and pharmacodynamics of functional molecules
- Osmoregulatory challenges in fish and shellfish with respect to altered environments
- Thermal tolerance in commercially important fishes
- Hypoxia tolerance in commercially important fishes
- Salinity tolerance in commercially important fishes
- Tolerance of nitrite of fish and shellfish

- Tolerance of ammonia in fish and shellfish and enhancing tolerance limits
- Interaction of nutrients and anti-nutrients on physiology of fishes
- Development of salinity tolerance in freshwater fishes for rearing in saline affected waters
- Rearing of marine economically important crustacea in low saline water
- Mineral fortification in inland saline water for aquaculture
- Multiple stressor interactions in fish
- Stress physiology during live transportation of fishes and their mitigation
- Waterless transportation of crustacean
- Waterless aquaculture for air breathing fishes
- Physiology of migration in commercially important migratory fishes
- Identifying physiological causes of retardation of growth in migratory fishes in captivity.
- Effect of climate change on fish physiology
- Ontogeny of gut in economically important fishes
- Physio-metabolic responses in fishes on feeding various macro and micro nutrients
- Factors affecting the immune system of fishes
- Interactions of stress and immunity
- Nanotoxicity in fishes and mitigation
- Endocrine disruption in fishes
- Effect of biotic and abiotic factors affecting brood stock and larval development
- Effect of endocrine disrupting compounds in sex determination in fishes
- Production of sterile fish
- Development of surrogate broods
- Sensor development for monitoring physiological distress
- Physio-metabolic response and pharmacodynamics of drugs administered in fishes
- Factors affecting molting frequency in crustacea
- Shell (Gastropod) selection and shell occupation behavior in hermit crab during adverse conditions
- Physiology of crab fattening
- Germ cell isolation and preservation for conservation of threatened/endangered aquatic animals
- Fish as a model for studying Systemic disorders in mammals.
- Development of chemoattractants
- Development of improved inducing systems for spawning aquatic animals
- Development of kits for assessing physiological status viz., maturity status, feeding and nutritional status
- Identifying molecular markers for assessing reproductive activity if fish and shellfish
- Development of In-vitro process of gametes maturation and ovulation.
- Development of in-vitro process for sperm production.
- Development of molecules for accelerating gonad maturity.
- Biochemical markers for evaluating purity of seed of fishes.
- Mitigation strategy of climate change effects through the nutritional intervention

ANNEXURE I

List of BSMA Committee Members for Fisheries Science-2020

(Ref: ICAR File No.7/6/2017 – EQR Dt: 04/04/2018)

Name	Address	Specialization
1. **Dr S. Felix** Vice Chancellor	Tamil Nadu Dr J. Jayalalithaa Fisheries University, Vetter River View Campus, Nagapattinam-611 002 felix@tnfu.ac.in Mobile No: 09443131025	Chairman
2. **Dr N. P Sahu** Dean	ICAR-Central Institute of Fisheries Education, Mumbai-400 061 npsahu@cife.edu.in npsahu1@rediffmail.com Mobile No: 09869120627	Convener
3. **Dr E J Jayaraj** Professor	Department of Aquaculture, College of Fisheries, Kankanady, Mangalore-575 002, Karnataka jayaettigi@yahoo.com jayaraj@fisheriesroundup.com Mobile: 09448033957	Aquaculture
4 **Dr Hukam Singh Dhaker** Dean	Faculty of Fisheries, Shirgaon, Ratnagiri, Maharashtra state, hukamsingh69@yahoo.com Mobile: 09421230257	Aquaculture
5 **Dr P. Jawahar Professor** Dean	Department of Fisheries Biology and Resource Management, Fisheries College and Research Institute, Thoothukudi-628 008, Tamil nadu jawaharphd@gmail.com Mobile: 09487078758	Fisheries Biology and Resource Management

Name	Address	Specialization
6 **Dr L.L. Sharma** Former Dean	College of Fisheries, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan Residential Address: PN-207,Road - 13, Ashok Nagar, Udaipur-313 001, Rajasthan llsharma.206@gmail.com Mobile: 09829230343	Aquatic Environment Management
7 **Dr Raman Kumar Trivedi** Professor	Department of Aquatic Environment Management, West Bengal University of Animal and Fishery Sciences, 37 & 68 Khudiram Bose Sarani, Kolkata, West Bengal-700 037 ramankumart@rediffmail.com Mobile: 09432491149	Aquatic Environment Management
8 **Dr J.J. Abraham** Professor	Department of Aquatic Animal Health Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Chakgaria, Kolkata-700 094, West Bengal abrahamtj1@gmail.com abrahamtj@yahoo.com Mobile: 09432206950 /09433368328	Aquatic Animal Health Management
9 **Dr S. Jahageerdar** Principal Scientist	Department of Fish Genetics and Biotechnology ICAR-Central Institute of Fisheries Education Panch Marg, off. Yari Road, Versova, Andheri West Mumbai, Maharashtra-400 061 jahageerdar@cife.edu.in jahageerdar@rediffmail.com jahageerdar@gmail.com Mobile: 09969300125	Fish Genetics and Biotechnology
10 **Dr K. Karl Marx** Professor	Directorate of Incubation and Vocational Training in Aquaculture (DIVA) ECR Muttukadu Chennai-603 112 kkmarx@gmail.com Mobile: 09444543858	Fisheries Biotechnology

Name		Address	Specialization
11	**Dr G. Sugumar** Professor	Directorate of Incubation and Vocational Training in Fisheries (DIVF) Mandapam Ramanathapuram-614 904 sukumar@tnfu.ac.in Mobile: 09443844820	Fish Processing Technology
12	**Dr M. Rajakumar** Professor	Department of Fisheries Extension Economics and Statistics Dr M.G.R. Fisheries College & Research Institute Tamil Nadu Dr J. Jayalalithaa Fisheries University Thalainayeru, Nagapattinam-611 002 Rajasaro@rediffmail.com Mobile: 09444232349	Fisheries Economics

Additional Technical Team

Name		Address	Specialization
1	**Dr S.A. Shanmugam** Dean (Basic Sciences)	Institute of Fisheries Postgraduate Studies OMR Campus, Vaniyanchavadi, Chennai-603 103. deanipgs@tnfu.ac.in shanmugam@tnfu.ac.in	Fisheries Microbiology & Fish Processing Technology
2	**Dr Sundaramoorthy** Dean	Fisheries College and Research Institute Tamil Nadu Dr J. Jayalalithaa Fisheries University Thoothukudi-628008 Tamil Nadu, India. deanfcrituty@tnfu.ac.in sundaramoorthy@tnfu.ac.in	Fishing Technology & Engineering
3	**Dr Sujath Kumar** Professor and Head	Dept. of Fisheries Extension, Economics and Statistics Fisheries College and Research Institute Tamil Nadu Dr J.Jayalalithaa Fisheries University Thoothukudi-628 008 sujathkumar@tnfu.ac.in	Fisheries Extension

Name		Address	Specialization
4	**Dr Aparna Choudhary** Principal Scientist & Head	Fish Genetics and Biotechnology, Central Institute of Fisheries Education, Versova, Mumbai-400 061 achaudhari67@gmail.com	Fish Biotechnology

ANNEXURE II

Consultation Process
Members of BSMA (Fisheries Science)

Chairman

Dr S.Felix, Vice-Chancellor, TNJFU, Nagapattinam

Convener

Dr N.P.Sahu, Dean, ICAR-CIFE, Mumbai

Members

1. Dr E.J.Jayaraj, Professor,
   Dept. of Aquaculture, College of Fisheries, Mangalore
2. Dr P.Jawahar, Professor,
   Dept. of Fisheries Biology and Resource Management,
   Fisheries College and Research Institute, Thoothukudi
3. Dr L.L.Sharma, Former Dean,
   College of Fisheries, Maharana Pratap University of
   Agriculture and Technology, Udaipur, Rajasthan
4. Dr Raman Kumar Trivedi, Professor
   Department of Aquatic Environment Management,
   West Bengal University of Animal and Fishery Sciences
   Presently working as Director (Students Welfare), BASU,
   Patna, Bihar
5. Dr T.J.Abraham, Professor,
   Department of Aquatic Animal Health,
   West Bengal University of Animal and Fishery Sciences,
   Kolkata
6. Dr S.Jahageerdar, Principal Scientist,
   Department of Fish Genetics and Biotechnology,
   ICAR-CIFE, Mumbai
7. Dr K.Karal Marx, Dean
   Institute of Fisheries Postgraduate Studies,
   TNJFU, Chennai
8. Dr ShyamSundar Dana, Professor
   Department of Fisheries Extension,
   West Bengal University of Animal and Fishery Sciences, Kolkata
9. Dr M.Rajakumar, Professor,
   Department of Fisheries Extension, Economics & Statistics
   Fisheries College and Research Institute, Thoothukudi
10. Dr Human Singh Dhaker, Dean
    Faculty of Fisheries, Shirgaon, Ratnagiri, Maharashtra.
11. Dr G.Sugumar, Dean
    Fisheries College and Research Institute, Thoothukudi

The consultation process was completed after four consultations involving all the stake holders like faculties of different fisheries colleges of the country, scientists of the fisheries research institutes and scientists of other ICAR research institutes, industry personnels, entreprenuers, students, faculty from overseas universities and alumini. First, third and fourth meeting was conducted among the BSMA members, whereas the 2nd workshop was conducted at ICAR-CIFE, Mumbai by involving all the stake holders for in depth discussion for 2 days. The details are given below:

First Consultation (6th August 2020)

The first meeting of the BSMA (Fisheries Science) Committee was held at ARTP, Madhavaram Campus of Tamil Nadu Dr J.Jayalalithaa Fisheries University, Chennai on 06.08.2018. The first meeting was conducted among the members of BSMA to appraise all the points to be covered while preparing the syllabus revision. It was decided that all the members to take up the task seriously as revision of PG courses is usually conducted once in 10 years and hence members should prepare a curriculum that would stay relevant for the next 10 years giving scope for improving knowledge, skill, entrepreneurship, attitude, competence and confidence of the students. The following points were discussed during the interaction

- Introduction of technology-oriented courses
- Global approach
- Developing common nomenclature for courses with ARS orientation
- Number of PG disciplines.
- Timely completion of the task

Further discussions were held on the following issues:

- Faculty improvement
- New teaching methods
- Infrastructure sharing
- Improving employability
- Bringing all fisheries professionals under one umbrella
- 4T approach (Tradition, Technology, Talent and Trade) in the course curriculum
- Uniformity among all colleges in credit load, duration of Ph.D. course work, examination pattern, supporting and compulsory courses, plagiarism, grading system, etc.
- It was decided to enlist the fisheries colleges with the courses offered
- Lengthy discussion held on bringing the subjects under 5 major disciplines in line with agriculture and animal science
- Revision of syllabus for courses and changes on need basis – A minimum of 20% change in the existing syllabi and industry requirements should be considered.
- No constructive changes be made and all based on need and changes in the field
- Aspects on climate change shall be included in all areas wherever necessary
- UG subjects shall not be repeated in PG courses although some overlap may be allowed if found inevitable
- Molecular and genetic approach should be included
- Recent references should be consulted
- New titles and content development
- Further, one credit load was suggested to be based on 6-9 instructional classes and equals 3 units of syllabus – unitization be revised accordingly.
- The non-credit course (six credits in PG) shall be completed by ICT based open / online courses relevant to fisheries
- Internship may be tried for students in industries
- Regarding admission criteria, UGC guidelines be followed

Instruction to BSMA – subject experts:

- All subject experts are requested to contact their peers in fisheries colleges and research institutes to seek for suggestions and ideas of innovations for revision of syllabus concerned to their subjects

- Any novel and new ideas shall be shared among members of BSMA for adoption
- All experts are to come up with details of
  - New titles
  - New courses
  - Percentage of content revision
  - Need for content revision
- The above details are to be presented by individual member
- All should join in a whatsapp group for fast communication
- All the members should discuss within the group if some new idea clicks, so that all will do the needful if it is accepted.
- The course contents of Animal science may be consulted for churning out any new things to be added. The experts from the overseas universities may also be consulted. All the members should share the link for overseas contact.

2.Second consultation (workshop from 18-19 February, 2019)

The second workshop on "Syllabus Revision and Academic Reformation in Higher Fisheries Education" was conducted at ICAR-Central Institute of Fisheries Education, Versova, Mumbai during 18-19th February 2019. The main objective of this workshop is to prepare a uniform syllabus for Masters and Ph.D. courses all over the country and building the competent human resource in the field of Fisheries Science by making the post-graduate programs at par with the global standard of Fisheries higher education.

Expert from various institutes, especially State Agriculture Universities and other ICAR-research institutes and student representatives from various disciplines of CIFE were attended the workshop. Discipline wise discussion was held among 12 different groups. Each group was allotted with minimum of two external subject experts, faculties of particular discipline and a student representative nominated from the particular discipline. The forenoon session included discussion of addition, deletion or modification of MFSc syllabus and PhD syllabus was covered in the afternoon session.

The second day of the programme was started with the introduction by Dr N.P. Sahu, Dean (Academics), ICAR-CIFE & Convener, BSMA (Fisheries Science) and remarks by Dr S. Felix, Vice-Chancellor, TNFU & Chairman, BSMA (Fisheries Science). Dr C. Gopal, Member Sec., CAA, Chennai, Dr Sanu Jacob, Joint Director, Export Inspection Agency, Mumbai, Dr A.K. Pal, Ex-Joint Director, ICAR-CIFE & Representative from Industry, Mr. Raghavan Sampathkumar, Executive Director, CLEFMA, Mumbai, Sri Vellanki Ravi, President, Shrimp farmers Association of India and Sri Saji Chacku, Vice-president ABG Aquaculture Ltd, Billimora, Gujarat conveyed their remarks including role of industry in framing academic curriculum. Dr G. Venkateshwarlu, ADG-EQR, ICAR and BSMA Coordinator and Dr Gopal Krishna, Director & Vice Chancellor, ICAR-CIFE conveyed their notes and commented on the remarks made by invitees.

A discussion held after the invited talks for three hours emphasizing the importance of practical oriented schemes for students, lessening course work duration for PhD, removal of compulsory non-credit courses, industry internships, graduate assistantship, video classes, improvisation of student exchange programmes and fellowships, credit course by industry, Research Ethics Committee constitution, economical support for data collection and abstract or paper publications, provisions for training to the faculties and PhD students and the reducing number of disciplines etc.

Towards the end of the session BSMA members Dr E.G. Jayaraj, Dr P. Jawahar, Dr L.L. Sharma, Dr R. K. Trivedi, Dr T.J. Abraham, Dr S. Jahageerdar, Dr K. K. Marx, Dr S.S. Dana, Dr M. Rajakumar, Dr H.K. Dhaker, Dr G. Sugumar and Dr S. Dasgupta were presented the major changes made in the syllabus of each discipline. Dr S. Felix, Dr G. Venkateshwarlu and Dr Gopal Krishna were concluded the session by emphasizing the points discussed and Dr Rupam Sharma thanked the invitees, speakers and students.

Third consultation (6th May 2019)

3rd Consultation was held on 6 May 2019 at TNJFU, Chennai among the members of BSMA (Fisheries). This was the first meeting after major revision of the course curriculum to discuss the following points:

- Semester-wise break-up of courses along with credit hours
- Courses should be breakup under the heading Major, Minor and supporting, Seminar and Research
- There will be two and one semester course work for Master and Ph.D, respectively.
- Filed visit may be kept within the total credit (2 credit) for one month. This is only subject specific. If you feel, it is not required for your discipline may not be kept.
- The Contents under each course should be divided into units and it should be uniformly followed. For example, if a course is 1+0, total units should be 3, which should be covered with 18 classes. Similarly, for 2+1 the units should be 6, which should be covered with 36 classes and for 3+1, it should be 9 units and covered with 54 classes.
- Inclusion of some references and suggest names of books for each courses
- 2-3 objectives should be written for each course, justifying the inclusion of that course
- For framing the academic rules the academic guidelines developed by the Rani Laxmi Bai CAU, Jhansi should be considered as the base with some modification as deemed fit with the consent of core committee members.

Fourth Consultation (14 May 2019)

The DDG -Education organized this meeting at the ICAR complex, New Delhi to finalize the no. of Disciplines for the Fisheries Science. All the committee members along with the Chairman, the Convener and the ADG (Edun.) have attended this meeting.

The Chairman presented all the 15 Disciplines of Fisheries Science currently being offered by institutions in the country. After a long deliberations the DDG permitted to have 12 Disciplines for the BSMA – Fisheries Science which include the following:

i. Aquaculture
ii. Fisheries Resource Management
iii. Aquatic Environment Management
iv. Aquatic Animal Health Management
v. Fish Genetics and Breeding
vi. Fish Nutrition and Feed Technology
vii. Fish Processing Technology
viii. Fish Biotechnology
ix. Fishing Technology & Engineering
x. Fisheries Economics
xi. Fisheries Extension
xii. Fish Physiology and Biochemistry

Fifth consultation (22-23 September, 2019)

The fifth consultation was conducted at TNJFU, Chennai from 22 to 23 September, 2019 to give a final shape with limited members along with Chairman and Convener. The uniformity was checked for all the courses at one go along with some minor corrections. The final draft was ready after 2 days consultation, which was circulated among the members.

Chairman
BSMA (Fisheries Science)

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VOL. 6

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Community Science

भाकृअनुप
ICAR

Education Division
Indian Council of Agricultural Research
New Delhi

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Agriculture and Allied Sciences
Volume-6

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- Extension Education and Communication Management
- Food and Nutrition
- Human Development and Family Studies
- Resource Management and Consumer Science

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एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the

syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language*.
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing*.
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

   (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

   (b) An application is made by the student concerned duly supported by the Advisory Committee;

   (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

   (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 6

Community Science
– Apparel and Textile Science

Preamble
(Apparel and Textile Science)

The field of Apparel and textiles is multidisciplinary with holistic approach to education. It is a combination of science, technology, fine arts, fashion, innovation, creative skills, soft skills, management, consumer education and many more. It provides trained personnel to the textile and apparel industry which accounts for 30% of the total employment generated in the country and 12% of the country's export earnings. It is imperative to develop skills in students so that they can cope with the present needs of textile and apparel industry and build career in the industry. The hands on trainings are necessary to implement the ideas and acquire the practical knowledge, which ultimately helps to implement the theoretical aspects into practical work. Keeping this in mind the course curricula of ATS is modified as per present needs.

The curriculum includes major, minor, supporting and compulsory courses which will strengthen the knowledge of the students both theoretically as well as practically. The students will be equipped with knowledge in apparel, textile chemistry, woven textile designing, Computer Aided Textile and Apparel Designing, Textile and Apparel Industrial Management, Historical Costumes, Textile Ecology (eco- friendly, natural clothing), Colour Application, Textile Conservation, Operational Management in Textiles and Apparels. The textile courses will focus on understanding the textile chemistry behind manufacturing, colouring and conservation of textiles. The apparel courses will highlight the designing using CAD application, fashion marketing and merchandising as well as socio- psycho aspects and revival of traditional costumes which reflects the culture of any country.

New subjects of current importance such as Textile and Apparel Product Development, Operation Management in Textiles and Apparels, Sustainability in Textile and Apparel Industry are introduced for brightening the career of the students and entreprise development. Students acquire advanced skills in all fields of apparel and textiles that increase their confidence to take up entrepreneurial activities online with the National policy on education 2020.

The Members of BSMA Community Science are thankful to faculty of different SAU's who have taken pains to share their experiences in the field and hope that the curriculum will be helpful for the PG students to learn, teach and undertake entrepreneurial activities which will fulfill the ever expanding requirements of Apparel and Textile industry, not only in India but abroad also.

Modifications Suggested in Courses in the Revised Curricula

M.Sc. (Community Science) Apparel and Textile Science

Course Code	Course Title	Credit Hours	Remarks
	Core Courses (20 Credits)		
*ATS 501	Textile Chemistry	3(2+1)	Content updated
*ATS 502	Textile and Apparel Quality Analysis	3(2+1)	Two courses Merged
*ATS 503	Pattern Making and Draping	3(1+2)	Two courses Merged
*ATS 504	Woven Textile Design	3(2+1)	Content Modified
ATS 505	Wet Processing of Textiles	3(2+1)	Title changed
ATS 506	Computer Aided Textile and Apparel Designing	2(0+2)	
ATS 507	Textile and Apparel Industrial Management	3(3+0)	Content Modified
ATS 508	Historic Textiles and Costumes	2(1+1)	Content Modified
ATS 509	Textile Auxiliaries	3(2+1)	
ATS 510	Socio Psychological Aspects of Clothing	2(2+0)	
ATS 511	Sustainability in Textile and Apparel Industry	2(2+0)	New course
ATS 512	Textile and Apparel Product Development	2(1+1)	New course
ATS 513	Laboratory Techniques in Textile Research	2(0+2)	New course
ATS 514	Special Project	1(0+1)	
	Minor Courses (08 Credits)		
FN 505	Nutrition and Physical fitness	3(2+1)	Minor Courses
FN 509	Food safety and Standards	3(2+1)	may be selected
FN 513	Human Physiology	3(3+0)	from subjects
EECM 502	Development communication	3(2+1)	closely related to a
EECM 505	Dynamic communication skills	2(0+2)	student's major
EECM 507	Organisational development and HRD	2(1+1)	subject. Apart from these
EECM511	Climate change management	2(1+1)	courses, a student
HDFS 503	Methods and techniques of assessment in human development	3(2+1)	can register any course offered by

Course Code	Course Title	Credit Hours	Remarks
HDFS 506	Management of differently abled	3(2+1)	any other department
	Supporting Courses (06 Credits)		
	Research Methodology	3(2+1)	Course numbers will be assigned by the departments that offer these courses.
	Statistical methods and application	3(2+1)	
	Common Courses (05 Credits)		
	Library and Information Services	1(0+1)	Common to all disciplines. The course numbers will be assigned by the departments that offer these courses
	Technical Writing and Communications Skills	1(0+1)	
	Intellectual Property and its management in Agriculture	1(0+1)	
	Basic Concepts in Laboratory Techniques	1(0+1)	
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)	
ATS 591	Seminar	1(1+0)	
ATS 599	**Thesis/ Research**	**30**	Increased credits for Research
	Total	**70**	

*Core courses/ compulsory courses

Ph.D. (Community Science) Apparel and Textile Science

Course Code	Course Title	Credit Hours	Remarks
	Major Courses (12 Credits)		
*ATS 601	Textile Ecology	2(2+0)	
*ATS 602	Technical Textiles	3(2+1)	Modified
ATS 603	Technological Developments in Textiles and Apparel	2(2+0)	
ATS 604	Colour Application in Textiles	2(1+1)	Content updated
*ATS 605	Functional Clothing	3(2+1)	

Course Code	Course Title	Credit Hours	Remarks
ATS 606	Textile Conservation	2(1+1)	Modified
ATS 607	Operational Management in Textiles and Apparel	2(2+0)	New
ATS 608	Technology of Nonwovens	2(2+0)	
ATS 609	Special Project	2(0+2)	
	Minor Courses (06 Credits)		
CS/PGS 601	Research and Publication Ethics	2(1+1)	Minor Courses may be selected from subjects closely related to a student's major subject. Apart from these courses, a student can register any course offered by any other department
FN604	Global Nutrition Problems	2(2+0)	
FN 608	Energy Metabolism	2(2+0)	
EECM 602	Impact Assessment of Development Programmes	3(1+2)	
EECM 603	Scaling Techniques for Behavioural Research	3(1+2)	
EECM 607	Media application and product promotion	4(2+2)	
HDFS 608	Qualitative research methods	3(2+1)	
RMCS 603	Globalization and Consumer Economics	3 (2+1)	
RMCS 606	Environmental Issues and Challenges	2 (2+0)	
RMCS 607	Family Dynamics and Women Power	3 (2+1)	

Supporting Courses (05 Credits)

A student can opt any course related to the topic of research offered by other faculties of agriculture university or SWAYAM portal or other online courses up to a maximum of 5 credits.

ATS 691	Doctoral Seminar I (Major Field)	1(1+0)	
ATS 692	Doctoral Seminar II (Minor Field)	1(1+0)	
ATS 699	**Research**	**75**	Increased credits for Research
	Total	**100 Credits**	

*Core courses/ compulsory courses

Course Title with Credit Load
M.Sc. in Apparel and Textile Science

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
*ATS 501	Textile Chemistry	3(2+1)
*ATS 502	Textile and Apparel Quality Analysis	3(2+1)
*ATS 503	Pattern Making and Draping	3(1+2)
*ATS 504	Woven Textile Design	3(2+1)
ATS 505	Wet Processing of Textiles	3(2+1)
ATS 506	Computer Aided Textile and Apparel Designing	2(0+2)
ATS 507	Textile and Apparel Industrial Management	3(3+0)
ATS 508	Historic Textiles and Costumes	2(1+1)
ATS 509	Textile Auxiliaries	3(2+1)
ATS 510	Socio Psychological Aspects of Clothing	2(2+0)
ATS 511	Sustainability in Textile and Apparel Industry	2(2+0)
ATS 512	Textile and Apparel Product Development	2(1+1)
ATS 513	Laboratory Techniques in Textile Research	2(0+2)
ATS 514	Special Project	1(0+1)
	Minor Courses (08 Credits)**	
FN 505	Nutrition and Physical fitness	3(2+1)
FN 509	Food safety and Standards	3(2+1)
FN 513	Human Physiology	3(3+0)
EECM 502	Development communication	3(2+1)
EECM 505	Dynamic communication skills	2(0+2)
EECM 507	Organisational development and HRD	2(1+1)
EECM511	Climate change management	2(1+1)
HDFS 503	Methods and techniques of assessment in human development	3(2+1)
HDFS 506	Management of differently abled	3(2+1)
	Supporting Courses (06 Credits)	
	Research Methodology	3(2+1)
	Statistical methods and application	3(2+1)
	Common Courses (05 Credits)	
	Library and Information Services	1(0+1)
	Technical Writing and Communications Skills	1(0+1)
	Intellectual Property and its management in Agriculture	1(0+1)

Course Code	CourseTitle	Credit Hours
	Basic Concepts in Laboratory Techniques	1(0+1)
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)
ATS 591	Seminar	1(1+0)
ATS 599	Thesis/ Research	30
	Total	70

*Core courses/ compulsory courses; **Apart from the courses listed under minor courses, the student may opt courses from any other department related to the research undertaken.

Course Contents
M.Sc. in Apparel and Textile Science

I. Course Title : Textile Chemistry

II. Course Code : ATS 501

III. Credit Hours : 3(2+1)

IV. Rationale

Fabrics made of different textile fibres exhibit varied properties. It is imperative to understand the structure and polymer content of the fibres. The reactions of these fibre polymers to different chemicals, finishing agents, dyes and other biological conditions provide an understanding for further processing and care of fabrics.

V. Aim of the course

- To provide knowledge on polymers and their molecular structure
- It provides understanding of the structure – property relations of textile fibres.
- To equip students to identify and evaluate different fibres and their performance.

VI. Theory

Unit I: Chemistry of polymers

Polymerization- types, degree and characteristics; Structure of textile fibres-molecular bonding, length, orientation; Requirements of fibre forming polymers; Bi-component and Bi-constituent fibres- types, characteristics, application and spinning (fibre forming systems)

Unit II: Structure-property relations of natural fibres

Repeating units, bonds, reactive groups; Reactions of cotton, linen, jute, silk, wool, and minor natural fibres to, heat, light, various chemicals and microorganisms.

Unit III: Structure-property relations of Man-made and Synthetic fibres

Repeating units, bonds, reactive groups and reactions of viscose rayon, modal (HWM), polyester, nylon, acrylic, spandex to heat, light, various chemicals and microorganisms; Fibre Blending- principles, types and scope.

Unit IV: Introduction to high performance fibres

Aramid, Ultra-High Molecular Weight Polyethylene (UHMWPE), High Density Polyethylene (HDPE), Carbon, Fibres with Limited Oxygen Index (LOI), Glass and Special fibres.

VII. Practicals

- Preparation of chemical solutions for fibre testing.
- Fibre testing – Natural fibres- cross sectional view of cotton, Jute, Linen, Wool and Silk.
- Cross sectional view of Man-made fibres – Viscose, polyester, acrylic and minor fibres.
- Effect of heat on cellulosic, protein and synthetic fibres.
- Effect of dilute and conc acids on cellulosic, protein and synthetic fibres.

- Effect of dilute and conc alkali on cellulosic, protein and synthetic fibres.
- Detection of acid damage on Cotton.
- Mercerization of cotton fibres and yarns- with and without tension.
- Effect of bleaching on textile fibres – Detection of damage due to over bleaching.
- Effect of finishing agents and solvents on cellulosic, protein and synthetic fibres.
- Detection of damage to cellulosic and protein fibres by acids and alkalies.
- Quantitative analysis of binary fibre blends.
- Conditioning and estimation of fibre blend ratio.
- Quantitative analysis of tertiary fibre blends.
- Conditioning and estimation of fibre blend ratio.
- End term Assessment.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Demonstrations
- Customised testing
- Group Work

IX. Learning Outcome

After successful completion of this course, the students can:

- Differentiate the fibres based on the chemistry of polymers and fiber structures
- Analyse the properties of fibres based on their structure
- Get acquainted with the recent developments in fibres and finishing
- Understand the performance of blends

X. Suggested Reading

- Andrea Wynne. 1997. *Textiles*. Macmillian, USA
- Bernard P Corbman. 1983. *Textiles - Fiber to Fabric*. McGraw-Hill, USA
- Kathryn L Hatch 2014. *Textile Science*, West Pub, USA
- Lyle DS. 1976. *Modern Textiles*. John Wiley & Sons, UK
- Marjory L. Joseph. 1966. *Introductory Textile Science*. Rinehart & Winston, UK
- Mather RR, Wardman RH. 2011. *The Chemistry of Textile Fibres*. Royal Society of Chemitry, Cambridge.
- Needles HL. 2001. Textile Fibres, Dyes, Finishes and Processes. Standard Publishers Distributors, Delhi.
- Vilensky G. 1987. *Textile Science*. CBS, India
- Wingate IB. 1984. *The Fabrics - Their Selection*. Prentice Hall, USA
- Journal of Applied Polymer Science https://onlinelibrary.wiley.com/journal/10974628
- Journal of Textile Science & Engineering https://www.omicsonline.org/textile-science-engineering.php

Weekly Lecture Schedule

Duration (week)	Topics
1	Polymerization- types, degree and characteristics
2-3	Structure of textile fibres- molecular bonding, length, orientation
4	Requirements of fibre forming polymers
5	Bi-component and Bi-constituent fibres- types, characteristics, application and spinning

Duration (week)	Topics
6	Repeating units, bonds, reactive groups and reactions of cotton, linen, jute, silk, wool, and minor natural fibres to various chemicals, heat, light and microorganisms
7	Repeating units, bonds, reactive groups and reactions of Linen and jute to various chemicals, heat, light and microorganisms
8	Repeating units, bonds, reactive groups and reactions of silk and Wool to various chemicals, heat, light and microorganisms
9	Repeating units, bonds, reactive groups and reactions of minor natural fibres to various chemicals, heat, light and microorganisms
10	Repeating units, bonds, reactive groups and reactions of Rayon and Modal fibres to various chemicals, heat, light and microorganisms
11	Repeating units, bonds, reactive groups and reactions of nylon and Polyester fibres to various chemicals, heat, light and microorganisms
12	Repeating units, bonds, reactive groups and reactions of Acrylic and Spandex fibres to various chemicals, heat, light and microorganisms
13	Aramid, Ultra-High Molecular Weight Polyethylene (UHMWPE)
14	High Density Polyethylene (HDPE) and Carbon fibres
15	Fibres with Limited Oxygen Index (LOI)
16	Glass and Specialty fibres

I. Course Title : Textile and Apparel Quality Analysis

II. Course Code : ATS 502

III. Credit Hours : 3 (2+1)

IV. Rationale

Textiles of different varieties are available in the market, the quality and price of which range from low to high. The consumer is in great confusion to select fabrics for their end-use performance. Textile industries need to check the quality of fibre raw material used for making customised quality of the final product such as yarn in case of spinning or fabric in case of knitting or weaving. Fabric quality is paramount in predicting the garment performance.

V. Aim of the course

- To familiarise the students with the methods and techniques used to analyze textile fibres, yarns and fabrics for end-use performance.
- To acquaint the students with principles, test methods of different testing equipment and the internationally accepted textile and apparel quality standards.
- To equip the students to analyze and interpret the results and predict the quality of textile and apparel.

VI. Theory

Unit I: Quality analysis and control

Importance of quality analysis and control; Effect of moisture and humidity on properties of textiles; Standard conditions of testing; Sampling – methods and techniques for fibre, yarn and fabric

Unit II: Fibre and yarn testing

Fibre testing - length, linear density, maturity and strength; Yarn testing – yarn count, single and lea strength, twist, crimp and evenness.

Unit III: Fabric testing

Fabric testing – Geometrical properties - thread count, weight, thickness, strength - breaking, tearing and bursting; Abrasion resistance, pilling, crease recovery, stiffness, drapability, air permeability, thermal properties, flammability, water absorbency and repellency, dimensional stability, colour fastness; Comfort and fabric handle measurement.

Unit IV: Apparel quality Control

Yarn and fabric defects; Preliminary inspection- Quality specifications and standards in raw material purchasing – fabric and accessories; In-process inspection - Quality control in spreading, cutting and bundling products; Quality factors in sewing, pressing, folding and finishing; Quality aspects of trims and accessories; Tolerance limits for garment dimensions; Final inspection – general garment defects; Procedure for quality checking and reporting.

Unit V: National and international organizations for standards

National and international organizations for standards – BIS and other global standards; Quality auditing system – process and product audit, internal quality audit procedure.

VII. Practicals

1. Sampling techniques of fibre, yarn and fabric.
2. Testing of fibre – length, maturity and linear density.
3. Yarn Testing – count, twist, crimp and evenness
4. Fabric testing – Geometrical properties - weight, thickness and fabric count
5. Fabric testing – abrasion resistance, pilling
6. Fabric testing – crease recovery, stiffness and drapability
7. Fabric testing – air permeability and thermal properties
8. Fabric testing – water permeability, wicking and dimensional stability
9. Breaking Strength– tensile strength of fibre, yarn and fabric
10. Estimation of tearing and bursting strength of fabrics
11. Processing, statistical analysis of the test data and interpretation of results
12. Garment Quality - Inspection of raw materials and analysis of defects in raw materials
13. Product quality analysis with respect to specification sheets- raw materials, product dimensions, construction and labeling.
14. Study of quality auditing system in the industry.
15. Quality analysis of low priced, medium priced and high priced garments available in market – fabric quality, workmanship, fitting and sizing
16. Visit to textile testing laboratory

VIII. Teaching Methods/ Activities

- Lecture
- Demonstration
- Hands-on-experience on textile and apparel quality testing machinery
- Industrial exposure
- Assignment
- Publication Review
- Student presentation
- Group Work

- Case Analysis and case studies
- Guest Lectures from industry experts

IX. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Perceive quality in fibre, yarn and fabrics for end-use performance
- Pursue career in quality control labs and apparel industries

X. Suggested Reading

- AATCC. 2010. *Technical Manual*-Vol 85. American Association of Textile Chemist and Colorist, USA
- Angappan 1987. *Textile Testing.* SSM Institute of Technology, Komarapalayam, India.
- BIS.1982. *ISI Hand Book of Textile Testing,* BIS Publications, India.
- Booth JL. 1983. *Principles of Textile Testing.* Butterworth.
- Gerry Cooklin 1997. *Garment Technology for Fashion Designers,* John Wiley & Sons, UK
- Gerry Cooklin. 2006. *Introduction to Clothing Manufacture,* Wiley, UK
- Latham Barbara and Carr Harold. 1999. *The Technology of Clothing Manufacture.* Blackwell Science, UK
- Pradeep V Mehta. 1998. *Managing Quality in Apparel Industry,* New Age International, India
- Pradeep V Mehta. 2004. *An Introduction to Quality Assurance for the Retailers,* iUniverse, USA
- Ruth E Glock. 1990. *Apparel Manufacturing.* Macmillan Publ. USA
- Textile Research Journal- https://journals.sagepub.com/home/trj

Weekly Lecture Schedule

Duration (weeks)	Topic
1	Importance of textile testing, standardization and quality control; Effect of moisture and humidity on properties of textiles. Standard conditions of testing
2	Sampling – methods and techniques for fibre, yarn and fabric; Functions of BIS and other standards
3	Fibre testing - length, linear density, maturity
4	Yarn testing - count, twist, crimp and evenness.
5	Tensile Strength measurement of textiles- Principles of tensile testing; various testers for tensile testing of fibres, yarns and fabrics
6	Fabric testing – geometric parameters- Fabric count, thickness; tearing and bursting strength, abrasion resistance and pilling
7	Fabric testing- crease recovery, stiffness, drapability and air permeability
8	Fabric testing - thermal properties, flammability, water absorbency and repellency, dimensional stability
9	Colour fastness tests; Comfort and fabric handle measurement
10	Yarn and fabric defects
11	Preliminary Inspection in garment industry- Quality specifications and standards in raw material purchasing; quality control in spreading, cutting and bundling products.
12	In-process inspection- Quality factors in sewing, pressing, folding and finishing; quality aspects of trims and accessories.
13	Final Inspection- Quality considerations in construction and finishing. Tolerance limits for garment dimensions
14	Various inspection systems. Procedure for quality checking and reporting.
15	National and international organizations for standards.
16	Quality auditing system – process and product audit. Internal quality audit procedure.

I. Course Title : Pattern Making and Draping

II. Course Code : ATS 503

III. Credit Hours : 3 (1+2)

IV. Rationale

Pattern making helps to interpret a design with a practical understanding of garment construction. It is a connection step between design and product. Draping serves as a major function in the customization and fit of a garment. Both are the methods of creating a garment as per the design. It is understood that they are not totally exclusive methods, but some designs call for a combination of both the techniques in achieving design satisfaction for both the designer and consumer. It will enable students to make advance patterns and obtain perfect fit and enable the students to make pattern from sketch/photograph.

V. Aim of the course

- To Understand the style reading, pattern making, draping and garment construction techniques
- To acquire skill in advance pattern making and obtain perfect fit and harmony between the fabric and design of the garment
- To enable students to make pattern from sketch/photograph

VI. Theory

Unit I: Advanced techniques of pattern making and draping

Advanced techniques of pattern making and draping: incorporating style lines and fullness.

Unit II: Contouring

Contouring – principles, contour guide patterns, classic, empire, surplice, off-shoulder designs, halters

Unit III: Bodice - Sleeve variations

Raglan sleeve variations – one-piece raglan, deep armhole raglan, armhole-princess raglan, yoke raglan with bell sleeve; Drop shoulder, exaggerated armholes, caftan

Unit IV: Pattern Grading and Fitting

Pattern grading – principles, grading bodice, sleeve, collar; Fitting – principles, standards, fitting problems and remedies

VII. Practicals

1. Dart manipulation through pivotal transfer
2. Dart manipulation through slash and spread method
3. Methods of adding fullness and contouring
4. Developing designs with added fullness and contouring using darts
5. Developing designs with added fullness and contouring using pleats
6. Developing designs with added fullness and contouring using tucks & gathers
7. Contouring -application in classic and empire designs
8. Contouring -application in off-shoulder designs
9. Contouring -application in halter neckline designs
10. Contouring -application in surplice designs
11. Draping of dartless shirt designs
12. Incorporating style lines

13. Draping collars
14. Draping Cowls at neckline and underarm
15. Draping Cowls in skirts
16. Draping Built-in necklines
17. Draping Flounces
18. Draping Ruffles
19. Draping Peplums
20. Draping designs with knit fabrics and making patterns
21. Pattern making for variations in sleeves
22. Pattern making for variations in skirts
23. Pattern making for variations in trousers
24. Pattern grading- Bodice and sleeves
25. Pattern grading of skirts; men's and woman's garments
26. Designing garment 1 based on both the methods of pattern making and draping and making patterns
27. Designing garment 2 based on both the methods of pattern making and draping and making patterns
28. Designing garment 3 based on both the methods of pattern making and draping and making patterns
29. Construction of custom garment 1
30. Construction of custom garment 2
31. Construction of custom garment 3
32. Assessment of custom garments for quality and body fit

VIII. Teaching Methods/ Activities

- Lecture
- Demonstration
- Design Scrapbook
- Student presentation
- Group Work
- Design Analysis
- Guest Lectures
- Assignment

IX. Learning Outcome

After successful completion of this course, the students are able to:

- Understand the style reading, pattern making, draping and garment construction techniques
- Get knowledge about advance pattern and obtain perfect fit and harmony between the fabric and design of the garment

X. Suggested Reading

- Amaden-Crawford C. 2018. *The Art of Fashion Draping.* V Edition Bloomsbury Publishing Inc, USA
- Bane A. 1996. *Creative Clothing Construction*. MC Graw-Hill
- Connie Amaden- Crawford. 1989. *The Art of Fashion Draping.* Fair Child Publ.
- Cooklin G. 2004 *Pattern Grading for women's Clothes.* Blackwell Publishing, France
- International Journal of Clothing Science and Technology https://www.emeraldinsight.com/loi/ijcst
- Janine Mee & Michal Purdy. 1987. *Modeling on the Dress Stand.* BSP Professional Books
- Joseph-Armstrong H. 2005. *Patternmaking for Fashion Design.* Pearson Education Inc. India

- Journal of Textile Engineering & Fashion Technology https://medcraveonline.com/JTEFT/
- Natalie Bray. 1994. *Dress Fitting*. Blackwell

Weekly Lecture Schedule

Duration (week)	Topics
1 & 2	Techniques of pattern making-drafting, flat pattern and draping
3 & 4	Use of style lines and fullness in pattern making
5,6 & 7	Understanding principles of contouring, surplice/off shoulder and halter designs
8 & 9	Types of Built -in necklines, cowls and collars
9,10 & 11	Introduction to advanced sleeve variations, exaggerated armholes, pockets and bias-cut dresses.
12, 13 & 14	Types of Skirts and pants
15 & 16	Pattern adoption to knits

I. Course Title : Woven Textile Design

II. Course Code : ATS 504

III. Credit Hours : 3 (2+1)

IV. Rationale

Consumers are seeking variety in woven textiles having new, interesting textures and functionality. Constant innovation in woven textiles is possible through textile design which combines elements from aesthetic creativity with technical skills. Knowledge on textile designing, aesthetics, materials, and techniques help in constructing new fabrics in tune with a new season's forecast.

V. Aim of the course

- To expose students to different looms and types of weaves
- To gain skills in designing woven patterns and weaving

VI. Theory

Unit I: Types of looms, scope and importance

Shuttleless looms –scope, importance and types -projectile, rapier, air jet, water jet weaving; multiple shed loom; Circular weaving; Tri-Axial looms; Pre-weaving processes for advance weaving; Automation in weaving.

Unit II: Woven designs and various weaves

Woven Design – fabric textures; Graphical representation of design, draft and peg plan; Classification of weaves; Warp weight and weft weight calculations; Twill weave and its modification; Colour and weave effects.

Unit III: Types of textured and decorative weaves

Construction of crepe, toweling- honeycomb, huck-a-back, bedford cord and curtain weaves-mockleno; Construction and production of complex structures - leno, double cloth, extra warp and extra weft figuring, terry pile and velveteens.

Unit IV: Specialty fabrics

Construction and production of damask and brocade fabrics using jacquard patterning devices; Methods of carpet making; Use of specialty fibres, specialty yarns, designing and production of specialty fabrics.

VII. Practicals

1. Weaving introduction – Procurement of yarn, setting up loom
2. Analysis of woven samples from different weaves
3. Construction of design, draft and peg plans for different weaves
4. Weaving samples of basic weave variations- plain and satin
5. Weaving samples of basic twill weave variations
6. Developing woven designs for weaving
7. Motif preparation and placement in different styles
8. Developing colour and texture plans
9. Weaving of the fabric with woven designs
10. Contd weaving of the fabric with woven designs
11. Documentation of traditional textile designs
12. Development of modified textile designs
13. Documentation of modified textile designs
14. Visit to Modern Weaving Mill with shuttleless looms
15. Portfolio development with woven samples and created designs
16. End term Assessment

VIII. Teaching Methods/ Activities

- Lecture
- Assignment
- Fabric structure Analysis
- Develop Compendium of woven designs and swatches
- Scrapbook of woven designs and weave calculations
- Student presentation
- Group Work
- Guest Lectures

IX. Learning Outcome

After successful completion of this course, the students are expected to:

- Be able to analyze different weave patterns
- Identifydifferent woven designs
- Be confidentin producing woven patterns on sample looms

X. Suggested Reading

- Grosick ZJ. 1975. *Watson's Textile Design &Colour*. Butterworths. Grosick ZJ. 1980.
- Grosick ZJ. 1989. *Watson's Advanced Textile Design - Compound Woven Structures*. Universal Publ.
- Gupta S. 1959. *Weaving Calculations*. DB Taraporawala Sons.
- Hayavadana J. 2017. Woven Fabric Design and Product Planning, Wood Head Publishers, New Delhi.
- Marjory J. 1972. *Illustrated Guide for Textiles*. RineHort & Winsoten, NewYork.
- Talukdar MK. *Weaving Machines, Mechanism and Management*. Mahajan Publications
- Mgbakoigba: Journal of African Studies- https://www.ajol.info/index.php/mjas
- ACM Digital Library- https://dl.acm.org/

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Shuttleless looms –scope, importance and types -projectile, rapier, air jet, water jet weaving
2	Multiple shed loom; Circular weaving; Tri-Axial looms

Duration (week)	Topics
3	Pre-weaving processes for advance weaving- machinery involved
4	Automation in weaving- Automatic controls
5	Woven Design – fabric textures; Graphical representation of design, draft and peg plan
6	Classification of weaves; Warp weight and weft weight calculations
7	Twill weave and its modification
8	Colour and weave effects for different weaves
9-10	Construction of crepe, toweling- honeycomb, Huck-a-back, bedford cord and curtain weaves-mockleno
11	Construction and production of complex structures - leno, double cloth, extra warp and extra weft figuring
12	Construction and production of complex structures- terry pile and velvetens
13	Construction and production of damask and brocade fabrics using jacquard patterning devices
14	Methods of carpet making
15	Use of specialty fibres, specialty yarns Designing and production of specialty fabrics.
16	Discussion on selection of weave for customized weaving

I. Course Title : Wet Processing of Textiles

II. Course Code : ATS 505

III. Credit Hours : 3 (2+1)

IV. Rationale

Almost all fabrics produced undergo some form of wet processing or other based on the market demand. Consumers do not prefer grey fabrics but rather demand specialised prints, textures and functional fabrics – all of which are produced with various wet processing techniques.

V. Aim of the course

- To develop knowledge about types of dyes and theory of dyeing
- To acquire skills in advanced dyeing and printing techniques
- To familiarize with the finishing treatments specific to fibre type

VI. Theory

Unit I: Chemistry of dyes and pigments

Theory of dyeing; Chemistry of dyes and pigments- composition, structure, properties, affinity towards fibres, method of application, fixing, after treatments and fastness properties; Dyeing with natural dyes and role of mordants.

Unit II: Advanced Dyeing and Printing Techniques

Dyeing of blends; Advanced dyeing techniques – macro, micro and nano; Dyeing machines used at the cottage and industrial level for fibre, yarn and fabric; Dyeing and printing defects and remedies; Advanced printing techniques- digital printing, 3D prints, automated flat bed and rotary screen printing; Assessment of colour fastness.

Unit III: Textile Finishes

Textile finishes – concept, scope and importance ; functional finishes on different fabrics – antimicrobial, soil and stain release, durable press, UV protective, flame retardancy; Comfort imparting finishes - application, uses, characteristics, problems and evaluation; Finishing with enzymes; Finishing of blended fabrics.

VII. Practicals

1. Preparation of fabrics for dyeing
2. Preparation of fabrics for printing
3. Preparation of fabrics for finishing
4. Developing shade cards on different substrate with various classes of dyes and colour matching.
5. Developing shade cards and colour matching.
6. Natural dyes
7. Dyeing with different mordants
8. Advanced techniques of fabric printing
9. Identification of finishing agents
10. Application of finishing agents
11. Eco-friendly finishing of textiles
12. Assessment of properties of finished fabrics
13. Study of labels pertaining to finishes
14. Theme based project work –Theme selection
15. Project preparation
16. End-term assessment

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Compendium of fabric shades
- Student's Swatch Book of printed textiles
- Student presentation
- Group Work
- Case Analysis and case studies
- Guest Lectures

IX. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Select dyes as per the fiber type
- Produce dyed and printed portfolios
- Showcase skill in surface enrichment with combination techniques of dyeing and printing

X. Suggested Reading

- Gopal Krishnan D and Karthik T. 2016. *Basics of Textile Chemical Processing*. Daya Publishing House, Astral International Pvt. Ltd., New Delhi.
- Hall AJ. 1955. *Handbook of Textile Dyeing & Printing*. The National Trade Press.
- Koushik CV and Josico AI. 2003. *Chemical Processing of Textiles: Preparatory processes and dyeing*. NCUTE, New Delhi.
- Nisbel H. 1978. *Grammer of Textile* Design. D.B. Taraporevale Sons.
- Prayag RS. 1988. *Textile Finishing*. Sri T Printers.
- Sekhri S. 2011. *Text Book of Fabric Science: Fundamentals to Finishing*. PHI Learning, Pvt.Ltd, New Delhi.
- Shanai. 1976. *Chemistry of Textile Axillaries*. Sevak Publ.
- Shenai VA. 1985. *Technology of Printing, Technology of Textile Processing*. Vol. IV. SevakPubl.
- Shenai VA. 1994. Technology of Dyeing. Sevak Publ.

- Shenia. 1995. *Technology of Bleaching & Mercerizing*. Sevak Publ.
- Story J. 1974. *The Thames & Hudson Manual of Textile Printing*. Thames & Hudson.
- Sule AD. 1997. *Computer Colour Analysis Textile Application*. New Age International.
- Vaidya A and Trivedi. 1975. *Textile Auxiliaries & Finishing Chemicals*. ATIRA, Ahemadabad.
- Vidyasagar PV. 1998. *A Handbook of Textiles*. Mittal Publ.
- Vilensky G. 1987. Textile Science. CBS.
- Wynne A. 1997. Textiles. Macmillian
- Journal of Saudi Chemical Society
  https://www.sciencedirect.com/journal/journal-of-saudi-chemical-society
- Chemistry International
  http://bosaljournals.com/chemint/

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Concept of colour and its relation to light. Classification of dyes/colouring matter
2	Theories of dyeing.
3&4	Chemistry of dyes and pigments- composition, structure, properties, affinity towards fibres, method of application, fixing, after treatments and fastness properties
5	Dyeing with natural dyes and role of mordants.
6	Dyeing of blends.
7	Advanced dyeing techniques – macro, micro and nano
8	Dyeing machines used at the cottage and industrial level for fibre, yarn and fabric
9	Dyeing and printing defects and remedies
10&11	Advanced printing techniques
12	Assessment of colour fastness
13	Textile finishes – concept, scope and importance
14	Application of functional finishes on different fabrics
15	Comfort imparting finishes - application, uses, characteristics, problems and evaluation
16	Finishing with enzymes. Finishing of blended fabrics.

I. Course Title : Computer Aided Textile and Apparel Designing
II. Course Code : ATS 506
III. Credit Hours : 2 (0+2)

IV. Rationale

Computers have become vital component in the fashion and textile designing arena. Computers have varied use in design room of a fashion/textile designer thereby reducing the demand for several manual skills and augment the industry in keeping up with high turnaround times.

V. Aim of the course

- To impart skill in computer aided textile and apparel designing
- To develop CAD portfolios as per fashion forecast
- To build design libraries in textiles and apparel styles

VI. Practicals

1. CAD commands
2. Textile designing softwares

3. Creation of textile designs (2D and 3D)
4. Application of Textile designs for different end uses.
5. Creating stripes using various commands
6. Creating checks using various commands
7. Creating weave library
8. Assigning weaves to the designed stripes and Checks for weaving.
9. Introduction to commands from different tool groups- file menu, freehand, geometric, selection, selection utility, colour utilities and general utilities.
10. Practicing on above tools
11. Developing motifs by scanning and drawing using the CAD commands
12. Creating full design/ repeat using drop devices.
13. Creating weaves and storing in Jacquard weave library.
14. Assigning weaves to the design plan.
15. Learning print commands- simulation and graph/ point paper.
16. Developing a computer aided portfolio of different motifs
17. Introduction to different software - Command bars and assistants. Menu bar and options. Drawing tools.
18. Colour rendering;
19. Fill, pattern and repeat
20. Creation of Special effects Layers and layer settings;
21. Apparel pattern making modules.
22. Development of basic pattern through CAD.
23. Principles of pattern making and basic blocks.
24. Adaptation of styles
25. Fundamentals of grading and marking.
26. Introduction to draping mode.
27. Outlining, creation of grid and editing the object
28. Draping scanned pictures
29. Texture mapping and creating effects
30. Development of library and printing designed patterns
31. Preparation of portfolio of developed designs,
32. Product designing and development of trims, foot wears, hand bags, buttons, buckles, belts, hats, scarf and jewellery.

VII. Teaching Methods/ Activities

- Demonstration
- Working with customised software
- Student's e Book on apparel and textile designs
- Student presentation
- Group Work
- Design Analysis & discussion
- Guest Lectures

VIII. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Customise the designs based on the clients requirement
- Build competency for a career in design studios and textile industry

IX. Suggested Reading

- Davis L Msrisn. 1980. *Visual Design in Dress.* Prentice Hall.

- Luther C. 2008. *Career in Textile and Fashion Designing*. Abhishek Publications, Chandigarh.
- Prakash K. 1994. *Impression – A Classic Collection of Textile Designs*. Design Points.
- Prakash K. 1995. *Traditional Indian Motifs for Weaving & Textile Printing*. Design Points.
- Rene Weiss Chase. 1997. *CAD for Fashion Design*. Prentice Hall.
- Srivastva M and Deepthi SS. *Computer aided designing* – e-manual (TXAD). ecourse.iasri.res.in.
- Vastrad J, Sakshi and Deepthi SS. Computer aided designing – textile designing – e-manual (TXAD). ecourse.iasri.res.in.
- Winfred Aldrich. 1992. *CAD in Clothing & Textiles*. BSP Professional Books.
- Yates MP. 1996. *Textiles – A Handbook for Designers*. W.W. Norton.
- International Journal of Fashion Design, Technology and Education https://www.tandfonline.com/toc/tfdt20/current
- Iowa State university digital repository- https://lib.dr.iastate.edu/

I. Course Title : Textile and Apparel Industry Management
II. Course Code : ATS 507
III. Credit Hours : 3 (3+0)

IV. Rationale

Textile and apparel industry occupy a prominent position in India next to agriculture providing employment to millions of people. The diverse culture and ethnicity in the country gives India a competitive advantage to cater to the needs of both the domestic and global clientele. Deep understanding of textile and apparel industry prepares the students to position themselves better in terms of future career prospects.

V. Aim of the course

- To identify the role of textile and garment industry in the Indian economy, industry trends and various export- import policies
- To understand the management issues related to apparel and textile industry
- To develop awareness about the quality standards and automation in enhancing productivity

VI. Theory

Unit I: Indian Textile industry

Textile industry- history, development and status; export and import policies of Government; Textile research associations; Textile crafts councils.

Unit II: Status of garment industry in India

Status of garment industry in India-production, marketing, distribution, consumption and export trends over last five years; problems of apparel industry and remedial measures. Complexity of management in garment industries: objective and expectations.

Unit III: Management in Apparel industry

Classification of apparel industry- large, medium, small and role of MSMEs; Infrastructural facilities and personnel management in apparel industry; Techniques in managerial application of cost volume profit analysis; Productivity analysis, case studies.

Unit IV: Trade related organisations

Apparel parks, apparel export promotion council, National fashion and design institutes; GATT, TUF, ISO 9001: 2015, 14001: 2015 and 26000: 2010 standards;

WTO and its impact on textile and apparel industries; Effect of trade globalization on apparel industry.

Unit V: Automation in apparel and textile industries

Recent advancements in CAD/CAM applications; automation in the industry; role of robotics in productivity management

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review - Discussion
- Student presentation
- Group Work
- Case Analysis and case studies
- Guest Lectures

VIII. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Enhance knowledge on management systems in apparel and textile industries
- Apply appropriate standards to augment and productivity through automation.

IX. Suggested Reading

- Cooklin G. 1997. *Garment Technology for Fashion Designers*. Blackwell.
- Dickerson K. 1995. *Textiles & Apparels in Global Economy*. Merrill Prentice Hall.
- Glock R. 1990. *Apparel Manufacturing*. Macmillan.
- Karpan 2004. *Change in Trends in Apparel Industry*. Abishek Publ.
- Kathryn MG.1978. *Fashion Innovation & Marketing*. Macmillan Co.
- Mehta PV. 1998. *Managing Quality in Apparel Industry*. New Age International.
- Uncertain Supply Chain Management http://m.growingscience.com/beta/uscm/
- University of Wollongong Research https://ro.uow.edu.au/

Weekly Lecture Schedule

Duration (weeks)	Topic
1&2	Introduction to Indian Textile Industry and its SWOT Analysis. History and development of textile industry. Export and Import policies of Government.Objectives and contributions of Textile Research Associations: NITRA, SITRA, BTRA and ATIRA and Textile Crafts Council.
3&4	Introduction to Indian Garment industry and its SWOT Analysis. Current status of garment industry in India in terms of production, marketing, distribution and consumption. Export trends of garments over the last five years.
5	Problems of apparel industry: lack of skilled manpower and automation, meeting lead times, logistic issues, maintaining optimum inventory levels, changing customer needs, cut throat competition, maintaining multichannel sales, managing supply chain and sustainability.Remedial Measures: ERP solutions, logistic and marketplace integration, centralized inventory management, following leagile supply chains, robust omnichannel solutions, progress report tracking, meeting corporate social responsibility, upgradation of skills of workforce and technology upgradation.
6	Strategic management in garment industry: top, middle and lower level management, objectives and expectations. Role of a Manager in a garment industry.
7	Classification of apparel industry: large, medium, small and MSME.Industry and infrastructure: need, existing facilities and challenges. Trade infrastructure for

Duration (week)	Topics
	export scheme (TIES) and its role in infrastructure development of export oriented units.Personnel Management in apparel industry: recruitment, training, work scheduling, compensation and rewards, motivation and promotion.
8&9	Cost Volume Profit (CVP) Analysis: need and assumptions. Factors affecting CVP Analysis: volume of production, product mix, internal efficiency, method of production and size of plant. Techniques of CVP analysis: break-even analysis and profit-volume analysis.
10&11	Key performance indicators(KPI) in apparel manufacturing. Productivity analysis and improvement in labour, equipment and resources productivity. Importance of productivity rate analysis. Technology upgradation of apparel units: use of CAD, CAM and CIM solutions, automated inspection (AIN), automated material handling devices (AMHD), Production planning/ inventory management software (PPIC) and pick-place robots (PPR).
12&13	Governmental schemes for boosting apparel exports: Scheme for Integrated Textile Parks (SITP), Technology Upgradation Fund Scheme (TUFS), Market Access Initiative (MAI) and Market Development Initiative (MDI).General Agreement on Trade and Tariff (GATT): Purpose and its effect on trade.World Trade Organization(WTO): organizational structure and functions. Impact of WTO on textile and apparel industries.
14	Apparel Export Promotion Council: role, vision and various AEPC's in India.
15	ISO textile testing standards. ISO 9000, 14000 and 26000 standards: their aim and application in textiles and apparel industries.
16	Globalization: definition, advantages and disadvantages for textile and apparel industry. Effect of trade globalization of apparel industry.

I. Course Title : Historic Textiles and Costumes

II. Course Code : ATS 508

III. Credit Hours : 2 (1+1)

IV. Rationale

Understanding the textiles and costumes worn in the past is way to learn the history inside out. Learning about the historic textiles and costumes is a definitive way to move forward as it generates new research questions and strengthens the student's design sensibilities. The style variations in the historic costumes inspire the student in creating contemporary styles.

V. Aim of the course

- To enable students to learn the historical development in Western textiles and costumes from ancient world to 21st century
- To acquaint students with textiles and costumes of western countries.
- To get design inspiration from historic costumes and textiles

VI. Theory

Unit I: Study of traditional textiles

Study of traditional dyed, printed, embroidered and non-woven textiles in terms of fibre content, fabrics, motifs, colours, designs and dyes used in Egypt, Greece, Rome, France, America, Japan and China.

Unit II: Study of traditional costumes

History and evolution of traditional costumes and accessories for men and women of Egypt, Greece, Rome, Japan, France, America and China.

VII. Practicals

1. Collection and documentation of traditional textile prints and surface designs of Egypt & Greece
2. Collection and documentation of traditional textile prints and surface designs of Rome & France
3. Collection and documentation of traditional textile prints and surface designs of America & Japan
4. Collection and documentation of traditional textile prints and surface designs of China
5. Developing textile surface designs with combination of motifs of different countries
6. Developing textile surface designs with combination of motifs of different countries
7. Documentation of various styles of men's garments of various countries
8. Documentation of various styles of women's garments of various countries
9. Designing and adaptation of outfits for men from historic costumes according to current trends.
10. Designing and adaptation of outfits for women from historic costumes according to current trends.
11. Visit to the museum 1
12. Visit to the museum 2
13. Reporting and Presentation of the visits
14. End term Assessment

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Develop costume style catalogue
- Create textile motif catalogue
- Student presentation
- Group Work
- Museum visits and videos
- Guest Lectures

IX. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Distinguish the patterns and designs in western textiles from ancient times to the present day.
- Portray style variations in ancient costumes of western countries across centuries.

X. Suggested Reading

- Annalce G. 1987. *One World of Fashion*. Fair Child Publ.
- Bhatnagar P. 2005. *Decorative Design History in Indian Textiles and Costumes*. Abhishek Publication, Chandigarh.
- Blanche P. 1965. *History of Costumes from the Ancient Egyptian to the Twentieth Century*. Harper & Row.
- Jack Cassin-Scott. 1994. *The Illustrated Encyclopedia of Costume and Fashion*. Studio Vista.
- Meadows CS. 2003. *Know Your Fashion Accessories*. Fairchild Books, NewYork.
- Peacock J. 1996. *A Complete Guide to English Costume Design and History - Costume* 1066–1990's. Thames & Hudson.

- Peacock J. 2000. *Fashion Accessories- The Complete 20th Century Source Book*. Thames and Hudson, London.
- Stecker P. 1996. *Fashion Design Manual*. Mac Millan.
- International Journal of Scientific Research in Science and Technology- http://ijsrst.com/
- DigitalCommons@University of Nebraska – Lincoln- https://digitalcommons.unl.edu/

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Introduction to historic textiles and costumes, and their application in textile and costume designing.
2	Traditional dyed, printed and embroidered textiles of Egypt with reference to fibre content, fabrics, motifs, colours, dyes and designs.
3	Characteristic features of male and female Egyptian costumes, accessories and hair styles.
4	Features of Grecian textiles with respect to fibre content, fabrics, motifs, colours, dyes and designs.
5	Characteristic features of male and female costumes of Greece, accessories and hair styles.
5, 6 & 7	Details of historic textiles of Rome and their symbolism in ancient Roman Empire. Costumes, accessories and hair styles worn by Romans.
8 & 9	Historical account of evolution of textiles, costumes, accessories and hair styles of France.
10 & 11	Colonial textiles of America with respect to fibre content, fabrics, motifs, colours, dyes and designs.
12 &13	Characteristic features of male and female colonial costumes, accessories and hair styles worn in America.
14, 15 & 16	Brief account of traditional textiles, costumes, accessories and hair styles used in Japan and China.

I. Course Title : Textile Auxiliaries

II. Course Code : ATS 509

III. Credit Hours : 3 (2+1)

IV. Rationale

Textile auxiliaries are widely used in the wet processing industry to bring out fabrics with special properties. In addition to improving the efficiency of the various wet processes, the auxiliaries help in cost optimisation and add to the functional properties of a textile. The role played by the textile auxiliaries in the industry is pivotal and hence it is essential for a student to learn of the new developments in the industry.

V. Aim of the course

- Become familiar with various textile auxiliaries used in textile processing
- Gain knowledge about the judicial use of auxiliaries based on end use performance

VI. Theory

Unit I: Introduction to auxiliaries

Textile auxiliaries– definition, classification, selection and uses in processing operations.

Unit II: Surface active agents

Chemistry and synthesis of surface-active agents - essential requirements of surfactants, classification and biodegradability; Physical principles of cleansing efficiency; Scouring, bleaching and mercerizing auxiliaries.

Unit III: Dyeing and Printing auxiliaries

Dyeing auxiliaries - Wetting, leveling, stripping, dye fixing, swelling, dispersing agents and carriers; Printing auxiliaries – thickeners and their classification, wetting, hygroscopic, antifoaming, reducing, oxidizing agents and pigment binders, fixers and miscellaneous auxiliaries.

Unit IV: Finishing auxiliaries

Stiffening, cross linking, optical brighteners, softeners, water proof/repellents, flame proof/ retardants, soil release, anti-pilling, antimicrobial, moth and mildew proofing; methods of producing nanoparticles of auxiliaries for textile finishing.

VII. Practicals

1. Textile auxiliaries-An Introduction
2. Market survey of different Textile auxiliaries
3. Analysis of the surfactant properties of surfactant 1
4. Analysis of the surfactant properties of surfactant 2
5. Preparation of detergent
6. Preparation of sizing combination 1
7. Preparation of sizing combination 2
8. Analysis of the sized samples
9. Selection of suitable combinations
10. Assessment of whiteness index of fabrics finished with various bleach 1
11. Assessment of whiteness index of fabrics finished with various bleach 2
12. Assessment of whiteness index of fabrics finished with optical brightening agent 1
13. Assessment of whiteness index of fabrics finished with optical brightening agent 2
14. Assessment of whiteness index of fabrics finished with detergent 1
15. Assessment of whiteness index of fabrics finished with detergent 2
16. End term Assessment

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Discussion on suitability of auxiliaries
- Problem solving approach
- Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning Outcome

After successful completion of this course, the students are expected to:

- Select appropriate auxiliaries for end-use performance
- Skill in analysing the textiles finished with various auxiliaries.

X. Suggested Reading

1. Bogley M. 1977. *Textile Dyes, Finishing and Auxiliaries*. Garland Publ.

2. Fiscus G and Grunenwald D. 1996. *Textile Finishing: A Complete Guide*. Textile Institute, Manchester.
3. Hall KJ. 1966. *Textile Finishing*. Heywood.
4. NPCS Board of Consultants and Engineers (2019). *Handbook on Textile Auxiliaries, Dyes and Dye Intermediates Technology,* Asia Pacific Business Press Inc., New Delhi
5. Textile Finishing Chemicals: An Industrial Guide http://library.aceondo.net/ebooks/Home_Economics/Textile_Finishing_Chemicals.pdf
6. Chemosphere- https://www.journals.elsevier.com/chemosphere
7. Journal of Hazardous Materials https://www.journals.elsevier.com/journal-of-hazardous-materials
8. *Textile auxiliaries and chemicals* https://www.academia.edu/30859937/Textile_Auxiliaries_ and_Chemicals_Ebook

Weekly Lecture Schedule

Duration (week)	topics
1	Definition and classification of textile auxiliaries
2	Selection of textile auxiliaries and uses in processing operations
3 & 4	Chemistry and synthesis of surface-active agents - essential requirements of surfactants, classification and biodegradability
5	Physical principles of cleansing efficiency.
6	Scouring, bleaching and mercerizing auxiliaries
7	Dyeing auxiliaries- wetting, levelling
8	Dyeing auxiliaries- stripping, dye fixing, swelling
9	Dyeing auxiliaries- dispersing agents and carriers
10,11 &12	Printing auxiliaries – thickeners and their classification, wetting, hygroscopic, antifoaming, reducing, oxidizing agents and pigment binders, fixers
13	Miscellaneous auxiliaries
14,15& 16	Finishing auxiliaries–stiffening, cross linking, optical brighteners, softeners, water proof/repellents, flame proof/retardants, soil release, anti-pilling, antimicrobial, moth and mildew proofing; Methods of producing nanoparticles of auxiliaries for textile finishing.

I. Course Title : Socio-psychological Aspects of Clothing

II. Course Code : ATS 510

III. Credit Hours : 2 (2+0)

IV. Rationale

Study of dress and human behaviour throws an insight into the definite relationship between dress, the body, and the self. Clothes act as a stimulus influencing one's behaviour and self esteem of both the wearer and the viewer. There exists a specific relationship between dress and specific social and cultural identities and changing attitudes concerning dress among several ethnic groups. Study of socio-psychological aspects of clothing of consumers will help the industry to come up with saleable solutions that the market can easily embrace.

V. Aim of the course

- To study the socio-psychological effects of clothing on the individual in social situations
- To develop understanding about consumer behaviour.

VI. Theory

Unit I: Clothing

Clothing-origin, theories, functions and modern philosophy of clothing in relation to culture; Clothing symbolism; Factors effecting clothing -fashion, fad, custom, tradition, culture contact, status, age, education, technology and role of legislation.

Unit II: Socio-psychological aspects of clothing

Socio-psychological aspects of clothing-first impression, individual values, interest, attitude, motivation in clothing choices, self-respect, self-enhancement, self-expression, gender desirability and individuality, clothing and society, clothing and social behaviour, influence of religion; beliefs, customs and traditions; clothes and conformity; cloths and occupation; socio-psychological impact of clothing among different age groups; significance of uniforms and national costumes. Clothes for conformity, mobility, aesthetic appearance. Health and sanitation related to clothing.

Unit III: Consumer behaviour

Consumer behaviour: concept and importance, consumer needs and motivations, consumer perspective and viewpoints; environmental influence; individual differences. Consumer resourses: involvement and motivation; knowledge, attitudes; individual differences in behaviour; psychological processes.

Consumer decision-making processes; model of consumer decision-making; consumer analysis and marketing strategy; retailing; consumer trends; market segmentation; diffusion of innovation; Counterfeit textiles and consumer protection measures; consumerism and role of media.

Unit IV: Marketing concept

Marketing concept; Types of customers; Understanding consumers and customer demand; Market segmentation and consumer adopter categories- their characteristics, psychographics and the interrelationship with production, price zones and marketing strategies in relation to fashion cycle; Theories of fashion adoption; Role of fashion influencers.

VII. Teaching Methods/ Activities

- Lecture
- Case Analysis and case studies
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group Work
- Guest Lectures

VIII. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Relate clothing to socio-psychological aspects of the individual.
- Establish backward linkage to the industry by passing on consumer oriented inputs

IX. Suggested Reading

- Cranz RLM. 1972. *Clothing Concepts*. Collier Macmillan.
- Horn MJ. 1981. *The Second Skin – An Interdisciplinary Study of Clothing*. Hughton Miffin and Hill House.
- Marion S. 1963. *Dress Selection and Design*. The Macmillan Co.

- Mary Kefgen and Phyllis 1971. *Individuality in Clothing Selection & Personal Appearance*. The Macmilliam Co.
- Ryan MS. 1966. *Clothing - A Study in Human Behaviour*. Winston
- Stecker P. 1996. *Fashion Design Manual*. Mac Millan.
- European Scientific Journal
  http://eujournal.org
- Journal of Fashion Marketing and Management: An International Journal
  https://www.emeraldinsight.com/loi/jfmm

Weekly Lecture Schedule

Duration (weeks)	Topic
1	Origin, theories, functions and modern philosophy of clothing in relation to culture. Clothing symbolism.
2	Factors effecting clothing -fashion, fad, custom, tradition, culture contact, status, age, education, technology and role of legislation
3&4	Socio-psychological aspects of clothing: first impression, individual values, interest, attitude, motivation in clothing choices, self-respect, self-enhancement, self-expression, gender desirability and individuality
5	Clothing and society: clothing and social behaviour, influence of religion, beliefs, customs and traditions; clothes and conformity; clothes and occupation; socio-psychological impact of clothing among different age groups.
6	Significance of uniforms and national costumes. Clothes for conformity, mobility, aesthetic appearance. Health and sanitation related to clothing.
7	Consumer behaviour: concept and importance, consumer needs and motivations, consumer perspective and view points.
8	Environmental influence; individual differencesin behavior and psychological processes.
9	Marketing concept. Types of customers. Understanding consumers and customer demand.
10&11	Market segmentation and consumer adopter categories- their characteristics, psychographics and the interrelationship with production, price zones and marketing strategies in relation to fashion cycle.
12	Theories of fashion adoption. Role of fashion influencers.
13	Consumer decision-making processes; model of consumer decision-making; consumer analysis and marketing strategy; retailing
14	Consumer trends; market segmentation; diffusion of innovation.
15&16	Counterfeit textiles and consumer protection measures; consumerism and role of media.

I. Course Title : Sustainability in Textile and Apparel Industry
II. Course Code : ATS 511
III. Credit Hours : 2 (2+0)

IV. Rationale

Incorporating sustainability into the supply chain is becoming a key priority for many textile and apparel companies owing to its detrimental effects to the eco system. Sustainability in terms of product strategy, investment, performance evaluation, corporate social responsibility, and environmental management system adoption contribute to the development of sustainable supply chain management in the textile and apparel industry. To safeguard the planet, sustainable eco measures need to be studied and improved upon.

V. Aim of the course

- To expose students to global environmental issues and strategies
- To understand the measures undertaken for maintaining ecological balance in micro and macro environment of Textile industry.

VI. Theory

Unit I: Impact of textile sector on environment

Environmental threats in textile and apparel industry- raw materials and processes; Banned dyes and chemicals in India; Concept of green supply chain; Certified organic, renewable and low impact raw material; Reduced toxicity in fiber processes and treatments; Effluent Treatment Plants; Concept of zero wastage and lean manufacturing; Pre -consumer and post-consumer textile wastage; 3-R approach and its advantages; Environmental friendly packaging and eco labeling; Certified agencies imparting eco label.

Unit II: Natural dyes

Natural dyes – importance, classification of natural pigments; extraction methods including the concept of supercritical dyeing, microwave and ultrasonication, mordants and dyeing methods; Role of natural dyes in safeguarding the environment.

Unit III: Reduced energy processes

Reduced energy processes; Use of alternative sources of energy during product lifecycle; Importance of carbon credits in textile and apparel manufacturing.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group Work
- Videos
- Case Analysis and case studies
- Exposure visit to ETP (Effluent Treatment Plants)
- Guest Lectures

VIII. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Identify the ecologically safe processes, dyes and chemicals
- Offer ecological solutions for mitigating the harmful effects of the textile effluents on environment

IX. Suggested Reading

- Blackburn RS. 2009. *Sustainable Textiles INNBUNDET*. Woodhead Publishing House.
- Miraftab M and Horrocks AR. 2004. *Ecotextiles: The Way Forward for Sustainable Development in Textiles*. Woodhead Publishing House.
- Subramanian SM. *Sustainability in the Textile Industry* (Textile Science and Clothing Technology).
- Wang Y. *Handbook of Sustainable Textile Production. 1st Edition. Recycling in Textiles.* Woodhead Publishing House.
- *Journal of Environmental Science and Health* https://www.tandfonline.com/toc/lesa20/current
- *Ecological Economics* https://www.sciencedirect.com/journal/ecological-economics

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Environmental threats in textile and apparel industry- raw materials and processes
2	Banned dyes and chemicals in India
3	Concept of green supply chain
4	Certified organic, renewable and low impact raw material
5	Reduced toxicity in fiber processes and treatments
6	Effluent Treatment Plants
7	Concept of zero wastage and lean manufacturing;
8	Pre -consumer and post-consumer textile wastage
9	3-R approach and its advantages; Environmental friendly packaging and eco labeling;
10	Certified agencies imparting eco label
11	Natural dyes – importance, classification and chemical groups of natural pigments
12	Natural dye extraction methods including the concept of supercritical dyeing, microwave and ultrasonication
13	Natural dye application on textiles- mordants used; mordanting and dyeing methods; Role of natural dyes in safeguarding the environment.
14	Reduced energy processes; Use of alternative sources of energy during product lifecycle;
15	Importance of carbon credits in textile and apparel manufacturing and estimation of carbon points
16	Discussion on adoption green technologies in Textile and apparel industries

I. Course Title : Textile and Apparel Product Development

II. Course Code : ATS 512

III. Credit Hours : 2 (1+1)

IV. Rationale

Product development in the field of apparel and textiles is identifying the market opportunity, create product that appeal the customers, developing technical specifications, testing and modification for production. Skill in product development provides immense career opportunities as merchandisers in indudtries.

V. Aim of the course

- To impart the knowledge about various product standards and product specifications
- To learn the process of product development towards market need

VI. Aim of this Course

The course is designed to impart both basic and applied knowledge on the subject of sustainability in textile and apparel industry. This course will impart the knowledge about various product standards and product specifications to the students. Further, students will learn the process of product development towards market need.

VII. Theory

Unit I: Textile and apparel product development

Textile and apparel product development – concept, history, objective; product design, product life cycle and new product development. Merchandising – role, responsibilities, use of calendar, branding, labelling and retailing.

Unit II: Product testing

Product – testing, economics, standards and specifications; product quality control; technical services, positioning and marketing.

Unit III: Organizational behaviour

Organizational behaviour; accounting; product intellectual property law.

Unit IV: Commercial product development

Commercial product development - Role of computers and related software in product development. e-marketing – concepts and application.

VIII. Practicals

- Product review- Analyzing existing products of textile in terms of design, life cycle and assessment of market need for new product development.
- Development of survey Performa for preparation of product profile of Textile product-1.
- Development of survey Performa for preparation of product profile of Textile product-2.
- Development of survey performa for preparation of product profile of Apparel product-1.
- Development of survey performa for preparation of product profile of Apparel product-2.
- Survey on selected products from textiles field.
- Survey on selected products from apparel field.
- Product testing and analysis of selected textiles – quality, serviceability, material.
- Product testing and analysis of selected textiles – construction, performance.
- Product testing and analysis of selected textiles – Products standard ,specifications and cost.
- Product testing and analysis of selected apparels – quality, serviceability, material.
- Product testing and analysis of selected apparels – construction, performance.
- Product testing and analysis of selected apparels – Products standard, specifications and cost.
- Product planning on the basis of- market needs, aesthetic, functional requirements and producibility.
- Production of new product- with aesthetic, functional requirements and producibility.
- Project work.

IX. Teaching Methods/ Activities

- Lecture
- Assignment
- Publication Review
- Student presentation
- Group Work
- Case Analysis and case studies
- Guest Lectures

X. Learning Outcome

After successful completion of this course, the students are expected to:

- Know about various product standards and product specifications

- Acquire skill in customized product development

XI. Suggested Reading

- Bhargav R. 2005. *Design Ideas and Accessories.* Jain Publ.
- Harold C and Pomeroy J. 1996. *Fashion Design and Product Development.* Blackwell Science.
- The International Journal of Advanced Manufacturing Technology https://link.springer.com/journal/170
- References, Conservation and Recycling https://www.sciencedirect.com/journal/References-conservation-and-recycling

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Concept, history and objectives of product development in textiles and apparel.
2&3	Product design process, stages of product life cycle and steps of product development
4	Role of merchandiser in product development and use of merchandising calendar
5	Branding, labelling and retailing
6	Importance of product testing, concept and types of market test
7	Product economics-analysis of design cost, product profitability and design profits or Economic analysis-market potential, estimation of sales, cost breakeven analysis, return on investment
8	Product standards and specifications.
9&10	Product Quality control- fabric, garment or design and manufacturingspecifications
11	Importance of product positioning in marketing plan.
12&13	Organizational behavior-B2B buying decisions, Stages of organizational buying process, R&D accounting
14	Role of Intellectual property law in product development
15	Role of computers in design development and manufacturing of product
16	Basic principles and concepts of e-marketing-chain of activities, ethical code and marketing mix

I. Course Title : Laboratory Techniques in Textile Research

II. Course Code : ATS 513

III. Credit Hours : 2 (0+2)

IV. Rationale

Textile research can include a wide gamut of areas – fibre, fabric and apparel. A researcher should have a broad understanding of the tools and equipment used in research- be it qualitative or quantitative. A prior knowledge of these tools/ techniques will equip the student to focus intensely on the areas of interest.

V. Aim of the course

- To impart knowledge on laboratory techniques in textile research.
- To provide hands on training on analytical instruments

VI. Practical

1. Preparation of buffers for pre-processes.
2. Preparation of reagents for pre-processes.

3-4. Preparation of standard solutions for pre-processes.

5-6. Demonstration on Microencapsulation– Preparation and application; assessment through TEM.

7-8. Demonstration on Microencapsulation– Preparation and application; assessment through SEM.
9-10. Demonstration on Microencapsulation– Preparation and application; assessment through FTIR.
11. Demonstration on Nano synthesis – Preparation and application; assessment through TEM.
12. Nano synthesis – Preparation and application; assessment through SEM.
13. Nano synthesis – Preparation and application; assessment through and FTIR.
14. Optimization of variables for various dyes.
15. Optimization of variables for various printing.
16. Optimization of conditions for various finishing treatments.
17. Optimization of conditions for various enzyme treatments.
18. Analysis of water- pH, TDS.
19. Analysis of dye extracts.
20. Analysis of finishing extracts.
21-22. Analysis of water -dye effluents, BOD, COD, anions, cations.
23. Laboratory techniques for assessing colour strength.
24. Laboratory techniques for assessing reflectance.
25. Laboratory techniques for assessing Spectrophotometry-visible, ultraviolet.
26. Laboratory techniques for assessing Spectrophotometry-infrared and chromatographic techniques.
27. Use of different scales to assess light fastness.
28. Use of different scales to assess washing fastness.
29. Use of different scales to assess rubbing fastness.
30. Management and interpretation of data generated.
31. Statistical analysis of test results in SPSS package.
32. End term Assessment.

VII. Teaching Methods/ Activities

- Demonstration on technical equipment handling/learning operations
- Assignment
- Laboratory manuals/Specification sheets
- Student interactive session
- Group Work on textile testing
- Use of SPSS Software for statistical analysis

VIII. Learning Outcome

After successful completion of this course, the students are expected to be able to:

- Confident in handling advanced instruments
- Prepare common analytical reagents for qualitative and quantitative analysis of dyes and finishes.

IX. Suggested Reading

- Roger Carpenter. 1999. *Vision Research: A Practical Guide to Laboratory Methods*, Oxford University Press, Oxford
- Research papers on functional testing, performance of textiles, Herbal treated/ Nano finished/ microencapsulated apparels and textiles, etc.
- Equipment manuals on Nano synthesis - assessment through SEM,TEM and FTIR.
- E book on- Principles of Textile Finishing by Asim Kumar Roy Choudhury
- E book on -A Practical Guide to Textile Testing By K. Amutha

Course Title with Credit Load
Ph.D. in Apparel and Textile Science

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
*ATS 601	Textile Ecology	2(2+0)
*ATS 602	Technical Textiles	3(2+1)
ATS 603	Technological Developments in Textiles and Apparel	2(2+0)
ATS 604	Colour Application in Textiles	2(1+1)
*ATS 605	Functional Clothing	3(2+1)
ATS 606	Textile Conservation	2(1+1)
ATS 607	Operational Management in Textiles and Apparel	2(2+0)
ATS 608	Technology of Nonwovens	2(2+0)
ATS 609	Special Project	2(0+2)
	Minor Courses (06 Credits)	
CS/PGS 601	Research and Publication Ethics	2(1+1)
FN604	Global Nutrition Problems	2(2+0)
FN 608	Energy Metabolism	2(2+0)
EECM 602	Impact Assessment of Development Programmes	3(1+2)
EECM 603	Scaling Techniques for Behavioural Research	3(1+2)
EECM 607	Media application and product promotion	4(2+2)
HDFS 608	Qualitative research methods	3(2+1)
RMCS 603	Globalization and Consumer Economics	3 (2+1)
RMCS 606	Environmental Issues and Challenges	2 (2+0)
RMCS 607	Family Dynamics and Women Power	3 (2+1)
	Supporting Courses (05 Credits)**	
ATS 691	Doctoral Seminar I (Major Field)	1(1+0)
ATS 692	Doctoral Seminar II (Minor Field)	1(1+0)
ATS 699	Research	75
	Total	**100 Credits**

*Core courses/ compulsory courses; **A student can opt any course related to the topic of research offered by other faculties of agriculture university or SWAYAM portal or other online courses up to a maximum of 5 credits.

Course Contents
Ph.D. in Apparel and Textile Science

I. Course Title : Textile Ecology
II. Course Code : ATS 601
III. Credit Hours : 2 (2+0)

IV. Rationale

The textile wet processing industry is considered as the highest polluting industry as the chemicals used are toxic and harmful to both human and the environment. Some of the dyes and chemicals are banned by the government due to their toxic nature and Effluent treatment is made mandatory. It is high time for the students who would like to take up career in these industries or personnel already working in the industry to acquire knowledge in effluent pollution and its mitigation processes. Hence the course.

V. Aim of the course

- To impart knowledge among the students about types of pollution caused by textile industry, effect on the environment and mitigating strategies.
- To understand the health hazards faced by textile workers and the remedial measures adopted.

VI. Theory

Unit I: Textile ecology

Textile ecology – concept and importance; Industrialization, eco-balance and sustainability; Air, noise and water pollution by mechanical and chemical textile processing units and their effect. Organic and coloured cotton, natural dyes and detergents.

Unit II: Treatment and disposal of textile effluents

Particulate matter and pollution control devices ; Treatment processes of sewage. Waste minimization and management strategies; Recovery and reuse of water and chemicals

Unit III: Banned dyes and chemicals used in Textile industries

Banned dyes, heavy metals, pesticides and auxiliaries in Textile and related industries. Health hazards of textile workers and their remedial measures; Colour removal technologies

Unit IV: Indian and international environmental legislations

Indian and international environmental legislations. Eco-standards, eco-labeling, management and auditing. Management of packaging waste.

VII. Teaching Methods/ Activities

- Lectures
- Assignment
- Student's presentation

- Case studies
- Guest Lectures
- Exposure visits
- Mini Project

VIII. Learning Outcome

After successful completion of this course, the students are expected to:

- Develop awareness on the types of pollution from textiles processing units and their effect on environment
- Design processes to reduce or alleviate pollution in wet processing
- Handle remedial measures to mitigate health hazards of textile workers

IX. Suggested Reading

- Bogley M. 1977. *Textile Dyes, Finishing and Auxiliaries.* Garland Publication, New Wood, London.
- Fiscus G and Grunenwald D. 1996. *Textile Finishing: A Complete Guide.* Textile Institute, Manchester.
- Mark KH, Woodlings and Atlas SM. 1971. *Chemical after Treatment of Textiles.* John Wiley & Sons.
- M Clark. 2011. *Handbook of textile and industrial dyeing*, Woodhead Publishing, New Delhi.
- Patricia Dolez. 2017. *Advanced Characterization and Testing of Textiles.* Woodhead Publishing,California.
- Shahid-ul-Islam and Butola B.S. 2019. *The Impact and Prospects of Green Chemistry for Textile Technology*. A volume in The Textile Institute Book Series
- Slater K. 2003 *Environmental Impact of Textiles-Production, Processes and Protection* Woodhead publication
- http://scvswap.com/2015/05/09/ecological-balance-and-its-importance/
- https://www.eionet.europa.eu/gemet/en/concept/2441
- https://www.textileschool.com/368/what-is-eco-textiles/
- https://scialert.net/fulltextmobile/?doi=jas.2005.1843.1849

Weekly Lecture Schedule

Duration (week)	Topics
1	Textile ecology – concept and importance
2	Industrialization, eco-balance and sustainability
3-4	Air, noise and water pollution by mechanical and chemical textile processing units and their effect
5	Organic and coloured cotton, natural dyes and detergents.
6	Particulate matter and pollution control devices
7-8	Treatment processes of sewage
9	Waste minimization and management strategies
10	Recovery and reuse of water and chemicals
11	Banned dyes, heavy metals, pesticides and auxiliaries in Textile and related industries.;
12	Health hazards of textile workers and their remedial measures
13	Colour removal technologies
14	Indian and international environmental legislations.
15	Eco-standards, eco-labeling
16	Management and auditing, Management of packaging waste

I. Course Title : Technical textiles
II. Course Code : ATS 602
III. Credit Hours : 3 (2+1)

IV. Rationale

Textile materials are finding ways into various walks of life from home to industry to warfare, with technical performance, meeting the demands of varied fields. The global demand for a variety of such textiles has continuously increased in end use industries. Demand is on the rise from these end use industries, such as automotive, construction, healthcare, protective clothing, agriculture, sports equipment/ sportswear and environmental protection. In India the area of technical textiles has to pace up to meet the ever growing demands of industry and other applications. The area of technical textiles provides immense research opportunities to the students to develop/ customize functional performance of clothing.

V. Aim of the course

- To impart knowledge regarding types, composition, characteristics and uses of technical textiles.
- To acquaint the students with manufacturing techniques and uses of nanofibres and micro fibres.

VI. Theory

Unit I: Introduction to technical textiles

Technical textiles- importance, classification, types of fibres and materials.

Unit II: Developments in nano fibre and micro fibres

Types of nano and micro fibres, performance characteristics, production and application; Developments in nano fibre based non-wovens

Unit III: Technical textiles in industrial applications

Agro tech, Build tech, Geo tech, Mobil tech, pack tech, indu tech and oeko tech.

Unit IV: Technical textiles in personal environment

Medi tech, Pro tech, Sport tech, Home tech and Cloth tech.

Unit V: Smart textiles

Factors affecting the selection and uses of smart textiles, phase change materials, chromic materials, shape memory materials. Conductive materials and other functional materials- characteristics and its applications.

VII. Practicals

1. Introduction to all types of Technical textiles – showcasing the fabric samples and their applications.

2-3. Survey for technical textiles in the market and collection of swatches.

4. Identification of swatches, preparation of technical textile portfolio.
5. Preparation of nano particles for an end-use and their characterization.
6. Application on textiles.
7. Assessment of the functional property of nano finish on textiles.

8-9. Agri tech applications- mulch formation for nursery raising (interface with Agricultural college).

10. Medi tech applications – preparation of any anti-microbial finishing solution for application on hospital textiles/ patient monitoring/ similar application.

11. Application of anti-microbial finish on fabric.
12-13. Assessment of anti-microbial finish on fabric – visit to the lab having microbiology facility.
14-15. Mini project (group activity)- Designing technical textiles/ smart textiles using phase change materials/ shape memory materials/ dopplers, etc. for specific functional performance.

VIII. Teaching Methods/ Activities

- Lecture
- Videos and films
- Video conferencing
- Assignments
- Student's presentation
- Group activity
- Exposure visits to Centre of Excellence for Technical Textiles

IX. Learning Outcome

After successful completion of this course, the students are expected to:

- Understand the functions and uses of various technical textiles, nanofibres and microfibers.
- Aware of recent development in the field of technical textiles
- Design and customize protective wear for various end uses

X. Suggested Reading

- Cooklin. 2012. *Garment Technology for Fashion Designers.* Wiley-Blackwell Publications Inc., New Jersey
- K Amutha. 2016. *A Practical Guide to Textile Testing.*Woodhead Publishing, Cambridge, UK.
- Patricia Dolez. 2017. *Advanced Characterization and Testing of Textiles*. Woodhead Publishing, USA.
- Susan M Watkins. 1995. *Clothing the Portable environment*. Iowa State University Press. Ames
- VT Bartels. 2011. *Handbook of Medical Textiles*. Woodhead Publishing Series in Textiles. Woodhead Publishing, USA.
- https://www.trade.gov/topmarkets/pdf/Textiles_Top_Markets_Report.pdf*2016 Top Markets Report Technical Textiles A Market Assessment Tool for U.S. Exporters U.S. Department of Commerce | International Trade Administration | Industry & Analysis (I&A) May 2016*
- http://nasdonline.org/1246/d001050/health-hazards-in-agriculture-an-emerging-issue.html
- https://careertrend.com/info-8239121-materials-do-firefighters-wear.html
- https://www.technicaltextile.net/articles/advances-in-protective-fabrics-2560?no_redirect=true
- http://textilelearner.blogspot.in/2014/04/applications-of-agro-textiles.html
- http://www.fibre2fashion.com/industry-article/1579/agro-textiles-a-rising-wave?page=1
- http://www.bch.in/agro-textiles.html
- http://www.technicaltextile.net/agro-textiles/
- http://www.ijarse.com/images/fullpdf/1373424521_APPLICATION_OF_TEXTILE_IN_AGRICULTURE.pdf

Weekly Lecture Schedule

Duration (week)	Topics
1	Technical textiles-Introduction, definitions, scope Classification of technical textiles-areas of application

Duration (week)	Topics
2	Fibres used in technical textiles-domestic fibres, high functional fibers, Form of Textile Fibers in technical textiles, Finishing of technical textile materials
3	Growth of textile materials, Progress of Technical textiles in Global Market
4	Developments in nanofibre and micro fibres
5	Types of nano and micro fibres, performance characteristics
6	Production and application, Developments in Nano-fibre, microfibre
7	Production and application, Developments in nanofibre based non-wovens
8	Technical textiles in industrial applications: Agro tech, Build tech
9	Technical textiles in industrial applications: Geo tech, Protech
10	Technical textiles in industrial applications: indu tech and oeko tech.
11	Technical textiles in industrial applications: Mobil tech, pack tech
12&13	Smart textiles: Factors affecting the selection and uses of smart textiles
14	phase change materials, chromic materials, shape memory materials
15	Conductive materials, - characteristics and its applications.
16	Other functional materials- characteristics and its applications.

I. Course Title : Technological Developments in Textiles and Apparel

II. Course Code : ATS 603

III. Credit Hours : 2 (2+0)

IV. Rationale

The advancements in Science and Technology have brought in revolutionary changes in the field of textiles and apparel. The application of these technologies improved the functional characteristics of textiles and made a beginning of functional clothing for variety end-use performance. The advancements in innovative fibre production, spinning, weaving, wet processing, dyeing and printing, garment production technology offer wide opportunities for research.

V. Aim of the course

- To develop awareness about the recent advances in production, manufacturing, processing, testing and quality control of various textiles and apparels.

VI. Theory

Unit I: Recent advances in manufacture of textile and garments

Recent researches in production and manufacture of textile fibres, yarns, fabrics and garments. Chemical processing of natural and synthetic textiles and their conversion into clothing.

Unit II: Developments in the field of functional textiles

Developments in the field of functional textiles; Use of special techniques in textile processing.

Unit III: Innovations in garment technology and apparel manufacturing

Innovations in apparel designing; Developments in garment manufacturing technology; Advances in retailing; merchandising; biological and psychological aspects of clothing.

Unit IV: Research issues

Thrust areas of contemporary research and future projections

VII. Teaching Methods/ Activities

- Lecture
- Videos/films
- Assignment
- Student's presentation
- Guest Lectures
- Expose visits
- Participation in seminars

VIII. Learning Outcome

After successful completion of this course, the students are expected to:

- Possess in depth knowledge of latest developments in textile and apparel industry
- Develop a perspective on contemporary research issues in the field of textiles and apparel.

IX. Suggested Reading

- http://www.craftmark.org/sites/default/files/Gota%20Patti%20Craft.pdf
- http://www.cohands.in/handmadepages/pdf/91.pdf
- http://blog.ninecolours.com/gota-patti-all-about-sophestication/
- http://handicrafts.nic.in/CmsUpload/2039201602393132%20craft%20process.pdf
- http://shodhganga.inflibnet.ac.in/bitstream/10603/35363/6/07_chapter%201.pdf
- http://jalsnet.com/journals/Vol_1_No_1_June_2014/7.pdf
- https://www.journals.elsevier.com/dyes-and-pigments
- Many online Journals

ISSN	Name of the Journal
1528	*Journal of Industrial Textiles*
0970	*Cotton Research Journal* (Journal of the Indian Society for Cotton Improvement)
0143	*Dyes and Pigments*
1229	*Fibers and Polymers*
0266	*Geo textiles and Geo-membranes*
0971	*Indian Journal of Fibre and Textile Research*
2250	*International Journal of Textile and Fashion Technology*
0972	*Journal of Cotton Research and Development*
1558	*Journal of Engineered Fibers and Fabrics*
1528	*Journal of Industrial Textiles*
1544	*Journal of Natural Fibers*
1388	*Journal of Nano particle Research*
1533	*Journal of Nano-science and Nanotechnology*
0163	*Journal of Natural Products*
0368	*Journal of the Textile Association*
0377	*Man Made Textile in India*
0369	*Pigment and Resin Technology*
0040	*Textile Research Journal*
0040	*The Journal of the Textile Institute*

Weekly Lecture Schedule

Duration (week)	Topics
1	Recent advances in production and manufacturing of textile fibres.
2	Recent advances in production and manufacturing of textile yarns and blends.
3	Recent advances in production and manufacturing of fabrics and garments.
4	Chemical processing of natural and synthetic textiles and their conversion into clothing

Duration (week)	Topics
5	Developments in the field of functional textiles
6&7	Special techniques in textile processing with reference to functional textiles
8	Innovations in apparel designing, softwares used
9	Innovations in textile designing, software used
10	Developments in garment manufacturing technology
11	Advances in merchandising
12	Advances in retailing
13	Biological and psychological aspects of clothing.
14	Future projections in apparel research
15&16	Future projections in textile research

I. Course Title : Colour Application in Textiles

II. Course Code : ATS 604

III. Credit Hours : 2 (1+1)

IV. Rationale

Colour plays a very important role in selection of textiles and apparel. The key issue in colouration of textiles is the colour control system in the industries where colour matching among the batches of dyed textiles is paramount. Knowledge of colour measurement is imperative to the students to take up research in the field of dyeing and printing and pursue career in the wet processing industries.

V. Aim of the course

- To give an in depth knowledge into theories of dyeing band dye chemistry.
- To acquaint the students with different color matching systems and its assessment.

VI. Theory

Unit I: Colour theory and Dye Structure

Theory of colour science. Dyeing theories- physical, chemical, fibre complex, solid solution and pigment. Dye structure- size, shape and molecular weight of dye, state of the dye, electrical nature of dye molecule, chemical groups attached to dye and dyeing parameters.

Unit II: Colour measurement system

Colour measurement systems- Spectrophotometer- features, types and viewing systems; Software and hardware for colour measuring systems; Objective specification of colour- tristimulus values, colour strength, colour difference, shade sorting and various colour spaces; Assessment of whiteness, yellowness and brightness; Assessment of fastness of colour.

Unit III: Computer Colour Matching

Computer Colour Matching- Theory, Isomeric and metameric colour matching, accuracy of match prediction, measurement of reflectance, benefits; Pass Fail Systems.

VII. Practicals

1-2. Identification of dye classes: primary and confirmatory tests- direct, basic, acid, sulphur, vat, and reactive dyes.

3-4. Handling colour spectrophotometer- familiarization of commands to use Software

5-6. Recording reflectance values of coloured samples, recording colour strength.
7. Assessment of colour fastness and recording the grey scale fastness grades
8. Colour assessment techniques for assessing dyed fibre, yarn and fabric.
9. Determination of relative dye strength in solution
10-13. Creation of data files and reproduce dyed samples with the match prediction
14. Management and interpretation of data generated
15. Exposure to Pass/ Fail system in industry
16. End-term assessment

VIII. Teaching Methods/ Activities

- Lecture
- Demonstrations and hands on experience
- Assignment
- Guest Lectures
- Exposure visits

IX. Learning Outcome

After successful completion of this course, the students are expected to

- Be Confident in handling the Spectrophotometers
- Assess the dyed fibre, yarn and fabric
- Predict computer colour matching

X. Suggested Reading

- Amutha K. 2016. *A Practical Guide to Textile Testing*.Woodhead Publishing, India.
- Booth JE. 2018.*Principles of Textile Testing*.CBS publishers and Distributors, New Delhi.
- Gulrajani ML. 2010. *Colour Measurement: Principles, Advances and Industrial Applications*. Woodhead Publishing Series in Textiles, UK.
- Janet. 2017. *Best Colour Design: Theories and Applications*. (The Textile Institute Book Series) 2nd Edition Woodhead Publishing, Cambridge, England.
- Padmanabhan AR. 1988. *A Practical Guide to Textile Testing,* SITRA, Coimbatore.
- Sule AD. 1997. *Computer Colour Analysis Textile Applications*. ATIRA Publication, Ahmadabad.
- Xin J. 2006. *Total Colour Management in Textiles*. Woodhead Publishing.
- https://www.elsevier.com/books/total-colour-management-in-textiles/xin/978-1-85573-923-9

Weekly Lecture Schedule

Duration (week)	Topics
1	Theory of colour science.
2	Dyeing theories- physical, chemical, fibre complex,
3	Dyeing theories- solid solution and pigment
4	Computers match prediction in dyeing fibres, yarns, fabrics and formulation of dyeing recipes
5	Dye structure- size, shape and molecular weight of dye, state of the dye
6	Electrical nature of dye molecule,
7	Chemical groups attached to dye; Dye and dyeing parameters.
8	Colour measurement systems- principles, types and uses in colour assessment
9	Software and hardware for colour measuring systems
10	Objective specification of colour, colour difference,
11	Shade sorting and various colour spaces.
12	Assessment of whiteness, yellowness & brightness
13	Assessment of fastness of colour

Duration (week)	Topics
14	Computer Colour Matching-Theory, Isomeric and metameric colour matching
15	Accuracy of match prediction, measurement of reflectance, benefits
16	Pass - Fail Systems

I. Course Title : Functional Clothing
II. Course Code : ATS 605
III. Credit Hours : 3 (2+1)

IV. Rationale

Today clothing is considered not only for aesthetic aspect but also to perform specific function. Functional clothing represents the evolutionary segment of the technical textiles market, representing an area where clothing crosses the conventional boundaries and integrates with the domains of medicine, biotechnology, nanotechnology, physics and computing among others, to meet the multifaceted and complex requirements of the user. Immense customised research opportunities make this course very interesting to the students.

V. Aim of the course

- To understand the importance of functional and portable clothing
- To identify and analyse the functional features in special purpose clothing
- To develop skill in designing functional clothing for special purpose

VI. Theory

Unit I: Introduction to functional clothing and other associated aspects

Clothing as a portable environment. Comfort in clothing - principles of heat transfer in apparels, thermal insulation, clothing systems for thermal protection, breathable textiles.

Unit II: Clothing design for special groups

Functional Design Process; Clothing design for special groups – expectant and lactating mothers, clothing design to accommodate differently abled. Geriatric clothing; Impact theory- designing impact-protective clothing

Unit III: Functional and protective clothing

Requirements and designing of functional and protective clothing – sports, farm, military, industrial workers, fire fighters, mines, space and marine. Fastening systems in clothing.

VII. Practicals

1-2. Survey on selected functional clothing available in the market.
3. Functional designing process- Assessment of functional aspects
4. Designing clothing for expectant woman
5. Designing clothing for nursing mothers.
6. Designing garments for physically handicapped – disabled hands.
7. Designing garments for physically handicapped – disabled legs
8. Designing garments for physically handicapped – wheel chair incumbent
9. Designing protective clothing for pesticide applicators and analysis
10. Designing protective clothing for selected industrial workers and analysis

11. Designing protective clothing for fire fighters and analysis.
12. Designing impact clothing- use of different material and techniques of padding
13. Designing locale specific sports clothes and analysis.

14-15. Mini Project- Designing customized functional clothing

16. End-term assessment

VIII. Teaching Methods/ Activities

- Lecture
- Assignment
- Publication Review
- Student presentation
- Group Work
- Case Analysis and case studies
- Guest Lectures
- Video

IX. Learning Outcome

After successful completion of this course, the students are expected to:

- Design functional clothing
- Customize clothing for a special purpose

X. Suggested Reading

- Cooklin G. 2012. *Garment Technology for Fashion Designers*. Wiley-Blackwell, New Jersey
- Dwight Garner. 2018. *Bill Cunningham, Style Maven, Leaves Behind a Memoir and It's 'a Real Dilly'*. Patricia Wall. New York
- Gandhi Kim. 2019.*Woven Textiles Principles, Technologies and Applications*. Woodhead Publishing, UK.
- Karen L LaBat. *Clothing Fasteners*. http://fashion-history.lovetoknow.com/clothing-closures-embellishments/clothing-fasteners
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- K Amutha. 2016. *A Practical Guide to Textile Testing.*Woodhead Publishing India in Textiles, ýCambridge.
- McCarthy J. 2011. *Textiles for Hygiene and Infection Control*. Woodhead Publishing Series in Textiles, UK
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- www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 2, August 2014)
- http://www.sun-protection-and-products-guide.com/UV-protective-clothing.html
- http://www.sunprotection.net/sunprotectionclothing.html
  http://www.umanitoba.ca/

Weekly Lecture Schedule

Duration (week)	Topics
1	Introduction to functional; Concept clothing and other associated aspects
2	Clothing as a portable environment.

Duration (week)	Topics
3	Comfort in clothing, Types of comforts
4	Principles of heat transfer in apparels
5	Thermal insulation, clothing systems for thermal protection; Breathable textiles
6	Functional Designing Process
7	Requirements and designing functional clothing for special groups – expectant and lactating mothers
8	Key requirements in designing functional clothing for special groups- physically handicapped
9	Impact theory- designing impact-protective clothing- Ballistic materials & bullet proof vests
10	Requirements and designing of functional and protective sports clothing
11	Requirements and designing of functional and protective farm clothing
12	Key issues in designing of functional and protective clothing military
13	Requirements and designing of functional and protective clothing industrial workers
14	Requirements and designing of functional and protective clothing fire fighters
15	Requirements and designing of functional and protective clothing mines, space and marine
16	Fastening systems in clothing.

I. Course Title : Textile Conservation

II. Course Code : ATS 606

III. Credit Hours : 2 (1+1)

IV. Rationale

Textiles and costumes of bygone era are valued for their historic interest, their aesthetic appeal and their cultural significance. A course on Textile conservation helps to understand the techniques to be adopted for addressing the damage of textile or a costume due to storage.

V. Aim of the course

- To impart basic knowledge on textile conservation.
- To develop awareness about textile conservation and skill in assessment of damage, repair and stabilization of textiles.

VI. Theory

Unit I: Introduction to textile conservation

Importance of textile conservation; Important terminologies in conservation; Various methods for analysis of textiles - fibre content, yarn and fabric structure.

Unit II: Object examination and Assessment

Object examination; Damage causing agents – insects, pests, microorganisms, mildew, and environmental factors; Condition assessment, repair and stabilization of textiles and apparel in museum collections; Recording, handling and pre-preparations in conservation; Materials and methods used for conservation treatments.

Unit III: Support and Considerations in textile conservation

Support and Considerations in textile conservation; Reassembly and Finishing;

Examination of storage and exhibition techniques; Transportation of artifacts/ historic textiles; Equipment and the workspace for textile conservation

Unit IV: Principles of cleaning fragile textiles

Principles of cleaning fragile textiles; Dry, aqueous and solvent cleaning; Conservation of Linen and Flags, historic costumes and feather work, lace, leather goods, tapestries and carpets; Proper conditions for storage and display of various textiles.

VII. Practicals

1-2. Visit to a museum and study of various textile conservation methods
3-4. Analysis of aged textiles - fibre content, yarn and fabric structure
5-6. Assessment of damage
7-9. Repair and stabilization of textiles
15. Determination of colour strength
11-12. Exposure to cleaning techniques
13-15. Mini Project work
16. End-term assessment

VIII. Teaching Methods/ Activities

- Lecture
- Videos/films
- Visit to Museums
- Student's presentation
- Case study

IX. Learning Outcome

After successful completion of this course, the students are expected to

- Develop skill in textile conservation and assessment of damage, repair and stabilization of textiles
- Become confident to take up career in Museum and related institutes

X. Suggested Reading

- Balazsy. 2012. Chemical Principles of Textile Conservation. Routledge, UK.
- Frances Lennard. 2012. *Textile Conservation: Advances in Practice*. A Butterworth-Heinemann, UK.
- Harris J. (Ed.). 2011. *Five Thousand Years of Textiles*. Smithsonian Books, UK.
- Leene JE. 1972. *Textile Conservation*. Butterworths, UK.
- Williams JC. 1977. *Preservation of Paper and Textiles of Historic and Artistic Value*. American Chemicals Society.
- https://en.wikipedia.org/wiki/Conservation_and_restoration_of_textiles#Display
- https://scindeks-clanci.ceon.rs/data/pdf/0351-9465/2017/0351-94651701094D.pdf
- https://www.researchgate.net/publication/318014663
- http://webspace.utexas.edu/ecb82/textile_care.doc

Weekly Lecture Schedule

Duration (week)	Topics
1	Importance of textile conservation; Important terminologies in conservation; Various methods for analysis of textiles - fibre content, yarn and fabric structure.
2	Various methods for analysis of textiles - fibre content, yarn and fabric structure.
3	Object examination. Damage causing agents – insects, pests, micro organisms, mildew, and environmental factors.

Duration (week)	Topics
4	Condition assessment, repair and stabilization of textiles and apparel in museum collections.
5	Recording, handling and pre-preparations in conservation; Materials and methods used for conservation treatments
6	Support and Considerations in textile conservation; Reassembly and Finishing
7	Examination of storage and exhibition techniques.
8	Transportation of artifacts/ historic textiles; Equipment and the workspace for textile conservation
9	Principles of cleaning fragile textiles Dry, aqueous and solvent cleaning.
10	Conservation of Linen and Flags
11	Conservation of historic costumes and feather work, lace
12	Conservation of leather goods, tapestries and carpets, etc.
13	Proper conditions for storing of various textiles
14	Proper conditions for display of various textiles – curtains, bedsheets, flat fabrics, carpets, tapestries, etc
15	Categorization of Display Techniques Mannequins, Slanting Technique, Mounting Technique
16	Categorization of Display Techniques, Hanging Technique, Vacuumed with Inert Gas

I. Course Title : Operations Management in Textiles and Apparel

II. Course Code : ATS 607

III. Credit Hours : 3 (3+0)

IV. Rationale

The very essence of any business is to cater needs of customer by providing services and goods, and in process create value for customers and solve their problems. Production and operations management talks about applying business organization and management concepts in creation of goods and services. Proper management of References based on effective planning, reduction in production costs through control of material handling, improving the productivity, ergonomic interventions, and so on contribute to success of the industry.

V. Aim of the course

- To enable students to understand the importance of operations management in textiles and apparel industries.
- To impart in depth knowledge about various concepts of production and operations management for textiles and apparel units.

VI. Theory

Unit I: Scope of production and operations management in textiles and apparel

Scope of production and operations management in textiles and apparel, methods and measurement of capacity planning. Plant climatology-Plant building and its significance, considerations of building design, types of industrial building- plant lighting; need, types and factors governing. Importance of ventilation.

Unit II: Plant location

Plant location; factors governing, types of location; rural, sub-urban and urban, merits and demerits. Plant layout; objectives of scientific layout, principles of layout, types of material flow, factors governing the layout, types of layouts, merits and demerits.

Unit III: Material handling

Material handling- need, classification, handling costs, principles and types of material handling equipment; Maintenance management- need, types, organisation of maintenance department, maintenance audit, maintenance cost, maintenance indices.

Unit IV: Work study

Work study- need, objectives from apparel and textile industry point of view; Method study- steps in method study, tools of record. Time study-time and motion economy, steps, elements, allowances, work measurement and derivation for standard minute value (s m v or s a m) – calculations from apparel industry; Ergonomics- meaning, scope in apparel and textile industry, impact on working conditions and productivity, recommendations for better ergonomically conditions.

Unit V: Automation in Textile & Apparel Industries & Government Policies:

Mechatronics in Apparel & Textile Industries; Scope for Robotics and applications in Apparel & textile Industries; Policies of the government in export and import of materials and made-ups. Government initiatives for various sectors of textile and apparel industry.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing) and student's presentation
- Group Work
- Guest Lectures
- Exposure visits

VIII. Learning Outcome

After successful completion of this course, the students are expected to:

- Acquired in depth understanding of various concepts of production and operations management in textiles and apparel units
- Prepare for management careers in Apparel and textile units

IX. Suggested Reading

- Aswathappa and Rao S. 2009. *Production and Operations Management*. Himalaya Publishing House, New Delhi.
- Chunnawala and Patel. 2007. *Production and Operations Management*. Himalaya Publishing House, New Delhi.
- Rao S. 2009. *Production Management*. Himalaya Publishing House, New Delhi.
- Vidyasagar P.V. 2010. *Encyclopedia of Textiles*. Vol 2 & 3. Mittal Publications, New Delhi
- http://www.fibre2fashion.com/industry-article/1579/agro-textiles-a-rising-wave?page=1
- http://www.bch.in/agro-textiles.html
- http://www.technicaltextile.net/agro-textiles/
- http://www.ijarse.com/images/fullpdf/1373424521_APPLICATION_OF_TEXTILE_IN_AGRICULTURE.pdf

Weekly Lecture Schedule

Duration (week)	Topics
1	Scope of production and operations management in textiles and apparel, methods and measurement of capacity planning.
2	Plant climatology-Plant building and its significance, considerations of building design
3	Types of industrial building- plant lighting: need
4	Ventilation- Importance and factors governing.
5	Plant location: factors governing, types of location: rural, sub-urban and urban, merits and demerits
6	Plant layout: objectives of scientific layout, principles of layout
7	Types of material flow, factors governing the layout, types of layouts, merits and demerits
8	Material handling- need, classification, handling costs
9	Principles and types of material handling equipment
10	Maintenance management- need, types, organisation of maintenance department; Maintenance audit, maintenance cost, maintenance indices
11	Work study- need, objectives from apparel and textile industry point of view; Method study- steps in method study, tools of record
12	Time study-time and motion economy, steps, elements, allowances; Work measurement and derivation for standard minute value calculations from apparel industry
13	Ergonomics- meaning, scope in apparel and textile industry, impact on working conditions and productivity, recommendations for better ergonomical conditions
14	Mechatronics in Apparel & Textile Industries
15	Scope for Robotics and applications in Apparel & textile Industries
16	Policies of the government in export and export of materials and madeups. Government initiatives for various sectors of textiles and apparel industry

I. Course Title : Technology of Nonwovens

II. Course Code : ATS 608

III. Credit Hours : 2(2+0)

IV. Rationale

Nonwoven textiles are one of the most popular multi-utility textiles produced in the world. These encompass a large variety of raw materials and production technologies and characteristics. Knowledge of nonwovens will help in increasing the competency of the students in the field of textiles.

V. Aim of the course

- To acquaint the students with raw materials used, manufacturing techniques, characteristics and uses of nonwovens
- To impart knowledge related to testing and evaluation of nonwoven textiles.

VI. Theory

Unit I: Development of the nonwovens industry

Development of the non-woven industry. Types of Nonwovens- dry, wet and polymer-laid non-woven, web formation, bonding and raw materials.

Unit II: Types of web formation

Types of web formation, mixing and blending, card clothing, cross lapping.

Developments, physical properties and practical applications of air laid fabrics. Wet-laid fabrics- raw materials, bonding systems, finishing and product application. Polymer- laid fabrics- raw materials, bonding techniques, spun-bond fabrics, characteristics, properties and other extrusion properties.

Unit III: Types of bonding

Types of bonding: Mechanical bonding- stitch, needle punching, hydro entanglements process technology and applications. Thermal bonding- raw materials, contact, thermal reaction/ infrared and ultrasonic bonding and applications. Chemical bonding- chemicals, binder polymers, mechanism, drying and applications.

Unit IV: Non-woven fabric finishing

Non-woven fabric finishing - wet, chemical, lamination, mechanical, surface and other developing technologies. Fabric inspection.

Unit V: Characterization of non-woven fabrics

Characterization of non-woven fabrics - weight, thickness, density and other structural parameters. General standards for testing non wovens- absorption, strength, bonder and optional properties.

VII. Teaching Methods/ Activities

- Lecture
- Videos/films
- Assignment
- Student's presentation
- Group Work
- Guest Lectures
- Field visits

VIII. Learning Outcome

After successful completion of this course, the students are expected to:

- Develop knowledge about fundamental techniques of nonwoven textiles.
- Undertake testing and evaluation of nonwoven textiles.

IX. Suggested Reading

- Amutha K. 2016. *A Practical Guide to Textile Testing*.Woodhead Publishing, UK.
- Chapman ARA. 2010. *Applications of Nonwovens in Technical Textiles*. Woodhead publishing limited, New Delhi.
- Dharmadhikary RK Gilmore TF Davis HA and Batra SK. 1995. *Thermal Bonding of Nonwoven Fabrics*. Textile Progress, Vol.26, No.2, Textile Institute Manchester, ISBN: 1870812786.
- Gohl. 2005. *Textile Science: An Explanation of Fibre Properties*. CBS Publishers & Distributors, New Delhi
- Jirsak O and Wadsworth LC. 2004. *Nonwoven Textiles*. Textile Institute, Manchester, 1999, ISBN: 0 89089 9788.
- Lewin M. 2006. *Handbook of Fiber Chemistry*. Taylor and Trancies e-books. Boca Raton
- Lunenschloss J Albrecht W and David S. 1985. *Nonwoven Bonded Fabrics*. Ellis Horwood Ltd., New York, ISBN: 0-85312-636-4.
- Mrstina V and Feigl F. 1990. *Needle Punching Textile Technology*. Elsevier, New York,
- Russel SJ. 2007. *Handbook of Nonwovens*. Woodheadpublishing limited, Cambridge, England.
- Vidyasagar PV. 2008. Handbook of Textiles. BS Publications, New Delhi, India
- Wilson J. 2001. *Hand book of Textile Science*. Woodhead Publishing, UK of Textile Design

Weekly Lecture Schedule

Duration (week)	Topics
1	Development of the non-woven industry.
2	Types of Non wovens- dry, wet and polymer- laid non-woven, web formation, bonding and raw materials.
3	Types of web formation, mixing and blending, card clothing, cross lapping
4	Development, physical properties and practical applications of air laid fabrics. Wet-laid fabrics- raw materials, bonding systems, finishing and product application
5	Polymer- laid fabrics- raw materials, bonding techniques, spun-bond fabrics, characteristics, properties and other extrusion properties.
6	Types of bonding: Mechanical bonding- stitch, needle punching, hydro entanglements
7	Process technology and applications. Thermal bonding- raw materials, contact,
8	Thermal reaction/ infrared and ultrasonic bonding and applications.
9	Chemical bonding- chemicals, binder polymers, mechanism, drying and applications.
10	Non-woven fabric finishing - wet, chemical, lamination, Fabric inspection.
11	Non-woven fabric finishing - mechanical, surface and other developing technologies. Fabric inspection.
12	Characterization of non-woven fabrics - weight, thickness, density and other structural parameters.
13	General standards for testing non wovens- absorption, strength, bonder and optional properties.
14	Testing and evaluating of Laminated fabrics

I. Course Title : Research and Publication Ethics
II. Course Code : ATS 611
III. Credit Hours : 2 (1+1)

IV. Aim of the course

- To focus on basics of philosophy of science and ethics, research integrity, publication ethics
- To provide hands-on experience to identify research misconduct and predatory publications, Indexing and citation databases, open access publications, research and plagiarism tools

V. Theory

Unit I: Philosophy and Ethics

Introduction to philosophy- definition, nature and scope, concept, branches; Ethics: definition, moral philosophy, nature of moral judgments and reactions

Unit II: Scientific Conduct

Ethics with respect to science and research; Intellectual honesty and research integrity; Scientific misconducts- Falsification, Fabrication, and Plagiarism (FFP); Redundant publications; duplicate and overlapping publications, salami slicing; Selective reporting and misrepresentation of data

Unit III: Publication Ethics

Publication ethics- definition, introduction and importance; Best practices/ standards setting initiatives and guidelines- COPE, WAME, etc.; Conflicts of interest;

Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types; Violation of publication ethics, authorship and contributorship; Identification of publication misconduct, complaints and appeals; Predatory publishers and journals

VI. Practicals

Unit IV: Open Access Publishing

Open access publications and initiatives; SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies; Software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestion tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggested, etc.

Unit V: Publication Misconduct

Group Discussions - Subject specific ethical issues, FFP, authorship; Conflicts of interest; Complaints and appeals: examples and fraud from India and abroad
Software tools- Use of plagiarism software like Tumitin, Urkund and other open source software tools

Unit VI: Databases and Research Metrics

Databases- Indexing databases; Citation databases: Web of Science, Scopus, etc.
Research Metrics - Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g index, i10 index, altmetrics.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 6

Community Science
– Extension Education and Communication Management

Preamble

(Extension Education and Communication Management)

Specialisation in Extension Education and Communication Management, should foster unique capabilities and competitive skills among students to satisfy the community that is with versatile information needs. This is exceedingly challenging in the world of digital media device and product development, as well as their usage. Extension education being an advisory system of application of latest scientific and technological innovations, its amalgamation with communication management for effective and sustainable human development is the cutting edge. Moreover the Education Policy lays meticulous emphasis on the development of creative potential of each individual, for remunerative career opportunities. Professionalism in planning of extension systems and implementation through effective communication thus becomes an integral part of this component. In the advent of change in the nomenclature from Home Science to Community Science where the sphere of clientele enlarged, it has become all the more crucial for improvisation.

Accordingly, the courses being offered were critically reviewed for their contribution in molding students as professional extension scientists. Based on this, some courses are continued, but with addition of content in view of contemporary developments. New courses, six and four course in M.Sc. and Ph.D., respectively are included to fill the gaps. Overall, the courses can be categorized into three: i) Extension systems and processes, ii) Media development and management and iii) Extension research. With adequate practical component, all the courses persuade participative learning.

A multi-dimensional approach is adopted to deal with the techniques/ technologies to encourage entrepreneurship development. Innovative methodologies are suggested to advance the understanding and vision of the students. Simulated learning through project mode i.e. attachment of students to AICRP units for transfer of technology, and University Extension programmes is incorporated. Knowledge entrepreneurship development education by means of special projects for teaching/learning materials for differently able groups is planned to enlarge the creativity of students. Special project encourages outsourcing of students skills, thus making them specialized service providers. Teaching methods like Inter-university exchange through online group discussions make students competitive.

Modifications Suggested in Courses in the Revised Curricula

M.Sc. Community Science (Extension Education & Communication Management)

Course Code	Course Title	Credit Hours	Remarks
	Major Courses		
EECM 501	Global Extension Systems	3 (3+0)	Content modified in view of emergence of innovative processes in extension systems
EECM 502	Development communication	3 (2+1)	Title changed and content modified to suit to developmental challenges
EECM 503*	ICT and New Media	4 (1+3)	Credits enhanced and content modified by focusing ICT in community education
EECM 504*	Technology Transfer and Management	3 (1+2)	New course to engage students for on-hands training by attaching to AICRP/KVKs
EECM 505*	Dynamic Communication skills	3 (1+2)	New course for development of holistic communication skills.
EECM 506	Participatory Programme Management	3 (1+2)	Content modified for practical orientation to application and analysis in different situations

Course Code	Course Title	Credit Hours	Remarks
EECM 507	Organizational Development and HRD	2 (1+1)	New course to orient students towards professional management of organizations.
EECM 508	Educational Technology	3 (2+1)	Content modified to achieve proficiency in teaching and learning.
EECM 509	Group Dynamics	2 (2+0)	Content modified, highlighting adoption of SHG for simulated learning
EECM 510	Community Development and Outreach	3 (2+1)	New course to stimulate strong connection with community and communication.
EECM 511*	Climate change management	2 (1+1)	New course to mold students as service providers in climate change management.
EECM 512	Gender Sensitization for Empowerment	2 (2+0)	Content modified to promote interest in national gender sensitive issues.
EECM 513	Special Project- Out sourcing for Media product development	2 (0+2)	New course for entrepreneurial skills.
	Minor Courses		
FN 505	Nutrition and Physical fitness	3(2+1)	Proposed minor courses from subjects closely related to a student's major subject.Apart from these courses a student can register any other course
FN 509	Food Safety and Standards	3(2+1)	
FN 513	Human Physiology	3(3+0)	
HDFS 503	Methods and Techniques of Assessment in Human Development	3(2+1)	
HDFS 506	Management of differently abled	3(2+1)	
ATS 512	Apparel and Textile Product Development	2(1+1)	
ATS 513	Laboratory Techniques in Textiles Research	2(0+2)	

Course Code	Course Title	Credit Hours	Remarks
RMCS 513	Environmental Resource Management	2(1+1)	offered by any other departments
RMCS 508	Product Design	3(1+2)	
RMCS 507	Consumer Issues and Legislations	2 (2+0)	
	Supporting Courses		
	Research methodology	3(2+1)	Course numbers will be assigned by the departments that offer these courses.
	Statistics	3(2+1)	
	Total	**6(4+2)**	
	Common Courses		
	Library and Information Services	1(0+1)	The common courses will be registered with the respective departments that offer these courses
	Technical Writing and Communication Skills	1(0+1)	
	Intellectual Property and its management in Agriculture	1(0+1)	
	Basic Concepts in Laboratory Techniques	1(0+1)	
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)	
		5(0+5)	
EECM591	Seminar	1(0+1)	
EECM599	Thesis/Research	30	
	Total	**70**	

*Compulsory core curses

Ph.D. Community Science (Extension Education and Communication Management)

Course Code	Course Title	Credit Hours	Remarks
	Major Courses		
EECM 601*	Managerial Skills for Extension Professionals	3 (2+1)	Content updated for delivery of specialized extension support in competitive environment

Course Code	Course Title	Credit Hours	Remarks
EECM 602	Impact Assessment of Development programmes	3 (1+2)	New title, by taking a part of content from HECM 606 , Monitoring, Evaluation and Impact Assessment. Content focuses on Case study method
EECM 603*	Scaling Techniques for Behaviour Research	3 (1+2)	New course, to provide expertise in development of scales.
EECM 604	Design and Development of e-Extension Project	3 (0+3)	New course to provide comprehensive experience of Extension-Research-Education through digital communication.
EECM 605	Sustainable Livelihood Systems	2 (1+1)	Content updated, highlighting sustenance processes to different contexts and situations of uncertainty
EECM 606	Extension Research Project Management	3 (1+2)	Title of HECM 604 Research project management is changed and content modified to focus on Extension research
EECM 607	Media application and Product Promotion	4 (2+2)	Basics of media are covered at UG and M.Sc. level. Hence HECM 603 Advanced media management is

Course Code	Course Title	Credit Hours	Remarks
			modified for application skills in media product development
EECM 608	Advocacy and Behavior Change Management	3 (1+2)	New course to provide skills for logical thinking in planning behaviour change communication programme.
	Total	24 (9+15)	
	Minor Courses		
FN 604	Global Nutrition Problems	2(2+0)	Proposed minor courses from subjects closely related to a student's major subject.Apart from these courses a student can register any other course offered by any other departments
FN 608	Energy Metabolism	2(2+0)	
HDFS 608	Qualitative research methods	3(2+1)	
ATS 602	Technical Textiles	3(2+1)	
ATS605	Functional Clothing	3(2+1)	
ATS 607	Operational Management in Textiles and Apparel	2(2+0)	
RMCS 603	Globalization and Consumer Economics	3 (2+1)	
RMCS 606	Environmental Issues and Challenges	2 (2+0)	
RMCS 607	Family Dynamics and Women Power	3 (2+1)	

Supporting Courses

Student can choose any course relevant to the research from other faculties of the University or from Swayam portal or online courses.

EECM 691	Doctoral Seminar I Optional Field)	1 (1+0)	
EECM 692	Doctoral Seminar II (Core Field)	1 (1+0)	
EECM 699	Research	75	
	Total	100 Credits	

*Compulsory core curses

** Detail missing

Course Title with Credit Load M.Sc. (Community Science) in Extension Education and Communication Management

Course Code	Course Title	Credit Hours
EECM 501	Global Extension Systems	3 (3+0)
EECM 502	Development communication	3 (2+1)
EECM 503*	ICT and New Media	4 (1+3)
EECM 504*	Technology Transfer and Management	3 (1+2)
EECM 505*	Dynamic Communication skills	3 (1+2)
EECM 506	Participatory Programme Management	3 (1+2)
EECM 507	Organizational Development and HRD	2 (1+1)
EECM 508	Educational Technology	3 (2+1)
EECM 509	Group Dynamics	2 (2+0)
EECM 510	Community Development and Outreach	3 (2+1)
EECM 511*	Climate change management	2 (1+1)
EECM 512	Gender Sensitization for Empowerment	2 (2+0)
EECM 513	Special Project- Out sourcing for Media product development	2 (0+2)
	Minor Courses**	
FN 505	Nutrition and Physical fitness	3(2+1)
FN 509	Food Safety and Standards	3(2+1)
FN 513	Human Physiology	3(3+0)
HDFS 503	Methods and Techniques of Assessment in Human Development	3(2+1)
HDFS 506	Management of differently abled	3(2+1)
ATS 512	Apparel and Textile Product Development	2(1+1)
ATS 513	Laboratory Techniques in Textiles Research	2(0+2)
RMCS 513	Environmental Resource Management	2(1+1)
RMCS 508	Product Design	3(1+2)
RMCS 507	Consumer Issues and Legislations	2 (2+0)
	Supporting Courses	
	Research methodology	3(2+1)
	Statistics	3(2+1)
	Total	6(4+2)
	Common Courses	
	Library and Information Services	1(0+1)
	Technical Writing and Communication Skills	1(0+1)

Course Code	Course Title	Credit Hours
	Intellectual Property and its management in Agriculture	1(0+1)
	Basic Concepts in Laboratory Techniques	1(0+1)
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)
	Total	**5(0+5)**
EECM591	Seminar	1(0+1)
EECM599	Thesis/Research	30
	Total	**70**

*Compulsory core curses

Course Contents
M.Sc. (Community Science) in Extension Education and Communication Management

I. Course Title : Global Extension Systems

II. Course Code : EECM 501

III. Credit Hours : 3 (3+0)

IV. Rationale

India has the pre and post-independence history of extension programmes. In course of time many changes occurred in policies and plans based on ever changing needs. Based on lessons learned with in the country and from other developing countries, all the time new efforts are being made making extension system more strategic. This course provides such information with an analytical perspective of Indian extension system in comparison with other countries over the Globe. It will give an opportunity to the students to get an insight into the strengths and weakness of each of the system, to mould themselves as policy contributors and planners.

V. Aim of the course

- To appraise students the perspectives of extension systems in India
- To enable students for comparative analysis of Indian extension systems with other countries
- To acquaint students with the extension systems in ICAR and SAUs.

VI. Theory

Unit I: Orientation to extension systems

Early extension efforts; Indian extension systems - reforms, challenges of extension management in India; Paradigm shift in extension systems; Extension approaches in view of globalization and market liberalization; Privatization of extension services – introduction, scope, advantages, limitations and experiences; Decentralization of extension systems; Revolution in extension systems.

Unit II: Governance and extension systems

Indian governance and role of extension systems - retrospection on Indian governance; Role of extension system; Ministries - rural development, agriculture, science and technology, human resource development, health, industries, education and women and child development; NGO collaboration; Review of five year plans.

Unit III: ICAR extension system

History; Extension system; Organisational structure; Policy issues; Existing extension systems and challenges; National and regional institutions - vision, objectives, activities, innovations, programmes; Extension systems in SAUs - organisational structure, personnel, roles, innovations, SWOT analysis.

Unit IV: Extension management and training organisations and institutions

FAO, IFAD, IFRI, WFO, WHO, *Biodiversity international,* MANAGE, NIRD, National Institute of Agricultural Marketing (NIAM), NAARM, EEI, SAMETI, FTC.

Unit V: Comparative analysis of extension system

India with USA, UK, Israel, China, Pakistan, Bangladesh, Japan, Italy, South Africa, Island, Indonesia, Philippines and Brazil - history, approaches, organizational structure, methodology, services, problems and research linkages.

VII. Teaching Methods/ Activities

- Lectures
- Assignment
- Student's Book/Publication Review
- Students' presentation
- Online group discussion

VIII. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend different national and other global extension systems and their focus areas.
- Compare and analyse the differences in extension systems between nations in terms of their approaches and priorities.
- Explain extension systems in ICAR and SAU.
- Conceptualise the challenges in execution of extension systems.

IX. Suggested Reading

- Azadi H and Filson G. 2009. *Comparative Study of Agricultural Extension Systems-A Systemic View Outlook on Agriculture*. https://www.rug.nl/research/portal/publications.
- Sagar M. 2013. *Text Book of Agricultural Extension with Global Innovations*. Kalyani Publishers, Ludhiana, ISBN: 978-93-272-2877-9.
- Salahuddin A and Magor NP. 2005. *Innovations in Rural Extension: Case Studies from Bangladesh*. CABI Publishing, Wallingford, UK.
- Sangeet G and Mithilesh V. 2011. *Global Extension Systems: A Textbook*. New Academic Publications ISBN-10: 8186772464 ISBN-13: 978-8186772461.
- Singh KK *et al.* 2015. *Agricultural Extension Explorer*. Kalyani Publishers, Ludhiana.
- *Global Approaches to Extension Practice: A Journal of Agricultural Extension*
- *International Journal of Agricultural Extension*
- *Indian Research Journal of Extension Education* published by Society for Extension Education Agra

Weekly Lecture Schedule

Duration (week)	Topic
1.	Early extension efforts, Indian Extension systems – Reforms, Challenges of extension management in India, Paradigm shift in extension systems.
2.	Extension approaches in view of globalization and market liberalization, Privatization of extension services - Introduction, Privatization of extension services – Scope, Advantages and limitations.
3.	Privatization of extension services – Experiences, Decentralization and devolution of extension services, Revolution of extension systems.
4.	Retrospection on Indian governance, role of extension system , Ministry of Rural Development, Ministry of Aagriculture and Farmers' Welfare.
5.	Ministry of Science and Technology, Ministry of Human Resource Development, Ministry of Industries.
6.	Ministry of Women and Child Development, Ministry of Health and Family Welfare.
7.	NGO collaboration, Review of five year plans.

Duration (week)	Topics
8.	History of extension systems in ICAR organisational structure of extension system, Policy issues, Existing extension systems and challenges, National and regional extension institutions – Vision and objectives.
9.	National and regional extension Institutions - Programmes and activities, National and regional extension institutions- Innovations and interventions, National and regional extension Institutions- Case studies and success stories.
10.	Extension systems in SAUs - Organisational structure, Personnel and roles, Extension systems in SAUs – Role of extension in academic, Research and training activities, Innovative extension systems in SAUs- Case studies.
11.	SWOT analysis of extension system in SAUs, Introduction, FAO and IFAD. WFO (World Farmers' Organisation) and WHO.
12.	*Bioversity International,* MANAGE, NIRD.
13.	NIAM, NAARM, EEI.
14.	SAMETI and FTC, IFPRI, India and USA, UK - History, Approaches, Organizational structure, Methodology, Services, Problems and research linkages.
15.	India with Israel, China - History, Approaches, Organizational structure, Methodology, Services, Problems and research linkages, India and Pakistan, Bangladesh - History, Approaches, Organizational structure, Methodology, Services, Problems and research linkages, India and Japan, Italy - History, Approaches, Organizational structure, Methodology, Services, Problems and research linkages.
16.	India and South Africa, Island - History, Approaches, Organizational structure, Methodology, Services, Problems and research linkages, India and Indonesia, Philippines - History, Approaches, Organizational structure, Methodology, Services, Problems and research linkages, India and Brazil - History, Approaches, Organizational structure, Methodology, Services, Problems and research linkages.

I. Course Title : Development Communication

II. Course Code : EECM 502

III. Credit Hours : 3 (2+1)

IV. Rationale

Globally, development communication is an approach for sustainable growth in versatile areas of quality life. Communication refers to the use of different types of media for the process of development, while development refers to the process of betterment of a society. Students specializing in EECM play multiple roles in the process of addressing various development issues pertaining to sustainable development goals, which the globe is looking at. This course imparts knowledge and skill to communicate responsive information aiming at feedback. The scope of innovation, creativity and continuity motivates students to make public programmes and policies real, meaningful and sustainable.

V. Aim of the course

- To familiarize students with global perspective of development communication issues
- To impart analytical skills with regard to the process of development communication
- To understand the role and use of media in attaining sustainable development goals.

VI. Theory

Unit I: Over view of development communication- Hypothetical concepts and theories- Press theories

Normative - authoritarian, libertarian, social responsibility, democratic participant theory; Sociological - uses & gratification, agenda setting; two-step flow; Psychological; Bullet theory; Theories of persuasion and advocacy; Critical theory of frank furt school; Attitude change theories; Political economy theory; Critical cultural theory of birmingham school and framing theory.

Unit II: National and international perspectives of development communication

National and international perspectives; Evolution of development communication concept; Government and non-government initiatives; Government and non-government organisations - FAO, UNDP, WHO, UNICEF, CARE and strategies.

Unit III: Millennium development goals (MDGs) and sustainable development goals (SDGs)

Achievements of MDGs - analytical review and recommendations; SDGs - document, vision and objectives; Targets and strategies for implementation.

Unit IV: Research perspectives of development communication:

Emerging issues; Measurable and variables of development communication; Existing research projects; Research lag and supporting organisations.

Unit V: Media initiatives for development communication:

Conventional and contemporary media technologies; Globalisation and media convergence; Ethical issues and media impact analysis.

VII. Practical

1. Research review on hypothetical concepts and theories of Development communication
2. Presentation on hypothetical concepts and theories of Development communication
3. Critical analysis of Sustainable Development goals (SDGs)
4. Report writing and presentation on critical analysis of SDGs
5. Case study preparation focusing national and international organisation efforts for development communication.
6. Presentation of national and international organisation efforts
7. Critical review on ongoing Development Communication research projects in respective SAUs
8. Presentation on ongoing Development Communication research projects
9. Interaction with personnel and consumers of development communication projects and group discussion.
10. Interaction with personnel and consumers of development communication projects and group discussion.
11. Selection of contemporary media for development of communication issue, dissemination through existing channels of respective SAUs
12. Analysis of contemporary media for development of communication issue
13. Analysis of contemporary media for development of communication issue

14. Presentation of media analysis of the issue
15. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignment
- Student's Book/Publication Review
- Simulation exercise
- Media development and transmission
- Student presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend the theories and perspectives of development communication
- Critically analyse SDGs in terms of niche research in development communication
- Understand the process of development communication in various national and international organizations
- Recognise the efforts of SAUs for development communication
- Plan and disseminate communication media on development issues

X. Suggested Reading

- Huesca R. 2003. Participatory Approaches to Communication for Development. In Mody B (Ed.) *International and Development Communication: A 21st Century Perspective*. Sage, California.
- Joshi Uma *Understanding Development Communication*. Dominant Publications, New Delhi.
- Karin G, Wilkins Thomas T and Rafael O. 2014. *The Handbook of Development Communication and Social Change*. Kindle Publication, ISBN: 9781118505311.
- Mefalopulos P. 2008. *Development Communication Sourcebook- Broadening the Boundaries of Communication*, The World Bank Publication.
- Mikkelsen and Britha. 2002. *Methods for Development Work and Research*. Sage Publications, New Delhi.
- Narula and Uma. 2007. *Development Communication Theory and Practice*. Har-Anand Publication, Ltd. New Dehli.
- Mefalopulos Paolo. 2008. *Development Communication Sourcebook Broadening the Boundaries of Communication Development Communication Sourcebook Broadening the Boundaries of Communication*. Washington DC ISBN 978-0-8213-7522-8.
- Servaes Jan. 2008. *Communication for Development and Social Change*. Sage Publications, New Delhi.
- *Journal of Development Communication*. Asian Institute for Development Communication
- Journal of Development and Communication Studies. Asian Journal of Communication

Weekly Lecture Schedule

Duration (week)	Topic
1.	Over view of Development communication- Introduction to hypothetical concepts theories, Press theories, Normative – Authoritarian.
2.	Libertarian, Social Responsibility.
3.	Democratic Participant theory, Sociological - Uses and gratification
4.	Agenda setting, Two-step flow.
5.	Psychological, Bullet theory.
6.	Theories of persuasion and advocacy, Critical theory of Frankfurt school.
7.	Attitude change theories, Political economy theory.
8.	Critical cultural theory of birmingham school and framing theory. National and

Duration (week)	Topics
	international perspectives of development communication - Evolution of development communication concept.
9.	Government and non-government initiatives, Organisations and strategies – FAO.
10.	Organisations and strategies - UNDP, Organisations and strategies - WHO.
11.	Organisations and strategies - UNICEF, Organisations and strategies - CARE.
12.	Millennium development goals (MDGs) and sustainable development goals (SDGs) - Achievements of MDGs - Analytical review and recommendations, Achievements of MDGs - Analytical review and recommendations.
13.	SDGs - Document, Vision and objectives of SDGs.
14.	Targets and strategies for implementation, Research perspectives of development communication - Emerging issues, Measurable and variables of development communication.
15.	Existing research projects, Research lag and supporting organisations, Media initiatives for development communication - Conventional and contemporary media technologies, Globalization and convergence.
16.	Mass media and ethical issues, Mass media impact analysis.

I. Course Title : ICT and New Media

II. Course Code : EECM 503

III. Credit Hours : 4 (1+3)

IV. Rationale

A revolution has occurred in information technology, significantly impacting human communication; thereby human development. The speed and rapidity of information process due to information technology revolution, maximised the gadget adoption and usage irrespective of geographical and demographical range. Thus, a new set of relationships and responsibilities emerged among the information processors to satisfy the information needs of versatile users. This course provides such competency among the students for interactive communication in a flash to any corner of the world.

V. Aim of the course

- To familiarize students with ICT and new media technologies and provide application skills though industry attachment
- To provide hands-on-experience on application of ICT tools and devices
- To expertise in analytics tracking to analyse information reach.

VI. Theory

Unit I: Information communication technology

Information communication technology - components of ICT, role of ICT in community education; IT enabled services - call centre, helpdesks, data warehouse; Current status of application; Government policy on ICT; Emerging research issues.

Unit II: Perspective of new media

Definitions, Soft and hardware components, Traditional media transition to new media; Knowledge management and archiving; Networks; Social Media - advantages and limitations.

Unit III: Multimedia - concept and evolution

Digital Audio - sound design and mixing, digital videography and photography, digital text writing.

Unit IV: Web and blog designing

Hosting; Introduction of HTML and basic tags and HTML document structure; Cascading style sheets; Text in CSS and working.

VII. Practical

1. Multimedia and emerging technologies - Introduction to Video-on demand, internet - radio and web television
2. Introduction to Internet and the browsers
3. Introduction to Internet access and browsing
4. Introduction to Internet access and browsing extension related websites, blogs and data bases
5. Exposure to network
6. Compose e-mails, send and receive mails
7. Video on demand- different video formats
8. Creating a Basic Video Clips with Video Editing software.
9. Adding audio into developed videos
10. Editing of existing videos and audios
11. Video on demand-accessing downloads and editing of required video formats
12. Internet radio- Accessing different radio channels in online websites and browsing
13. Web Television- Exposure and accessing
14. Impact of new media on traditional media- listing of various traditional media and new media formats- collection of literature
15. Group discussion/debate on advantages and disadvantages of traditional media and new media
16. Writing on specialized area on the web
17. Writing for general interest web- script writing concepts, principles for web
18. Writing for online- script writing concepts, principles, styles for online
19. Writing for net newspapers and editions- script writing concepts, principles, styles for online
20. Writing for blogs and search engines- script writing concepts, principles, styles for online
21. Writing for video logs, citizen journalism- script writing concepts, principles, styles for online
22. Evaluation of e-journals- Exposure to electronic journals, browsing sites, accessing and down loading the journal articles
23. Evaluation of e-journals
24. Submission of reports
25. Unique features of web language-, open source softwares, viz., wordpress, joomla, moodle
26. Introduction and basics to Advanced HTML
27. Introduction of Cascading Style Sheets
28. Orientation – java script and HTML scripts
29. Designing web page- Home page(landing page), hyperlinks with using CSS
30. Practical exercise on designing a web page by using HTML5 and CSS3.
31. How to create responsive (Mobile friendly) Pages with Using HTML5 and CSS3.

32. Designing web page- Home page, hyperlinks - open source softwares, viz., Wordpress
33. Explanation of WordPress Dashboard and creating blog in Wordpress
34. Hosting a WordPress Blog online
35. Creating Google Analytics
36. Adding Google Analytics into HTML page and Wordpress Pages
37. Introduction to interactive web media- web animation
38. Understanding web animation- jquery, dream weaver and Photoshop
39. Exposure to animated graphics in the web
40. Introduction to designing interactive elements, sound addition
41. Introduction to web visual editor, creation and editing.
42. Acquiring a domain and webhosting to host the website/blog.
43. Familiarisation with FTP and Cpanel
44. Hosting website into Online
45. Updating/change the contents and images online Website after Hosting.
46. How to take the backups of the website after hosting a website.
47. Tracking Web Traffic from Analytics
48. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignment
- Student's Book/Publication Review
- Practice sessions
- Media development and transmission
- Student presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend the role of ICT based services for community education and development
- Figure out the required soft and hard ware components in application of new media for interactive communication
- Develop content for web sites
- Design, develop and manage websites
- Track web analytics and analyse the impact

X. Suggested Reading

- Andleig PK and Thakrar K. 2003. *Multimedia Systems Design*. PHI: New Delhi.
- Chrisanthi Avgerou, Robin Mansell, Danny Quah and Roger Silverstone. 2009. *The Oxford Handbook of Information and Communication Technologies*. http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199548798.001.0001/oxfordhb-9780199548798.
- Earnshaw RA and Vince JA. 1995. *Multimedia Systems and Applications*. London: Academic Press.
- Grace Kite. 2012. *The Impact of Information Technology Outsourcing on Productivity and Output: New Evidence from India* Volume 1. Pages 239-48.
- ST Nandasara. 2009. *Information Communication Technology – Grade 11*. Educational Publications Department, Ministry of Education, Sri Lanka https://www.researchgate.net.
- Thatchinamoorthi J and C Meenambigai. 2018. *Textbook of Extension Communication & Information Technology*. ISBN-10: 9788183214681 ISBN-13: 978-8183214681.

- Vanaja and Rajasekar. 2016. *Information & Communication Technology* (*ICT*) *In Education*. First Edition, Neelkamal ISBN- 0: 8183165192 ISBN-13: 978-8183165198.
- https://www.india.gov.in/topics/communication/information-and-technology
- Smart Villages Through Information Technology – Need of Emerging India https://www.researchgate.net/publication
- http://atcm.mathandtech.org/EP2009/papers_ full/2812009_17282.pdf
- https://www.emeraldinsight.com/doi/abs/10.1108/eb047157

Weekly Lecture Schedule

Duration (week)	Topic
1	Information communication technology - Components of ICT.
2	Role of ICT in community education.
3	IT enabled services - Call centre, Helpdesks, Data warehouse.
4	Current status of application.
5	Government policy on ICT.
6	Emerging research issues.
7	Perspective of New media - Definitions, Soft and hardware components.
8	Traditional media transition to new media.
9	Knowledge management and archiving, Networks.
10	Social Media - Advantages and limitations.
11	Multimedia - Concept and evolution - Digital Audio - Sound design and mixing.
12	Digital videography and photography.
13	Digital text writing.
14	Web and blog designing – Hosting.
15	Introduction of HTML and basic tags and HTML document structure.
16	Cascading style sheets, Text in CSS and working.

I. Course Title : Technology Transfer and Management

II. Course Code : EECM 504

III. Credit Hours : 3 (1+2)

IV. Rationale

Technology transfer is the process of transferring skills and knowledge of a proven technology to users for application to enhance and sustain qualitative life. It is the mandate of Agricultural universities to ensure that scientific and technological developments are accessible to a wider range of users who can then further develop and exploit the technology into new products, processes, applications, materials or services. On the other hand, the importance of technology transfer has been increasing with the growing need for modern technologies, innovation, inventions and R&D. In this context, it is pertinent to provide adequate skill and knowledge to the students in transfer of technology and management.

V. Aim of the course

- To acquaint students with the process of TTM
- To provide hands-on-experience in TTM
- To sensitise students towards technology transfer career.

VI. Theory

Unit I: Introduction to technology transfer

Transfer of Technology - Definition and importance; Models of technology transfer -

different models, qualitative technology transfer models, dimensions of technology transfer, features of technology package, routes of technology transfer; FLD, OFT, Minikits.

Unit II: Technology acquisition

Technology acquisition; Alternatives for acquiring new technologies; Reasons; Management of acquired technology; Measures of scale and mechanisms for acquiring technologies - economy of scale, levels of scale, measurement of scale, factors affecting the choice of scale.

Unit III: Introduction to technology management

Concept and meaning of technology management; Evolution and growth of technology management.

Unit IV: Role and significance of technology management

Impact of technology on society; Technology and competition; Key issues in managing technological innovation, Forms of technology - product and process technologies; Technology forecasting - methods and principles; Role of government in technology management.

Unit V: Technological change

Characteristics of technological change; Classification of technological change; Impact of technological change; Technology life cycle; Technology transformation; Technology policies and policy instruments.

Unit VI: Technology assessment

Technology choice; Technology assessment and refinement; Technology assessment process; Technology leadership and followership; Writing technology assessment report.

Unit VII: Invention, innovation and creativity

Meaning and differences; Innovation management; Intellectual property management.

Unit VIII: Technology adoption, diffusion, and absorption

Technology adoption diffusion and absorption; Role of technology absorption - benefits, constraints in technology absorption, technology package and technological dependence, Indian experience in technology absorption efforts, issues involved in the management of technology absorption and government initiatives.

Unit IX: Development of technology

Development process and steps; Technology development and competition; Managing research & development (R & D); Reforms in technology development.

Unit X: Social issues in technology management

Technological change and industrial relations; Implementation of rationalization and automation in India.

VII. Practical

Note: Students may be attached to AICRP on Home Science/ Research project all through the semester for practical experience with either one of the departments, or for a stipulated duration with every department may be left to the discretion of course-in-charge. Students' report may consist the following information.

1. Enlisting of technologies already transferred under five disciplines/ research project.
2. Selection of technologies for observation of change attained and preparation of observation schedule
3. Field visit and interaction with clientele to collect data
4. Analysis of data and preparation of report
5. Presentation of report
6. Group discussion on technology refinement/ sustainability issues
7. Enlisting and description of technologies transferred by the concerned scientist/s during the semester
8. Description of invention, innovation and creativity of the selected technology
9. Description of transfer of technology model
10. Design and development of transfer of technology process
11. Presentation of technology transfer process
12. Preparation and finalisation of work plan for participation in technology transfer

13–25. Execution of work plan as per time line

26. Analysis of technology adoption and diffusion stages
28. Preparation of report on technology transfer
29. Presentation of report
30. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignment
- Student's Book/Publication Review
- Implant training/ Placement
- Student presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend technology transfer perspectives
- Select and execute technology in accordance with the needs of community
- Practice the management process
- Analyse the stages of technology adoption, diffusion and absorption
- Write the report on TTM

X. Suggested Reading

- A Inzelt and Jan Hilton. 1999. *Technology Transfer: From Invention to Innovation*. Springer Science and Business Media, Kluwer academic publishers.
- Albert E Muir. 1997. *The Technology Transfer System*: *Inventions: Marketing, Licensing, Patenting, Setting, Practice, Management, Policy*. Book News, Inc., Portland.
- Ali Hussein Saleh Zolai. 2012. *Knowledge and Technology Adoption, Diffusion, and Transfer*: *International Perspective*. University of Bahrain, Bahrain ISBN13: 9781466617520.
- Avid B, Audretsch Erik E, Lehmann Albert N, Link Alexander Starnecker. 2012. *Technology Transfer in a Global Economy*. Springer Science & Business Media, ISBN 146146102.
- Thomas J Allen. 1984. *Managing the Flow of Technology*. Edition III, Massachusetts Institute of Technology, ISBN 0262510278.
- *International Journal of Technology Transfer and Commercialisation*. Interscience Publishers, Genèva.

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction to technology transfer - Transfer of technology models, Traditional technology transfer models, Qualitative technology transfer models, Dimensions of technology transfer features of technology package, Routes of technology transfer, FLD, OFT, Minikits.
2	Technology acquisition - Technology acquisition, Alternatives and reasons for acquiring new technologies, Management of acquired technology, Measures of scale and mechanisms for acquiring technologies, Economy of scale.
3	Technology acquisition - Levels of scale, Measurement of scale factors affecting the choice of scale, Introduction to technology management - Concept and meaning of technology management, Evolution and growth.
4	Role and Significance of technology management, Impact of technology on society technology and competition, Key issues in managing technological innovation.
5	Forms of technology; Product and process technologies, Technology forecasting-Methods and principles.
6	Role of government in technology management, Technological change - Characteristics and classification of technological change.
7	Technological change - Impact of technological change, Technology life cycle, Technology transformation, Technology policies and policy instruments.
8	Technology assessment - Technology choice, Technology assessment process, Technology leadership and followership.
9	Technology assessment - Reporting technology assessment - Method, Invention, Innovation and creativity - Meaning and differences.
10	Invention, Innovation and creativity - Innovation management, Intellectual property management.
11	Technology adoption, diffusion, and absorption - Technology adoption diffusion and absorption, Role of technology absorption- Benefits.
12	Technology adoption, diffusion, and absorption - Constraints in technology absorption, Technology package and technological dependence.
13	Technology adoption, diffusion, and absorption - Indian experience in technology absorption efforts, Issues involved in the management of technology absorption government initiatives.
14	Development of technology - Developmental process and steps, Managing research & development (R & D).
15	Development of technology - Technology development and competition, Reforms in technology development.
16	Social issues in technology management - Technological change and industrial relations, Implementation of rationalization and automation in India.

I. Course Title : Dynamic Communication Skills

II. Course Code : EECM 505

III. Credit Hours : 3 (1+2)

IV. Rationale

Academic success and career achievement depend much on communication and presentation skills. As master's student, the individual is expected to analyse, prepare and present the content in the class room, conferences and seminars and also write technically and scientifically. Hence dynamic communication includes both oral and written communication. This course builds awareness, understandings and frameworks for skills development in the qualities and attributes of presentational formats that involve the voice and the body when used together with technologies to present ideas and concepts that not only inform but also seek to persuade and motivate.

V. Aim of the course

- To develop competency of students in effective oral communication skills.
- To develop skills in science communication
- To understand corporate and business communication.

VI. Theory

Unit I: Need and importance of communication in present context

Types of communication skills - verbal, non-verbal and written communication; Types of corporate and business communication skills - oral presentations, group discussions, facing interviews, e-mail, memos, business letters, blogs, inter office memorandums, report writing; Hard and soft skills; difference between hard and soft skills.

Unit II: Scientific communication

Meaning; Need and importance; Fora of scientific writing - conference, seminar, symposium, workshop and colloquia; Writing for scientific journals; Thesis writing and writing articles for popular media; Farm journalism and its importance in agriculture and allied sectors; Science communication and formats for scientific writing; Writing for scientific journals and their ratings; NAAS rating; Impact factor and h-index; Oral and poster presentation; Reading and comprehension of - print and audio video media; General and technical articles.

Unit III: Introduction to public speaking

Types of speeches - persuasive, informative, and motivational or inspirational speech; Structuring the speech - introduction, body content and conclusion; Effective delivery - voice modulation, appearance during speeches and delivery; Platform performance - posture, gesture, eye contact, emphasis, pause, voice pitch, overcoming fear and anxiety of public speaking; Visuals in presentation - type of visuals for public speaking, tips for effective use, computer aided visual presentation, body language.

Unit IV: Importance of listening

Introduction; Listening styles - active & passive and direct & indirect listening, thinking & listening, adjusting listening style to that of speaker, social situations & listening; Listening improvement techniques.

VII. Practical

1. Orientation to NAAS rated Journals related to respective discipline
2. Enlisting relevant national and international journals
3. Exercise on writing a review article on given topics
4. Presentation of the topic
5. Exercise on writing popular articles for Newspapers, Magazines and farm journals in English
6. Presentation and group discussion
7. Exercise on writing popular articles for Newspapers, Magazines and farm journals in vernacular language
8. Presentation and group discussion
9. Exercise on writing thesis in UAS format

10. Presentation and group discussion
11. Exercise on Numbers, Units, Abbreviations and nomenclature
12. Presentation and group discussion
13. Scientific style and use of English in research paper
14. Presentation and group discussion
15. Exercise on writing business letters, e mail, blogs, Internet etiquettes
16. Presentation and group discussion
17. Exercise on listening skills
18. Presentation and group discussion
19. Exercise on presentation skills
20. Presentation and group discussion
21. Exercise on writing for radio
22. Presentation and group discussion
23. Message preparation for SMS
24. Practice on modalities of SMS dissemination
25. Presentation and group discussion
26. Learning skills of indexing, footnote and bibliographic procedures
27. Presentation and group discussion
28. Tips for public speaking
29. Exercise on public speaking
30. Organising public speaking- Impromptu, Extemporaneous, Manuscript and Memorized
31. Evaluation of public speaking
32. End term assessment

VIII. Teaching Methods/ Activities

- Participatory lectures
- Assignment
- Simulation exercises
- Online group discussions
- Organise public speaking
- Student's Book/Publication Review
- Students' presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Understand the importance of communication skills for goal achievement
- Differentiate scientific writing from other writings
- Write for different contexts and different media
- Organise and present public speaking
- Recognise the importance of NAAS rating for professional career

X. Suggested Reading

- D'Souza YK. 2000. *Encyclopedia of Advanced Journalism*. Vols. I-III. Anmol Publ.
- Khan PM. 2002. *Textbook of Extension Education*. Himanshu Publications, New Delhi.
- Lamerton J. 2001. *Everything You Need to Know Public Speaking*. Harper Collins Glasgow.
- Ravindran RK. 1999. *Hand Book of Reporting and Editing*. Anmol Publ.
- Ray GC. 1991. *Extension Communication & Management*. Kalyani Publishers, Ludhiana.

Weekly Lecture Schedule

Duration (week)	Topic
1	Need and importance of communication in present context - Types of communication skills - Verbal, Non-verbal and written communication.
2	Types of corporate and business communication skills - Oral presentations, Group discussions, Facing interviews, E-mail, Memos, Business letters, Blogs, Inter office memorandums, Report writing.
3	Hard and soft skills; difference between hard and soft skills.
4	Scientific communication - Meaning; Need and importance; Fora of scientific writing - Conference, Seminar, Symposium, Workshop and colloquia.
5	Writing for scientific journals; Thesis writing and writing articles for popular media.
6	Farm journalism and its importance in agriculture and allied sectors.
7	Science communication and formats for scientific writing; Writing for scientific journals and their ratings; NAAS rating; Impact factor and h-index; Oral and poster presentation.
8	Reading and comprehension of - Print and Audio Video Media; General and technical articles.
9	Introduction to public speaking - Types of speeches - Persuasive, Informative, and Motivational or Inspirational speech.
10	Structuring the speech - Introduction, Body content and conclusion; Effective delivery- Voice modulation, Appearance during speeches and delivery.
11	Platform performance - Posture, Gesture, Eye contact, Emphasis, Pause, Voice pitch, Overcoming fear and anxiety of public speaking.
12	Visuals in presentation - Type of visuals for public speaking.
13	Tips for effective use, Computer aided visual presentation, Body language.
14	*Importance of Listening* -Introduction.
15	Listening styles - Active & passive and direct & indirect listening, Thinking & listening.
16	Adjusting listening style to that of speaker, Social situations & listening; Listening improvement techniques.

I. Course Title : Participatory Programme Management

II. Course Code : EECM 506

III. Credit Hours : 3 (1+2)

IV. Rationale

In the context of community development, the participatory programme planning and management is a process by which a community undertakes to reach a given socio-economic goal by consciously diagnosing its problems and charting a course of action to resolve those problems. The belief behind participatory programme management is its capability in leading to increased productivity, motivation and quality assurance. This is very essential for students of all disciplines to learn, especially for those who will be undertaking change agent career. This course creates a learning experience for students to develop positive attitude towards management of programme with the participation of people, rather than working in isolation.

V. Aim of the course

- To orient the students towards principles, procedure and approaches PPM
- To facilitate application of PPM techniques in field situation.

VI. Theory

Unit I: Overview to PPM

Concept; Meaning; Importance; Types of participation in development; Advantages and disadvantages of participation by different stakeholders; Role of government and non profit organizations in promoting participation; Conceptual framework of extension programme planning; Objectives; Principles and process.

Unit II: Participatory planning

Concept; Importance; Process; Techniques of participatory planning - RRA, PRA, PLA and their application in extension; Approaches of participatory planning - cooperative, democratic, bottom up and down.

Unit III: Project management techniques

Administration of the Project; Concept of Professional management - stakeholder analysis, force field analysis, SWOT analysis, logical framework analysis, PERT, CPM.

Unit IV: Monitoring and evaluation

Concept; Meaning and importance of monitoring and evaluation; Components of M&E - physical, financial, staff performance; Technical aspects - output, outcome & impact; Trends in people‘s participation in M & E; Contribution of right to information Act.

VII. Practicals

1. Literature survey and research review on different perspectives of PPM
2. Presentation of review reports
3. Observation of PPM techniques in SHGs (female groups)
4. Observation of PPM techniques in SHG village federations
5. Observation of PPM techniques in SHG mandal/block level federations
6. Observation of PPM techniques in SHG district level federations
7. Observation of PPM techniques in SHGs (male groups)
8. Observation of PPM techniques in watershed management groups
9. Preparation of case study and presentation
10. Preparation of case study and presentation
11. Preparation of case study and presentation
12. Application of PRA methods – Critical analysis of different methods through research review- Mapping techniques
13. Application of PRA methods – Critical analysis of different methods through research review- Ranking techniques
14. Application of PRA methods – Critical analysis of different methods through research review- Transaction techniques
15. Application of PRA methods – Critical analysis of different methods through research review- Focus group discussion
16. Application of PRA methods – Critical analysis of different methods through research review- Problem analysis
17. Application of PRA methods – Critical analysis of different methods through research review- Institutional analysis
18. Preparation and implementation of home improvement work plans
19. Preparation and implementation of home improvement work plans
20. Critical evaluation of work plan

21. Critical evaluation of work plan
22. Application of project management techniques- PERT
23. Presentation of feedback on project management techniques- PERT
24. Application of project management techniques – CPM
25. Presentation of feedback on project management techniques – CPM
26. Application of project management techniques- SWOT
27. Presentation of feedback on project management techniques- SWOT
28. Application of project management techniques- Stake holder analysis
29. Presentation of feedback on project management techniques- stakeholder analysis
30. Application of project management techniques- Logical frame work analysis
31. Presentation of feedback on project management techniques- Logocal frame work analysis
32. End term assessment

VIII. Teaching Methods/ Activities

- Participatory lectures
- Assignment
- Simulation exercises
- Online group discussions
- Preparation of work plans
- Student's Book/Publication Review
- Students' presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Understand the underlying perspectives of PPM
- Realise the importance of PPM for sustainable achievement
- Acquire skill in observation of PPM techniques applied in different situations
- Plan, apply and analyse PPM techniques and write reports

X. Suggested Reading

- Elizaphan N. 2015. P*roject Monitoring and Evaluation: Tools and Techniques*. Kindle Edition, Ekon Publishers. *J. Agril. Res. Innov. & Tech.* **3**(2): 72-78, December, 2013 http://www.ijarit.webs.com
- Koen K, Maartjede G and Louise B. 2016. *Participatory Planning, Monitoring and Evaluation of Multi-stakeholder Platforms in Integrated Landscape Initiatives.* (Working Paper). https://www.researchgate.net/publication/311100782.
- Nabhi. 2005. *Handbook for NGOs*: *An Encyclopaedia for Non-government Organisations and Voluntary*. *Agencies* Vol1. Nabhi Publications, New Delhi.
- Rory B. 2014. *Burke Publishing Project Mmanagement Techniques.* 2nd College Edition, http://www.burkepublishing.com/component/%20content/article.html?id=16
- Uddin MN and Anjuman N. 2013. *Participatory rural appraisal approaches: an overview and an exemplary application of focus group discussion in climate change adaptation and mitigation strategies.* ISSN: 2224-0616.
- *Team FME SWOT Analysis Strategy Skills* ISBN 978-1-62620-951 http://www.free-management-ebooks.com/dldebk/dlst-swot.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Overview to PPM - Concept, Meaning and Importance.
2	Types of Participation in development.

Duration (week)	Topics
3	Advantages and disadvantages of participation by different stakeholders.
4	Role of Government and Non-Profit Organizations in promoting participation.
5	Conceptual framework of extension programme planning; objectives, principles and process.
6	Participatory planning - Concept, importance, process.
7	Techniques of participatory planning - RRA, PRA, PLA and their application in extension.
8	Approaches of participatory planning - cooperative, democratic, bottom up and down.
9	Project management techniques - Administration of the Project.
10	Concept of professional management - Stakeholder analysis.
11	Force field analysis, SWOT Analysis.
12	Logical Framework Analysis, PERT, CPM.
13	Monitoring and evaluation - Concept, Meaning and Importance of Monitoring and Evaluation.
14	Components of M&E - Physical, Financial, Staff Performance.
15	Technical aspects - Output, outcome and impact.
16	Trends in People 's Participation in M & E; Contribution of Right to Information Act.

I. Course Title : Organizational Development and Human Resource Development

II. Course Code : EECM 507

III. Credit Hours : 2 (1+1)

IV. Rationale

Every organization caters to the needs of its customers. But the best corporate thinking is leading the institution towards success by means of simplified processes and models. There are many frame works and models available, towards which the students are to be exposed to critically analyse the best means. The contemporary HRD trends and process provide students professional skills in capacity building and employee motivation programme planning. Beyond this, the students as employees in any organization in future endeavors can be professionals as they acquire technical skills in identifying the required deliverables for the company.

V. Aim of the course

- To orient students with OD and provide diagnostic skills in HRD processes
- To make students capable of applying the principles and techniques as professionals for developing human resources in an organization.

VI. Theory

Unit I: Introduction to organization development

Definition; scope and importance; Relevance of organization development in community science; History of organizational development; Revolution in organizational development; Planned change - theories of planned change, models of planned change; General and specific.

Unit II: Designing interventions for organisational development

Types; Interpersonal and group process approaches - process consultation, third party evaluation; Organisation process approaches - organization confrontation meeting, intergroup relations interventions, large group interventions; Techno-structural interventions - engineering approach, motivational approach, socio-technical systems approach; Human resource management interventions performance management - goal setting performance appraisal and rewards systems.

Unit III: Introduction to human resource development

Concept; Relationship between human resource management and human resource development; HRD mechanisms - processes and outcomes; HRD matrix; HRD interventions; Roles and competencies of HRD professionals; Challenges in HRD.

Unit IV: HRD process

Assessing need for HRD; Designing and developing effective HRD programmes; Implementing HRD programmes; Evaluating effectiveness of HRD programmes; HRD audit; HRD culture and climate; Employee development activities - approaches, leadership development, action learning, assessment and development centres; Intellectual capital and HRD.

Unit V: HRD Trends

Coaching and mentoring; Career management and development; Employee counselling; Competency mapping (CM); People capability maturity model (PCMM); Balanced score card; Appreciative inquiry; Integrating HRD with technology and Employer branding and other emerging trends.

VII. Practical

1. Visit to an organization to study the models of planned change and preparation
2. Presentation of report on models of planned change
3. Research review and presentation of organizational interventions in national context
4. Research review and presentation of organizational interventions in international context
5. Collection of data/information and preparation of case studies on organizational interventions in health
6. Collection of data/information and preparation of case studies on organizational interventions in education
7. Collection of data/information on organizational interventions in welfare and training organizations and preparation of case studies.
8. Presentation of case studies.
9. Study of existing HRD strategies of respective SAUs/Institutions
10. Analysis of existing HRD strategies of respective SAUs
11. Analysis of existing HRD strategies of respective Institutions
12. Presentation of reports with recommendations
13. Preparation of CM of the organization and planning for planned change
14. Preparation of PCM of the organization and planning for planned change
15. Presentation of reports
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignment
- Field visit

- Case study writing
- Student's Book/Publication Review
- Students'presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend and differentiate OD processes and HRD strategies
- Enlist, explain and prepare case study OD interventions in organisations
- Analyse HRD strategies of organisations
- Prepare CM and PCM plan for planned change

X. Suggested Reading

- Brown D. 2010. *Experiential Approaches to Organization Development.* (8th Ed.), Prentice Hall, New Jersey.
- Cheung-Judge M and Holbeche L. 2015. *Organization Development: A Practitioner's Guide for OD and HR.* 2nd Ed., Kogan, London.
- Cummings TG and Worley CG. 2014. *Organization Development and Change.* 10th Edition, West Publishing Company, New York.
- David M. 2009. *Human Resource Development.* Oxford University Press, Delhi.
- Haldar UK. 2010. *Human Resource Development*, Oxford University Press India.
- Harris DM and Desimonerady L. 2001. *Human Resource Development.* The Dryden Press, Orlando.
- Harvey DF and Brown DR. *An Experimental Approach to Organization Development.* Prentice-Hall, Englewood Cliffs, N.J. Mankin D. *Human Resource Development.* Oxford University Press, India.
- Pace RW, Smith Philip and Mills GE. 1991. *Human Resource Development.* The Field, Prentice Hall, New Jersey.
- Traeger J and Warwick R. 2018. *Organization Development: A Bold Explorer's Guide*. Libri Publishing, Farringdon, England.
- International Journal of Human Resources Development and Management
- IOSR Journal of Humanities And Social Science
- European journal of work and organizational psychology
- Human Resource Development Quarterly (Online)
- Human Resource Development International
- International Journal of Human Resource Studies

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction to Organization Development - Definition, scope and importance, History of Organizational Development.
2	Revolution in Organizational Development, Relevance of organization development in community science.
3	Planned Change - Theories of Planned Change, Models of Planned Change-general and specific.
4	Designing Interventions for Organisational Development – Types - Interpersonal and Group Process Approaches, Process consultation, Third party evaluation, Organisation process approaches Organization confrontation meeting, Intergroup relations interventions, Large group interventions.
5	Techno-structural interventions - Engineering approach, Motivational approach, Socio-technical systems approach, Human Resource Management Interventions Performance Management, Goal setting performance appraisal, Rewards systems.
6	Introduction to Human Resource Development – Concept, Relationship between human resource management and human resource development.

Duration (week)	Topics
7	HRD mechanisms - processes and outcomes, HRD matrix.
8	HRD interventions, Roles and competencies of HRD professionals.
9	Challenges in HRD, HRD Process - Assessing need for HRD.
10	Designing and developing effective HRD programs, Implementing HRD programs.
11	Evaluating effectiveness of HRD Programs, HRD audit.
12	HRD culture and climate, Employee development activities- Approaches, leadership development, action learning, assessment and development centres.
13	Intellectual capital and HRD, HRD Trends - Coaching and mentoring.
14	Career management and development, Employee counselling.
15	Competency mapping (CM), People Capability Maturity Model(PCMM).
16	Balanced Score Card, Appreciative inquiry, Integrating HRD with technology Employer branding and other emerging trends.

I. Course Title : Educational Technology

II. Course Code : EECM 508

III. Credit Hours : 3 (2+1)

IV. Rationale

Educational technology is a process of adopting modern technology for quality education. This primarily focuses on the educational values of the tools and applications, and later how adequate they are in acquisition of knowledge. Both theoretical and practical inputs the students are taught this course, mold them for effective learning at present and proficient instructors in future endeavors. Rational exposure to conventional and contemporary educational approaches and strategies will help the students for self learning as well promote learning.

V. Aim of the course

- To sensitize students towards the role of educational technology for effective teaching and learning
- To build competency as a teacher and public speaker
- To enable self learning among students for application of education technology.

VI. Theory

Unit I: Overview of educational technology

Meaning; Concepts and scope of educational technology; Curriculum design and development; Lesson planning; Concept and methodology; Modularised instruction - fundamentals, process, formulation of objectives, selection of media, field testing and evaluation of module.

Unit II: Teaching learning process

Meaning and characteristics of teaching and learning; Maxims of teaching - stages, forms and levels of teaching and learning; Motivation - concept, importance and techniques; Teaching styles - expert, formal authority, personal model, facilitator, delegator; Learning Styles - visual, aural, read/write, kinaesthetic (VARK).

Unit III: Teaching learning strategies

Microteaching; Programmed instruction; Simulation role-play; Team teaching; Experiential learning; Traditional media; ICT Applications in education; Multimedia based teaching and learning.

Unit IV: Current education

Genesis and trends; Management of formal and non formal education in India; Vocationalization of education; Distance education; Guidance and counselling; Innovative instructional aids - web instruction, e-learning, virtual laboratories.

Unit V: Educational technology for differently able

Visual impaired script - advances in braille; Hearing impaired - advances in Indian sign language; People with special needs - educational programmes and government policies.

Unit IV: Evaluation

Question bank; Introduction to evaluation - need and importance in education appraisal of teacher performance; Development of question bank; Evaluation of instructional effectiveness; Competency based question paper; Reliability and validity of question papers.

VII. Practical

1. Identification of key terms in educational technology and preparation of directory
2. Critical analysis of UG and PG curriculum of Community Science in relation to course objectives
3. Research review on planning and implementation of lesson planning
4. Presentation of research review report
5. Preparation of lesson plan
6. Conducting class as per lesson plan and self and peer evaluation
7. Preparation of inventory for identification of teaching styles and execution
8. Preparation and presentation of report
9. Preparation of inventory for identification of learning styles and execution
10. Preparation and presentation of report
11. Construction of Objective questions- Multiple choice, fill in the blanks
12. Construction of competency based question paper- Matching, Technical terms
13. Construction of subjective questions- Short type
14. Construction of subjective questions- Essay type
15. Analysis of questions in terms competency evaluation- knowledge, memory, application, analysis
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignment
- Student's Book/Publication Review
- Survey and analysis
- Mock sessions
- tudent presentation
- Online group discussion

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend conventional and contemporary trends of educational technology for various groups of learners
- Analyse critically the course curriculum and lesson planning in terms of reaching course objectives

- Prepare and execute inventory to identify learning styles
- Construct competency based objective and subjective question papers

X. Suggested Reading

- Dahama OP and Bhatnagar OP. 2005. *Education and Communication for Development*. Oxford & IBH.
- Bhaviskar SG. 2006. *Modern Technology in Education*. Kalyani Publication, New Delhi.
- Suhaskumar and Ruprao P *Modern Trends in Curriculum Organization*. Kalyani Publication, New Delhi.
- Heidi HJ. 2010. *Curriculum Essential Education for a Changing World*.
- Kochhar SK. 1985. *Methods and Techniques of Teaching*. Sterling Publication.
- Ray GL. 2006. *Extension Communication and Management*. Kalyani Publication, New Delhi.
- Anita S *Encyclopaedia of Curriculum Reforms and New Teaching Methods* (*4 Vol. Se*t). Dominant Publishers and distributors, New Delhi.
- The International Journal of Educational Technology in Higher Education
- *International Journal of Educational Technology* (ISSN 2476-0730)

Weekly Lecture Schedule

Duration (week)	Topic
1	Overview of Educational Technology- Overview of educational technology, Meaning, concepts and scope of educational technology, Curriculum design and development.
2	Overview of Educational technology-Lesson planning, concept and methodology.
3	Overview of Educational technology-Modularised Instruction - fundamentals, process, formulation of objectives, Selection of media, Field Testing and Evaluation of module, Teaching learning process-Meaning and characteristics of teaching and learning.
4	Teaching learning process-Maxims of teaching, Stages, forms and levels of teaching and learning.
5	Teaching learning process-Motivation - concept, importance and techniques, Teaching styles - expert, formal authority, personal model, facilitator, delegator.
6	Teaching learning strategies-Learning styles- visual, aural, read/write, kinaesthetic, Microteaching, Team teaching.
7	Teaching learning strategies-Programmed instruction, Simulation role-play.
8	Teaching learning strategies-Experiential learning, Traditional media.
9	Teaching learning strategies-ICT applications in education, Multimedia based teaching and learning.
10	Genesis and trends in modern education-Management of formal and non formal education in India, Vocational education.
11	Genesis and trends in modern education-Distance education, Guidance and counselling.
12	Educational technology for differently able-Innovative Instructional Aids - Web Instruction, e learning, Virtual laboratories, Educational technology for differently able-Visual impaired- Advances in Braille script.
13	Educational technology for differently able-Hearing impaired- Advances in Indian sign language, People with special needs- Educational Programs and Government policies.
14	Introduction to evaluation- need and importance in education, Evaluation-Development of Question Bank.
15	Evaluation-Appraisal of Teacher Performance, Evaluation of instructional effectiveness.
16	Evaluation-Competency based question papers, Reliability and validity of question papers.

I. Course Title : Group Dynamics

II. Course Code : EECM 509

III. Credit Hours : 2 (2+0)

IV. Rationale

Group approach is proved to be the effective strategy as well as approach for execution of extension interventions through participation. By orienting students who are pursuing expertise in the field of extension education, towards group behavior and its dynamics they can accelerate the participatory development processes by means of team and conflict management. Further, group dynamics is a system of behaviors and psychological processes occurring within a social group or between social groups i.e intra and intergroup dynamics. Hence it will be useful in understanding decision-making behaviour, forms of social prejudice and discrimination, which are some of the major influencing factors of human development.

V. Aim of the course

- To develop understanding about group behavior and dynamics for effective communication and group management
- To acquaint students with techniques for sustainable group dynamics.

VI. Theory

Unit I: Introduction to group and group dynamics

Meaning; Characteristics; Types and functions of groups; Stages and process of group formation; Group norms and structure; Values; Ethics; and Morals.

Unit II: Understanding group behaviour

Definitions; Theories - social comparison, cognitive dissonance, self presentation, drive, social impact, self attention, social cognition theories; Individual; Interpersonal and human behaviour and dimensions.

Unit III: Group dynamics

Cooperation; Competition; Communication; Group pressure; Group cohesiveness; Group leadership; Measurement of group dynamics - tools and techniques; Group break down - causes and solutions; Strengths; Weaknesses and myths; Crowds and the mob mentality; Diversity and difference; Group dynamic skills - training and development.

Unit IV: Managing group

Team building; Conflict management; Stress management; Active listening and feedback; Achieving cooperative group structure.

Unit V: Understanding collective action in groups

Collective action meaning; Theories and applications; Incentives for collective action; Research reviews on collective action for sustainable group dynamics.

VII. Teaching Methods/ Activities

- Participatory lectures
- Field visits and interaction
- Assignment
- Demonstration
- Role play

- Presentation
- Research review

VIII. Learning Outcome

After successful completion of the course the students will be able to:

- Analyze the features and developmental stages of groups and team process
- Critically evaluate the theoretical concepts of group behaviour in real situation Able to measure group dynamics
- Demonstrate group dynamic skills
- Apply problem-solving skills and higher level thinking strategies

IX. Suggested Reading

- Ernest S and Sharon AR. 1985. *Effective Group Communication- How to Get Action by Working in Groups*. National Textbook Company, Lincolnwood.
- George RG. 2011. *Chapter on Theories of Group Behavior:* Commentary.
- Mary AG and Hennen. 2009. *Stages of Group Development*. Shared by Extension Center for Community Vitality, 10-21-14.
- Mary S. 2010. *Book of Conflict Resolution Games Quick, Effective Activities to Improve Communication, Trust, and Collaboration*. ISBN: 978-0-07-174366-2.
- Smith GE. 2001. *Group Development: A Review of Literature and A Commentary on Future Research Directions. Group Facilitation.*
- Susan WA. 2005. *Facilitating Group Communication*. The Handbook of Group Research and Practice, Sage Publications, Inc, Thousand Oaks.
- Vanni F. 2014. *The Role of Collective Action*. Agriculture and Public Goods, 21. DOI 10.1007/978-94-007-7457-5_2, © Springer Science +Business Media Dordrecht.
- *Managing Stress*. 2010. MTD Training and Ventus publication Aps. ISBN-978-87-7681-658-2. https://www.mindtools.com/pages/article/newTMM_79.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction to group and group dynamics - Meaning and Characteristics of group and group dynamics, Types and functions of groups.
2	Stages and process of group formation, Group norms and structure.
3	Values, Ethics, and Morals, Understanding group behaviour – Definitions
4	Theories - social comparison, cognitive dissonance, self presentation, drive, social impact.
5	Self attention, social cognition theories
6	Individual, interpersonal and human behaviour and dimensions. Group dynamics-concept and indicators - Concept and indicators of Cooperation.
7	Concept and indicators of Competition, Concept and indicators of Communication.
8	Concept and indicators of Group pressure, Concept and indicators of Group cohesiveness.
9	Concept and indicators of Group leadership, Measurement of group dynamics - tools and techniques.
10	Group break down - causes and solutions, Strengths, weaknesses and myths
11	Crowds and the mob mentality, Diversity and difference.
12	Group dynamic skills - training and development. Managing group - Team building
13	Conflict management, Stress management.
14	Active listening and feedback, Achieving cooperative group structure.
15	Understanding collective action in groups - Collective action meaning, Theories and applications.
16	Incentives for collective action, Research reviews on collective action for sustainable group dynamics.

I. **Course Title : Community Development and Outreach**

II. **Course Code : EECM 510**

III. **Credit Hours : 3 (2+1)**

IV. **Rationale**

This course prepares students for an interdisciplinary field working. It teaches facilitation and organize a grassroots effort, equipping with skills to empower a local, regional or international community to bring about change. A real-world experience through the programs' will benefit strong connections in and with the community and communicate effectively with local groups as well as public and private agencies. It builds skills for critical thinking in matters of social justice, sustainable development, community engagement, community asset-mapping, fundraising, team building, collaborative leadership, project management, research and project evaluation.

V. **Aim of the course**

- To orient students with community development and outreach perspectives
- To impart participatory research skills
- To handle a special project for analysis of community development outreach.

VI. **Theory**

Unit I: Community development

Definition; Issues and concepts; Historical perspective of community development in India and emerged changes since inception to current era.

Unit II: Approaches

Approaches - concept and characteristic features gandhian approach, community development approach, sectoral approach, target approach, area approach, minimum need approach, integrated or holistic approach, participatory development approach; Strategies - multipurpose strategy, growth oriented strategy and spatial planning strategy; The modernization theory; Human development model (components, HDI, ranking, gender related development index, HPI)

Unit III: Key principles of community development

Community participation - definition and scope; Inclusion; Equality; Collective action; Empowerment and community development process; Provision of information; Identification of felt needs and common issues; Consultation for Shared vision; Mobilisation for action; Reflection and evaluation.

Unit IV: Community development and governance in India

Community development policy in India; Community development perspectives in five year plans.

Unit V: Cross cutting edges of community development

Horizontal edges - education, health, women empowerment, skill development, agriculture and caste occupations; Vertical edges - adults, youth, adolescents, children, pregnant and lactating mothers, physically and mentally challenged.

Unit VI: Outreach of community development

General orientation to outreach models - precede model, evaluation and indicator metrics; Outreach of urban; Rural and tribal community development programmes; Impact - economic and social perspectives.

Unit VII: Globalisation impact on community development

Impact on social forms - individualism, enclavism and fatalism, transition between **gemeinschaft and gesellschaft, issues of migration and mitigation.**

VII. Practical

Development of special project to study Community Development programme outreach in selected area and execution. Preparation of project report and presentation

1. Selection of Community development programme and detailed description of the programme in terms of objectives, targets, inputs, expected outputs and outcome
2. Visit to programme operating area and interaction with stakeholders- implementing agency, personnel and beneficiaries
3. Visit to programme operating area and interaction with stakeholders- implementing agency, personnel and beneficiaries
4. Framing of special project for measurement of outreach – title, objectives, study area, research review and plan of work
5. Finalisation of tools and techniques for execution of project
6. Finalisation of tools and techniques for execution of project
7. Preparation of tools for execution of project
8. Field testing and finalization of tools

9-12. Execution of work plan

12. Data analysis and preparation of project report
13. Data analysis and preparation of project report
14. Presentation of report
15. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignment
- Field visit
- Case study writing
- Special project
- Student's Book/Publication Review
- Students' presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend and differentiate OD processes and HRD strategies
- Critically analyse different approach of community development
- Plan and execute special project
- Analyse the results and write report
- Write research paper based on the special project

X. Suggested Reading

- Jerry WR and Gary P. 2014. *Introduction to Community Development*: *Theory, Practice, and Service-Learning*. 1st Edition, *ISBN*-13: 978-1412974622 ISBN-10: 1412974623
- Manohar P. 2014. S*ocial and Community Development Practice* http://dx.doi.org/10.4135/9789351507987
- Marianne R, Woodside and Tricia McClam. 2015. *An Introduction to Human Services*. 8th Edition, ISBN-13: 978-1285749907 ISBN-10: 1285749901
- Patil AR. 2013. *Community Organization and Development*: *An Indian Perspective*. PHI Learning Private Limited, Delhi 110092ISBN 978-81-203-4694-9

- Rhonda P and Robert P. 2015. *An Introduction to Community Development* (*Volume 1*) 2nd Edition, ISBN-13: 978-0415703550 ISBN-10: 0415703557
- *A Step by Step Guide to 'Turning Outward' in Your Community*. American Library Association. http://www.ala.org/tools/sites/ala.org.tools/files
- From Project to Branch Integration and Sustainability: Community-Led Work. http://publiclibrariesonline.org/2013/04/from-project-to-branch-integration-and-sustainability-community-led-work-at-halifax-public-libraries

Weekly Lecture Schedule

Duration (week)	Topic
1	Community development - Definition, issues and concepts, Historical perspective of community development in India and emerged changes since inception to current era.
2	Approaches- concept and characteristic features - Gandhian approach, Community Development Approach.
3	Sectoral Approach, Target Approach.
4	Area approach, Minimum Need Approach.
5	Integrated or Holistic approach, Participatory Development approach.
6	Strategies - Multipurpose strategy, Growth oriented strategy and Spatial planning strategy.
7	Key principles of Community development - Community participation- definitions and scope, Inclusion, Equality and Collective action.
8	Empowerment and community development process, Provision of information Identification of felt needs and common issues.
9	Consultation for participation Shared vision, Mobilisation for action, reflection and evaluation.
10	Community Development and Governance in India - Community development policy in India, Community development perspectives in Five year plans.
11	Community Development issues - Horizontal issues - Education, health, Empowerment, Vocational and skill development, Agriculture and caste occupations.
12	Vertical - Adults, Women ,Youth, Adolescents, Children, Pregnant and lactating mothers.
13	Physically and mentally challenged, Outreach of community development - General orientation to outreach models - precede model.
14	Evaluation and indicator metrics, Outreach of Urban, Rural and Tribal community development programmes.
15	Impact - Economic and social perspectives, Globalisation impact on community development - Impact on social forms – Individualism.
16	Enclavism and Fatalism, Transition between Gemeinschaftand Gesellschaft, Issues of migration and mitigation.

I. Course Title : Climate Change Management

II. Course Code : EECM 511

III. Credit Hours : 2 (1+1)

IV. Rationale

Geographically, every community is facing numerous challenges due to changes in the climate. This course provides students to address such challenges covering adaptation and mitigation solutions across a wide range of sectors and regions, with special reference to domestic management practices. It provides an opportunity to get exposed to climate change policies and prepares for climate change communication. It also creates a research question, gather and analyse data, and share findings academically and in lay terms.

V. Aim of the course

- To conversant students with CCM and equip with managerial skills at home level
- To generate interest for climate communication to cope up with climate changes.

VI. Theory

Unit I: Basics of climate and climate change

Introduction to climate and climate change - Definition and meaning; Climate change classification; Method of classification; General concept of environmental Science; Natural and manmade causes of climate change; Affects for climate change; Consequences risks and uncertainty of climate change; Climate system; Major predictions.

Unit II: Greenhouse gases and global warming

Major greenhouse gases and sources; Global warming effect and causes, Responses to global warming; Different views on greenhouse gases and global warming natural resource management; Solid waste management; Biodiversity; Alternative livelihood security; Drought prone technologies.

Unit III: Climate change Impacts

Impacts on biodiversity - wetland, forest, agriculture, transportation, coastal area, water resources; Global, National and regional impacts; Vulnerability assessment; Climate modelling.

Unit IV: Climate change policy

Introduction; Various policies in India; National action plan; Sector specific policies and policies instruments; Environment impact assessment; Environment planning and management; Climate resilient technology.

Unit V: Climate change communication

Introduction - definition, perspectives and importance; Engaging climate change communication; Audiences; Frames; Values and Norms.

Unit VI: Visual communication on climate impacts and solutions

Theories of visual perception; Classification and selection of visuals.

Unit VII: Advocacy and communicating global climate action

National international advocacy groups and organisations; Strategies and programmes.

Unit VIII: Role of stake holders

Media; Scientific Experts; Policymakers; and academic institutions on climate change communication.

VII. Practical

1-4. Visit to Climate management organization to understand strategies and observe the impacts
5. Identification of climate management needs at home level and development of suitable technology- Apparel and textiles
6. Identification of climate management needs at home level and development of suitable technology- Food and Nutrition

7. Identification of climate management needs at home level and development of suitable technology- General health
8. Identification of climate management needs at home level and development of suitable technology- domestic appliances and arrangements
9. Identification of climate management needs and development of suitable technology- Children and senior citizens.
10. Identification of climate management needs and development of suitable technology- differently able
11. Preparation of climate communication media – print
12. Preparation of climate communication media – radio
13. Preparation of climate communication media – video
14. Preparation of climate communication media – blog/web writing
15. Exhibition on climate change management
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignment
- Field visit
- Product making
- Student's Book/Publication Review
- Students' presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend climate climate change affects species, societies and ecosystems, and the consequences these changes can have on natural systems
- Have advanced knowledge about national and international climate policy, and its application
- Knowledge of how the society can transform energy production and use in a more environmentally friendly direction
- Advanced knowledge of strategies, actions and tools for adapting to climate change and reducing greenhouse gas emissions, nationally and globally
- Critically assess different sources of information, and use them to structure and develop an academic argument
- Identify climate management needs and prepare communication media products on versatile issues

X. Suggested Reading

- Gopal B. 2004. *Global Warming and Climate Changes: Transparency and Accountability*. 3 ISBN-10: 8182050782 ISBN-13: 978-8182050785
- Kandarp TP and Vaishnav. 2018. *Climate Change Solutions, Global Warming Solutions and Innovative Ideas for Construction of World Development*. Notion Press; 1 edition ISBN-10: 1643241818 ISBN-13: 978-1643241814
- Lenka S and Lenka NK. 2013. *Climate Change and Natural Resources Management*. New India Publishing Agency SBN-10: 9789381450673 ISBN-13: 978-9381450673
- Mark M. 2009. *Global Warming: A Very Short Introduction*. ISBN-10: 0199548242 ISBN-13: 978-0199548248
  http://envfor.nic.in/e-books
- *Climate Change: Impacts, Vulnerabilities and Adaptat.ion in Developing Countries.* https://unfccc.int/resource/docs/publications/impacts.pdf

- Mom L and Pin M. 2010. *Education Sector Responses to Climate Change Background Paper with International Examples*. UNESCO Bangkok Asia and Pacific Regional Bureau for Education, Bangkok, Thailand.
- *Journal of Climate Change* https://www.iospress.nl/journal/journal-of-climate-change

Weekly Lecture Schedule

Duration (week)	Topic
1	Basics of climate and climate change - Introduction to climate and climate change, Climate change classification, Method of classification.
2	General concept of environmental Science, Natural and man made causes of climate change.
3	Effects of climate change, Consequences, risks and uncertainty of climate change.
4	Climate system, Major predictions.
5	Greenhouse gases and Global Warming - Major greenhouse gases and sources.Global warming effect and causes, responses to global warming.
6	Different views on Greenhouse gases and Global warming Natural Resource Management, Solid waste management.
7	Biodiversity, Alternative livelihood security using drought prone technologies, Climate change Impacts - Impacts on Biodiversity - Wetland, Forest, Agriculture, Transportation.
8	Coastal area, water resources, Global, National and regional impacts.
9	Vulnerability assessment, Climate modeling, Climate Change Policy - Introduction, Various policies in India.
10	National action plan, Sector specific policies and policies instruments.
11	Environment impact assessment, Environment planning and management.
12	Climate resilient technology, Climate Change Communication – Introduction, definition, perspectives and importance.
13	Engaging Climate Communication, Audiences, Frames, Values and Norms.
14	Visual Communication on Climate Impacts and Solutions - Theories of visual perception, Classification and selection of visuals.
15	Advocacy and Communicating Global Climate Action -National international advocacy groups and organisations, Strategies and programmes, Role of stake holders – Media.
16	Scientific Experts, Policymakers, Academic Institutions on climate change communication.

I. Course Title : Gender Sensitization For Empowerment

II. Course Code : EECM 512

III. Credit Hours : 2 (2+0)

IV. Rationale

This course provides sensitivity among the students towards involvement of women in decision making processes in all aspects of economic, political, social and cultural life as active administrators, decision makers, participants and beneficiaries. It also provides skill to identify lapses in gender equity and equality like sex ratio, employment and wages, literacy and education and health. With this perspective they can play an active role in issues of national interest like gender budgeting, gender accounting and gender analysis frame work.

V. Aim of the course

- To sensitize students towards gender perspectives and development, legal rights

and using gender tools and methodologies
- To enhance students' capability for identifying and analyzing gender issues in family/home, community, agriculture and allied sector.

VI. Theory

Unit I: Overview of gender

Concept; Meaning and related terms; Gender sensitization - concept, meaning and importance of gender sensitization; Gender and empowerment - meaning, definitions and need; Gender issues in home - community and organization.

Unit II: Gender issues

Gender issues and challenges in development; Understanding gender and subordination of women; Gender as a development tool; Policy approaches for women development; Gender perspectives in development of women - roles, responsibilities, access and control over resources, constraints and opportunities.

Unit III: Gender tool kit for assessment of gender empowerment

Gender budgeting and gender analysis framework - context, activities, resources and programme action profile; Concept of GDI, GEM, GSI; National and regional indicators.

Unit IV: Gender issues and development

National policy for empowerment of women since independence; Interventions to enhance women's empowerment at individual; Community and national level; Livelihood implications of gender - health and nutrition, agriculture, violence, governance, education, media and legal issues.

VII. Practicals

1. Simulation role play to understand sex and gender, gender blind: gender aware: gender sensitive: gender equity.
2. Critical analysis of status of women in different sectors
3. Presentation of reports
4. Public speaking on Gender issues- Gender mainstreaming
5. Public speaking on Gender issues- Drudgery
6. Public speaking on Gender issues- Agriculture and allied sectors
7. Public speaking on Gender issues- Health and Nutrition
8. Public speaking on Gender issues- Business and Enterprise
9. Public speaking on Gender issues- Politics and Public administration
10. Preparation of case studies on selected issues/personalities
11. Gender sensitive interventions in SAUs and their objectives and frame work
12. Critical analysis of selected interventions and projects in operation
13. Preparation of report
14. Presentation of report
15. Critical review of Gender policy of GOI
16. End term assessment

VIII. Teaching Methods/ Activities

- Participatory lectures
- Assignment
- Mock sessions
- Student's Book/Publication Review
- Student presentation

VIII. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend gender issues and challenges for development
- Realise the need for modification of behavior by raising awareness of gender equality concerns
- Examine their personal attitudes and beliefs and questioning the 'realities' they thought they know
- Prepare themselves for public speaking on gender issues
- Analyse the gender sensitive interventions of SAUs

IX. Suggested Reading

- Adriana DS. 2010. *Gender Issues and International Legal Standards: Contemporary Perspectives*. Publisher, Catania, Italy.
- Grover I and Grover D. 2002. *Empowerment of Women*. Agrotech Publ. Academy.
- Sahoo RK and Tripathy SN. 2006. *SHG and Women Empowerment*. Anmol Publ.
- Sinha K. 2000. *Empowerment of Women in South Asia*. Association of Management Development Institution in South Asia, Hyderabad.
- *Gender Budgeting Handbook for Government of India Ministries and Departments* (2007) Ministry of Women and Child Development, GOI http://wcd.nic.in/gender-budgeting.
- *Measuring Women's Empowerment:* An assessment of the Gender-related Development Index and the Gender Empowerment Measure www.tandfonline.com
- *A Toolkit for Women's Empowerment and Leadership in Health and Welfare* http://www.who.int/kobe_centre/publications/womens_empowerment 2005.pdf
- *Indicators for Gender Equality and Women's Empowerment* – An Introduction http://www.oecd.org/development/gender-development/43041409.pdf
- Indian Journal of Gender Studies
- International Journal of Gender and Women's Studies

Weekly Lecture Schedule

Duration (week)	Topic
1	Overview of Gender - Concept, meaning and terminology.
2	Gender sensitization - Concept, meaning and importance of gender sensitization.
3	Gender and empowerment - meaning, definitions and need.
4	Gender issues in home, community and organization.
5	Gender issues - Gender issues and challenges in development.
6	Understanding gender and subordination of women.
7	Gender as a development tool, Policy approaches for women development.
8	Gender perspectives in development of women - roles, responsibilities, Access and control over resources, constraints and opportunities.
9	Gender tool kit for assessment of gender empowerment - Gender budgeting and gender analysis framework - context, activities, resources and programme action profile.
10	Concept of GDI, GEM, GSI, International, National and Regional indicators.
11	Gender issues and development - National Policy for empowerment of women since independence.
12	Interventions to enhance women's empowerment and leadership at the individual level.
13	Interventions to enhance women's empowerment and leadership at the community level.
14	Interventions to enhance women's empowerment and leadership at the national level.
15	Livelihood implications of gender, Health and nutrition, Agriculture, violence and governance.
16	Education, media and legal issues.

Course Title with Credit Load Ph.D. (Community Science) in Extension Education and Communication Management

Course Code	Course Title	Credit Hours
EECM 601*	Managerial Skills for Extension Professionals	3 (2+1)
EECM 602	Impact Assessment of Development programmes	3 (1+2)
EECM 603*	Scaling Techniques for Behaviour Research	3 (1+2)
EECM 604	Design and Development of e-Extension Project	3 (0+3)
EECM 605	Sustainable Livelihood Systems	2 (1+1)
EECM 606	Extension Research Project Management	3 (1+2)
EECM 607	Media application and Product Promotion	4 (2+2)
EECM 608	Advocacy and Behavior Change Management	3 (1+2)
	Minor Courses**	
FN 604	Global Nutrition Problems	2(2+0)
FN 608	Energy Metabolism	2(2+0)
HDFS 608	Qualitative research methods	3(2+1)
ATS 602	Technical Textiles	3(2+1)
ATS605	Functional Clothing	3(2+1)
ATS 607	Operational Management in Textiles and Apparel	2(2+0)
RMCS 603	Globalization and Consumer Economics	3 (2+1)
RMCS 606	Environmental Issues and Challenges	2 (2+0)
RMCS 607	Family Dynamics and Women Power	3 (2+1)
	Supporting Courses	
	Student can choose any course relevant to the research from other faculties of the University or from Swayam portal or online courses.	
EECM 691	Doctoral Seminar I (Optional Field)	1 (1+0)
EECM 692	Doctoral Seminar II (Core Field)	1 (1+0)
EECM 699	Research	75
	Total	**100 Credits**

*Compulsory core curses

Course Contents
Ph.D. (Community Science) in Extension Education and Communication Management

I. Course Title : Managerial Skills for Extension Professionals

II. Course Code : EECM 601

III. Credit Hours : 3 (2+1)

IV. Rationale

This course is a capsule programme for imparting competency skills among students in management process, to be professionals in delivery of extension services. The students explore the fundamental roles and processes of planning, leading, organizing and controlling that comprise the managers' role, while acquainting themselves with the basic concepts and processes of management. It focuses on the entire organization from both a short and long term perspective for strategic vision, setting objectives, crafting a strategy and then implementing it. This creates a demand for specialized extension support. This course will develop skills related to professional management practices as required in today's competitive environment.

V. Aim of the course

- To orient to professional management perspective with special reference to modern management trends
- To motivate for learning professional management practices.

VI. Theory

Unit I: Orientation to management

Concept; Process; Functions; Management problems in extension organizations; Managerial skil1 – definition, nature and importance; Skills for effective management of extension activities and organizations.

Unit II: Theories of management

Scientific theory; Administrative theory; Bureaucratic theory; Human relations theory; Systems theory y; X&Y theory.

Unit III: Strategic planning

Importance; Steps and techniques; Concept of management by objective (MOB) as applicable to extension organizations; Techniques of transactional analysis for improving interpersonal communication.

Unit IV: Contemporary professional management trends

Artificial intelligence (AI), Unified talent management (UTM); Self-directed micro learning (SDML); Personalisation; Design thinking; Augmented reality and virtual reality tools (AR&VR).

Unit V: Creative problem solving techniques

Stress management practices; Total quality management (TQM); Team building and management; Concept of learning organization; Time management practices; Management of information system; Self-management techniques.

Unit VI: Work motivation

Organizational climate; Resource management - concept and methods; Team building- process and strategies at organizational and village levels; Mobilization and empowerment skills; Concept and strategies in mobilization; Concretisation and empowerment of rural people.

VII. Practicals

1. Identification of professional management skills required for extension organisation through literature survey
2. Finalisation of major and specific professional management skills
3. Preparation of case studies of professional extension management professionals and visual presentation
4. Preparation of inventories for identification of professional skills
5. Finalisation and presentation of inventories for identification of professional skills
6. Execution of inventories- interviews with extension professionals in Government organisations
7. Execution of inventories- interviews with extension professionals in Non-Government organisations
8. Compilation and analysis of data
9. Report writing and presentation of data with special reference input training for professional skills
10. Hands-on-training for selected professional skills
11. End term assessment

VIII. Teaching Methods/ Activities

- Participatory lectures
- Assignment
- Simulation exercises
- Online group discussions
- Case study writing
- Student's Book/Publication Review
- Students' presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend the fundamentals of management and managerial effectiveness
- Explore the required professional skills for extension managers
- Develop and execute inventories for measurement of extension professional skills
- Analyse and interpret the data to compare and contrast professional skills between Government and Non-Government extension professionals
- Practice certain professional skills

X. Suggested Reading

- Basford TE, Offermann and Lynn R. 2012. Beyond Leadership: The Impact of Coworker Relationships on Employee Motivation and Intent to Stay. *Journal of Management and Organization* Vol. 18, No. 6.
- Chitale AK, Rajendraprasad Nishith M and Dubey R. 2012. *Organizational Behaviour: Text and Cases.* Prentice Hall India Learning Private Limited SBN-10: 8120346963 ISBN-13: 978-8120346963.

- Craig C and Pinder. 2008. *Work Motivation in Organizational Behavior*. 2nd Edition Psychology Press. ISBN-13: 978-0805856040 ISBN-10: 0805856048.
- Kumar Sanjeev and Dash MK. 2011. Management education in India: Trends, issues and implications. *Research Journal of Internatýonal Studýes*. Issue 18 January, 2011.
- Prasad LM. 2015. *Principles and Practice of Management*. Sultan Chand & Sons-New Delhi ISBN-10: 9351610500 ISBN-13: 978-9351610502
- Rajan G. 2007. *Marketing Management: Concepts, Cases, Challenges and Trends*. 2nd Edition, Prentice Hall India Learning Private Limited, ISBN-10: 8120332598, ISBN-13: 978-8120332591.

Weekly Lecture Schedule

Duration (week)	Topic
1	Orientation to management - Concept of management, Process of management.
2	Functions of management, Management problems in extension organizations.
3	Managerial skil1 - nature and importance, Skills for effective management of extension activities and organizations.
4	Theories of Management - Scientific Theory, Administrative Theory.
5	Theories of Management - Bureaucratic Theory, Human Relations Theory.
6	Theories of Management - Systems Theory, X&Y Theory.
7	Strategic planning - Importance; Steps and techniques, Concept of management by objective (MOB) as applicable to extension organizations.
8	Techniques of transactional analysis for improving interpersonal communication, Contemporary professional management trends - Artificial intelligence (AI).
9	Unified talent management (UTM), Self directed micro learning (SDML).
10	Personalisation, Design thinking.
11	Augmented reality and virtual reality tools (AR&VR), Creative problem solving techniques - Stress management practices.
12	Total quality management (TQM), Team building and management.
13	Concept of learning organization, Time management practices.
14	Management of information system, Self-management techniques.
15	Work motivation - Organizational climate, Resource management - concept and methods.
16	Team building - process and strategies at organizational and village levels, Mobilization and empowerment skills - concept and strategies in mobilizationConcretisation and empowerment of rural people.

I. Course Title : Impact Assessment of Development Programmes

II. Course Code : EECM 602

III. Credit Hours : 3 (1+2)

IV. Rationale

Impact assessment is to weigh up the relevance and effectiveness of a project, programme or public policy in bringing about a desired change in the well-being of the target population. Further, it measures improvements in pre-defined indicators in the sector concerned that can be attributed to the development intervention. Hence this course contributes a research perspective of an evaluation when undertaken during a defined period subsequent to an intervention. It facilitates the use of techniques, that measure and compare the results achieved with what would have happened, if the project/programme intervention not taken place.

V. Aim of the course

- To familiarise students with impact assessment procedures and provide skill in documentation
- To provide hands-on-experience for impact assessment of development programme.

VI. Theory

Unit I: Orientation to development programme

Development issues and goals; National and International Perspectives - goals, strategies, structure and achievements.

Unit II: Analysis of contemporary national development programmes

Public Health; Nutrition; Education; Environment; Employment; Income generation; Welfare; Marketing; Human Resource Development - objectives, clients, salient features, inputs, deliverables, outputs and outcomes.

Unit III: Orientation to impact assessment

Sustainability impact; Social impact; Health impact; Environmental and institutional impact - frame works and element; Log frame analysis.

Unit IV: Impact identification and prediction

Identification techniques - checklist, matrices, networks, overlays, expert systems, professional judgements; Prediction methods - extrapolative-trend and scenario analysis, analogies; Intuitive forecasting from group consensus(Delphi technique); Normative methods - mathematical models, statistical models, field and laboratory experiment methods, physical models and expert judgement.

VII. Practical

1. Documentation of exiting national and international development programmes and their objectives
2. Presentation and group discussion on developmental issues of each programme
3. Research review on development policy of India and developed countries
4. Presentation of comparative analysis
5. Preparation and presentation of case study on impact of Public Health programmes
6. Preparation and presentation of case study on impact of Nutrition programmes
7. Preparation and presentation of case study on impact of Education programmes
8. Preparation and presentation of case study on impact of Environment programmes
9. Preparation and presentation of case study on impact of Employment programmes
10. Preparation and presentation of case studyon impact of Income generation programmes
11. Preparation and presentation of case study on impact of Welfare programmes
12. Preparation and presentation of case study on Marketing programmes
13. Consolidate report writing focusing on inputs, deliverables, outputs and outcome of every programmes and analysis of achievements and gaps.
14. Hands-on-experience on impact assessment – measurement of sustainability impact
15. Hands-on-experience on impact assessment – measurement of social impact
16. Hands-on-experience on impact assessment – Health impact
17. Hands-on-experience on impact assessment – Environment
18. Hands-on-experience on impact assessment – Long frame analysis

19. Hands-on-experience on impact assessment – Institutional impact
20. Hands-on-experience on impact identification techniques- Checklist
21. Hands-on-experience on impact identification techniques- Matrices
22. Hands-on-experience on impact identification techniques- Networks
23. Hands-on-experience on impact identification techniques- Overlays
24. Hands-on-experience on impact identification techniques- Expert systems
25. Hands-on-experience on impact identification and prediction techniques- Professional judgements
26. Hands-on-experience on impact prediction techniques- Trend and scenario analysis
27. Hands-on-experience on impact prediction techniques- Delphi technique
28. Hands-on-experience on impact prediction techniques- Statistical model
29. Hands-on-experience on impact prediction techniques-Field and laboratory experiment methods
30. Selection and planning for impact analysis development programme
31. Presentation and group discussion
32. End term assessment

VIII. Teaching Methods/Activities

- Participatory lectures
- Assignment
- Research review
- Survey
- Case study writing
- Students' presentation
- Hands-on-training

IX. Learning Outcome

After successful completion of the course the students will be able to:

- Comprehend the national and international perspectives of assessment of development programmes
- Review on development policy of India and developed countries
- Enlist and explain impact assessment and prediction techniques
- Write case studies on the impact of development programmes
- Apply impact assessment and prediction techniques, analyse and predict the results of the selected development programmes

X. Suggested Reading

- Anjaneyulu Y. 2010. *Environmental Impact Assessment Methodologies*. BS Publication.
- Arland T. 2012. *Knowledge and Beliefs about National Development and Developmental Hierarchies: the Viewpoints of Ordinary People in Thirteen Countries*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3462366/
- Fateh Azzam. 2013. *The Right to Development and Implementation of the Millennium Development Goals*. http://www.academia.edu
- *E-Book of Ministry of Rural Development*. https://www.india.gov.in/download-e-book-ministry-rural-development
- Mc Donnell Ida *An International Perspective On Communication Strategies For The Millennium Development Goals*. http://www.oecd.org/development
- Lincoln CC *Nutrition in Developing Countries and the Role of International Agencies: In Search Of A Vision*. https://www.ncbi.nlm.nih.gov/books/NBK231298/
- Asian Development Bank (2018) *Health Impact Assessment*, Asian Bank Publication.

- *Impact Evaluation in Practice.* Second Edition. World Bank Group and the Inter-American Development Bank.

Weekly Lecture Schedule

Duration (week)	Topic
1	Orientation to development programme - Development issues and goals.
2	National and international perspectives – goals and strategies.
3	Structure and achievements.
4	Analysis of contemporary national development programmes - Public health, nutrition, education and environment.
5	Employment,income generation, welfare, marketing.
6	Human Resource Development - Objectives, clients, salient features, inputs, deliverables, outputs and outcomes.
7	Orientation to impact assessment - Sustainability impact assessment.
8	Social impact assessment and health impact assessment.
9	Environmental and institutional impact assessment - frame works and element.
10	Log frame analysis.
11	Impact identification and prediction of impact - Identification techniques - checklist, matrices, networks, overlays, expert systems, professional judgment.
12	Prediction methods, extrapolative- trend and scenario analysis, analogies.
13	Intuitive forecasting from group consensus (Delphi technique).
14	Normative methods - Mathematical and statistical models.
15	Field and laboratory and experiment methods.
16	Physical models and expert judgment.

I. Course Title : Scaling Techniques for Behaviour Research

II. Course Code : EECM 603

III. Credit Hours : 3 (1+2)

IV. Rationale

This course is highly essential for students undertaking social and behavioural research as it provides knowledge on developing scales for measuring attributes of objects and people. Measurement is a process of mapping empirical phenomena by using system of numbers. Basically, the events or phenomena that researchers interested can be existed as domain. Measurement links the events in domain to events in another space which called range; which is nothing but consisting of scale. This enables researchers to interpret the data with quantitative conclusion which leads to more accurate and standardized outcomes, without which systematic and accurate interpretation of data is impossible.

V. Aim of the course

- To familiarize students with scaling techniques and the development process for behaviour measurement
- To provide hands-on-experience in development of scale for behavior measurement.

VI. Theory

Unit I: Introduction

Definition - scaling techniques and behaviour research; Need and importance; Attitude, Knowledge and Practice measurement techniques and relevance to behaviour research.

Unit II: Structured techniques

Nominal; Ordinal; Interval; Ratio scales; Self rating scales- graphic rating scale; Itemized rating scales- likert scale, semantic differential scale, stapel's scale, multi-dimensional scaling, thurston scales, guttman scales/scalogram analysis and the q sort technique.

Unit III: Non structured techniques

Projective - association, completion, construction, expressive, problems and promises; Word association; Sentence completion; Story completion and pictorial; Advantages and limitations for adoption in behaviour research.

Unit IV: Knowledge and practice tests

Knowledge - objective multiple choice questions (MCQs); True/False Assertion - reason questions; Multiple response questions (MRQs); Text/Numerical matching ranking questions; Sequencing questions; Field simulation questions; Graphical hotspot questions; and Subjective tests; Practice - worksheets, performance metrics.

Unit V: Scalability of techniques

Measurement of Reliability and Validity of scales.

VII. Practical

1. Presentation of research review on need and importance of scaling techniques in behavior research
2. Review and presentation of research articles on different scaling techniques Self rating scales- Graphic Rating Scale
3. Review and presentation of research articles on different scaling techniques Itemised rating scales-Likert Scale
4. Review and presentation of research articles on different scaling techniques-Semantic Differential Scale
5. Review and presentation of research articles on different scaling techniques-Stapel's Scale
6. Review and presentation of research articles on different scaling techniques-Multi-Dimensional Scale
7. Review and presentation of research articles on different scaling techniques-Thurston Scale
8. Review and presentation of research articles on different scaling techniques-Scalogram Analysis
9. Review and presentation of research articles on different scaling techniques-The Q Sort technique
10. Review and presentation of research articles on Projective techniques- association and sentence completion
11. Review and presentation of research articles on Projective techniques-Construction, and expressive
12. Review and presentation of research articles on Projective techniques- Problems and promises
13. Review and presentation of research articles on Projective techniques- Word association
14. Review and presentation of research articles on Projective techniques- Story completion and pictorial
15. Development of Self rating scales- Graphic Rating Scale

16. Execution and presentation of results
17. Development of Self rating scales- Likert Scale
18. Execution and presentation of results
19. Development of Self rating scales- Semantic Differential Scale
20. Execution and presentation of results
21. Development of Self rating scales- Stapel's Scale
22. Execution and presentation of results
23. Development of Self rating scales- Multi Dimensional Scale
24. Execution and presentation of results
25. Development of Self rating scales- Thurston Scale
26. Execution and presentation of results
27. Development of Self rating scales- Scalogram Analysis
28. Execution and presentation of results
29. Development of Self rating scales- Q sort technique
30. Execution and presentation of results
31. Hands-on-experience in writing research article on scale development
32. End term assessment

VIII. Teaching Methods/Activities

- Participatory lectures
- Assignment
- Research review
- Survey
- Case study writing
- Students' presentation
- Hands-on-training

IX. Learning Outcome

After completion of this course the students will be able to:

- Recognise the importance of scaling techniques in social and behavioural research
- Define the nature and characteristic feature of each scale
- Review, interpret and present the results of each scale
- Develop and apply different scales and analyse the data for presentation
- Write research article based on the selected scale

X. Suggested Reading

- Colleen K. 2012. *Measurement in Health Behavior: Methods for Research and Evaluation*. 1st Edition. Jossey-Bass Publishers; ISBN-10: 9780787970970 ISBN-13: 978-0787970970
- Donnellan MB, Lucas RE and Fleeson W. 2009. *Introduction to personality and assessment at age 40: Reflections on the legacy of the person-situation debate and the future of person-situation integration. Journal of Research in Personality*. 43, 117-119.
- Eid M and Diene E. 2006. *Handbook of Multi Method Measurement in Psychology*. American Psychological Association, Washington, DC.
- Gaudry E Vagg P and Spielberger CD. 1975. *Validation of the state-trait distinction in anxiety research. Multivariate Behavioral Research*. 10, 331-341.
- Hampson SE and Goldberg LR. 2006. *A first large cohort study of personality trait stability over the 40 years between elementary school and midlife. J Pers Soc Psychol*. 91(4) 763-779.
- Jagadish R Raiyani. 2012. *Research Methodology: Theory and Teachniques*. New Century Publications ISBN: 9788177082944, 8177082949
- John A and Swets Signal. 2009. *Detection Theory and ROC Analysis in Psychology and Diagnostics*.Collected Papers www.questia.com/library
- Paul E, McNamara and Joyous S Tata. 2015. *Principles of Designing and Implementing*

Agricultural Extension Programs for Reducing Post-harvest Loss. Agriculture. 5, 1035-1046; doi: 10.3390/agriculture 5041035

- Peter D, Gerald A, Susan and Shuqiang Z. 2004. *Scaling Method.* 2nd Edition. Lawrence Erlbaum Associates.
- Shuchi M. 2017. Scaling techniques of attitude measurement. *International Journal of Advanced Education and Research.* ISSN: 2455-5746, Impact Factor: RJIF 5.34 www.alleducationjournal.com Volume 2 Issue 2, March 2017; Page No. 41-50.
- Chapter 3: *Levels of Measurement and Scaling* http://www.fao.org/docrep/w3241e/w3241e04.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction - Definition - scaling techniques and behaviour research.
2	Need and importance.
3	Attitude, Knowledge and Practice measurement techniques and relevance to Behaviour research.
4	Structured techniques - Nominal, Ordinal, Interval, Ratio scales.
5	Self rating scales - Graphic Rating Scale.
6	Itemized Rating Scales- Likert Scale, Semantic Differential Scale.
7	Stapel's Scale, Multi-Dimensional Scaling, Thurston Scales.
8	Guttman Scales/Scalogram Analysis and The Q Sort technique.
9	Non structured techniques - Projective - association, completion, construction, expressive, problems and promises.
10	Word association, sentence completion, story completion and pictorial.
11	Advantages and limitations for adoption in behaviour research.
12	Knowledge and Practice tests - Knowledge - Objective multiple choice questions (MCQs).
13	True/False assertion - Reason questions multiple response questions (MRQs).
14	Text/Numerical matching ranking questions, sequencing questions, field simulation questions, graphical hotspot questions and subjective tests.
15	Practice - worksheets, performance metrics.
16	Scalability of techniques - Measurement of reliability and validity.

I. Course Title : Design and Development of E-extension Project

II. Course Code : EECM 604

III. Credit Hours : 3 (0+3)

IV. Rationale

Keeping in view the extension service system under the National Agricultural Extension Policy, this course is planned to sensitise the students towards the need for ICT mediated extension services to ensure quality life in the sectors of health, nutrition, family and human relationships, which are vital areas of community science. It is essential to gain digital communication skills to reach masses for knowledge empowerment by transferring research findings compatible to the situation and context. Hence this course guides the students in gaining comprehensive experience of Extension-Research-Education by exposing themselves to the existing e-extension projects of SAU and designing new projects.

V. Aim of the course

- To orient students with design, development and analysis of e- extension projects
- To provide hands-on-experience in executing e-extension project.

VI. Practicals

1. Orientation to e-extension projects- Knowledge projects-moocs
2. Orientation to e-extension projects -Marketing projects- e choupla
3. Orientation to e-extension projects- Bulk SMS (Text and Voice) MMS
4. Orientation to e-extension projects- Video lessons
5. Orientation to e-extension projects-Virtual class rooms
6. Orientation to e-extension projects- Off line and Online Community Radio.
7. Interaction with personnel/professionals for understanding of media tools, hardware requirements of e-Extension projects
8. Interaction with personnel/professionals for understanding of media tools software requirements of e-Extension projects
9. Report writing and presentation
10. Identification of needs for skill development and proposal for skill training to undertake e-Extension project- application of software, access to hardware, etc.
11. Orientation to existing e-Extension projects of respective SAUs
12. Hands-on-experience in e- Extension projects of SAUs - content development, management and analytics report
14. Selection of multimedia e-Extension project and submission of proposal-knowledge management, product promotion, message alerting, analytical reports, etc. (Example Digital literacy promotion, Audio/ Video streaming, Social media for product promotion)
15. Presentation of proposal
16. Content development and time lines for execution of project

17-23. Execution of project and measurement of analytics as per time line

24. Report writing and presentation
25. Practical examination

VII. Teaching Methods/Activities

- Assignment
- Research review
- Group discussions
- Report writing
- Students' presentation
- Hands-on-training

VIII. Learning Outcome

After completion of the course the students will be able to:

- Identify public and private e-extension projects in the discipline of community science
- Recognise essential skills for undertaking e-extension projects
- Gain first-hand experience in content writing, management and track analytical report
- Write e-extension project, execute and measure analytics as per timeline

IX. Suggested Reading

- Martin M. 2016. *Editorial – Extension education theory and research in India.* Pages 105-109 www.tandfonline.com
- Paul E McNamara and Joyous S. 2015. *Principles of Designing and Implementing Agricultural Extension Programs for Reducing Post-harvest Loss Agriculture 2015*, 5, 1035-1046; doi: 10.3390/agriculture5041035

- Richard F, Douglas A and Carolyn W. 2003 *National "e-Extension" Programs*: *Feasibility and Structure*, American Agricultural Economics Association Annual Meeting, Montreal, Canad.
- Ujjwal K, Abhay K and Thakur PK. 2012. *Status of Agricltural Development in Eastern India*. Chapter 7.1 Status and Constraints of Extension Services https://www.researchgate.net
- Volker H, Maria GB, Anja C and Mamusha L. *Handbook: Rural Extension Volume 1 Basic Issues and Concepts*. Scientific books, Margraf Publishers, GmbH, Government of India Planning Commission Report of the Working Group on Agricultural Extension for Agriculture and Allied Sectors for the Twelfth Five Year Plan(2012-17) http://planningcommission.gov.in
- ICT Applications in Agricultural Extension Management. Report on USAID-INDIA-Afghanistan Feed The Future India Triangular Training (FTF ITT) Programme on 'e-Extension http://www.manage.gov.in/ftf-itt/prgReports/afgan.pdf

I. Course Title : Sustainable Livelihood Systems

II. Course Code : EECM 605

III. Credit Hours : 2 (1+1)

IV. Rationale

Sustainable livelihood is a systemic and adaptive approach that links issues of poverty reduction, sustainability and empowerment processes. For this, the large scale success of sustainable livelihoods will depend on our ability to design sustainable technologies, sustainable enterprise, sustainable economies and sustainable institutions of governance. The attractiveness of Sustainable livelihoods lies in its applicability to different contexts, situations of uncertainty and in its capacity as a consultative and participatory process of ideas and strategies between various stakeholders.This course imparts students the link between livelihoods ands and security systems and interventions to address the gap.

V. Aim of the course

- To develop understanding about resources and livelihood systems and dimensions for livelihood security
- To sensitize students towards tools and techniques for sustainable livelihood.

VI. Theory

Unit I: Orientation to livelihood system

Livelihood perspectives - definition, approaches and frame works; Livelihoods and life support systems; Designing livelihood interventions; Process; Tools and technique.

Unit II: Sustainable livelihood systems

Definition; Origin; Principles; Livelihoods - agriculture, horticulture, sericulture, forestry, animal husbandry, dairying, fisheries, non-farm activities; Urban livelihoods - linkage with food security, nutritional security, health security, livelihood security; Measuring sustainable livelihood systems.

Unit III: Critical understanding of livelihood interventions

Intervention of national and international organisations - agriculture based, forest based, non-farm based, market-led based; DFID sustainable livelihoods framework - elements, vulnerability context, policies, institutions and processes, coping and adaptive strategies.

Unit IV: Sustainable development concepts and challenges

Sustainable development concepts and challenges; Ecological; Social and economic dimensions of sustainable development; Peoples participation and sustainability; Indicators of environmental sustainability; Sustainable livelihoods; Quality of life.

Unit V: Livelihood analysis tool kit

Operational model - tools, process; Gaps and challenges; Institutional issues; Participatory methods for analysis.

VIII. Teaching Methods and Activities

- Participatory lectures
- Field visits and interaction
- Assignment
- Demonstration
- Role play
- Presentation
- Research review

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Understand the history and evolution of the sustainable livelihoods approach
- Exercise the sustainable livelihoods framework to analyse the complexities and dynamics of poverty
- Apply and analyse sustainable livelihoods analysis tool kit in the field
- Plan projects from a Sustainable Livelihoods perspective

X. Suggested Reading

- Alan de B and Suryanarayana MH. 2015. Linkages between poverty, food security and undernutrition: evidence from China and India. *China Agricultural Economic Review.* Vol. 7 Issue: 4, pp.655-667
- Baumgartner R and Högger R. 2004. *In Search of Sustainable Livelihood, Managing Resources and Change*, Sage publications, New Delhi.
- Bijju MR. 2008. *Panchayati Raj System: Towards Sustainable Rural Livelihood and Development.* Kanishka Publishers, Distributors ISBN-10: 9788184570557
- Harishkumar HV. 2012. *Livelihood Security of Farm Households Under Different Farming Systems In Kolar District Of Karnataka – An Economic Analysis*. University of Agricultural Sciences, Bangalore. http://krishikosh.egranth.ac.in/bitstream/1/89107/1/Thesis.pdf
- Scoones Ian. 2015. *Sustainable Livelihoods and Rural Development*. Practical Action Publishing
- Nadel. 2007. *Working with a Sustainable Livelihoods Approach*. NADEL, Zurich, Bern: SDC. www.povertywellbeing.net
- Premchander S and R Menon. 2006. Engendering Development: Challenges and Opportunities for Mainstreaming Gender in Development Policy. In Premchander, S. & C. Mueller 2009 *Gender and Sustainable Development: Case Studies from the NCCR North-South. Perspectives of the Swiss NCCR North-South*, University of Bern. Vol. 2. Bern: Geographica Bernensia.
- *Livelihood Manual Integrated Watershed Management Programme* (*IWMP*). 2012. Commissionrate of Rural Development. www.ruraldev.gujarat.gov.in
- Food security: concepts and measurement. http://www.fao.org/docrep/005/y4671e/y4671e06.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Orientation to livelihood system - Livelihood perspectives –definition, approaches and frame works.
2	Livelihoods and life support systems, Designing livelihood interventions.
3	Process, Tools and technique.
4	Sustainable livelihood systems - Definition, Origin, Principles.
5	Livelihoods – Agriculture, Horticulture.
6	Sericulture, Forestry.
7	Animal husbandry, Dairying.
8	Fisheries, Non-farm activities.
9	Urban livelihoods, Linkage with food security.
10	Nutritional security, health security.
11	Livelihood security, Measuring sustainable livelihood systems.
12	Critical understanding of livelihood interventions - Intervention of National and International organisations - agriculture based, Forest based livelihood interventions.
13	Non-farm based livelihood interventions, Market-led based livelihood interventions.
14	Sustainable development - concepts and challenges - Ecological factors, Social and economic dimensions of sustainable development.
15	Peoples participation and sustainability, Indicators of environmental sustainability.
16	Sustainable livelihood - indicators, Quality of life- indicators.

I. Course Title : Extension Research Project Management

II. Course Code : EECM 606

III. Credit Hours : 3 (1+2)

IV. Rationale

Extension research projects are unique in nature as they call for interactivity with human beings to get timely feedback; thereby reconsider the gaps and restructure the strategy to cope up with the goals to be achieved. It is all together a scientific and methodical approach, where a researcher need to plan meticulously to impress upon stakeholders with a set of activities and milestones to be reached. Through this course the students would be engaged in observation of different dimensions of extension research project in terms of models, types, policy and management practices.

V. Aim of the course

- To familiarize with different dimensions of extension research project management
- To provide investigative and analytical skills for extension research.

VI. Theory

Unit I: Overview to extension research

Definition; Concepts; Models- linear, advisory, facilitation; Types - advisory services, value chains, supply chains, incubation centres, knowledge management; Market led extension; Demand driven extension; Enterprise extension; Mainstreaming extension.

Unit II: Areas of extension research

Policy analysis; Gender issues; Public and private partnership; Product extension;

Process extension; Behaviour change - health security, nutritional security, food security; Impact analysis - technology, training; Funding agencies and project proposal formats.

Unit III: Research project management practices

Project charter and mission; Project life cycle; Project network diagram; Project progress/ performance measures; Project resource loading; Project SOW (statement of work); Project WBS (work breakdown structure) – budgeting, cost benefit analysis, resource management; Risk breakdown structure; SWOT.

Unit IV: Project management approaches and tools

Approaches - result oriented approach, constructivist approach, reflexive approach; Tools - PERT, CPM, GANNT.

VII. Practical

1. Preparation and presentation of case study on linear model extension project
2. Preparation and presentation of case study on advisory model extension project
3. Preparation and presentation of case study on facilitation model extension project
4. Comparative analysis of different models of extension projects
5. Preparation and presentation of case study on advisory services
6. Preparation and presentation of case study on value chains
7. Preparation and presentation of case study on supply chains
8. Preparation and presentation of case study on incubation centers
9. Preparation and presentation of case study on knowledge management
10. Preparation and presentation of case study on market led extension
11. Preparation and presentation of case study on demand driven extension
12. Preparation and presentation of case study on enterprise extension
13. Preparation and presentation of case study on mainstreaming extension
14. Comparative analysis different extension projects
15. Identification of niche areas of extension research in Community Science discipline
16. Identification of organizations for extension research and presentation of organizational objectives
17. Critical analysis of formats for research project writing and presentation
18. Preparation of extension research project (2)
19. Revising the project as per suggestions
20. Presentation of case study on Project Life Cycle
21. Presentation of case study on Project Network Diagram
22. Presentation of case study on Performance Measures
23. Presentation of case study on Project Resource Loading
24. Presentation of case study on Project SOW (statement of work)
25. Presentation of case study on Project WBS (work breakdown structure)
26. Presentation of case study on cost benefit analysis,
27. Presentation of case study on Risk Breakdown Structure;
28. Visit to existing extension research projects of SAU for observation
29. Report writing
30. Presentation of report
31. End term assessment

VIII. Teaching Methods/Activites

- Assignment
- Research review

- Group discussions
- Report writing
- Students' presentation
- Institutional visits

IX. Learning Outcome

After completion of the course the students will be able to

- Comprehend existing extension research models and types
- Analyse and write case studies on extension research projects focusing management practices
- Identify niche areas of research in the discipline of community science
- Recognise supporting organisations for writing extension research projects and write project
- Present case study on SAUs extension research projects

X. Suggested Reading

- Anandajayasekeram P, Puskur R, Sindu W and Hoekstra D. 2008. *Concepts and Practices in Agricultural Extension in Developing Countries*: *A Source Book*. IFPRI, Washington, DC, USA.
- Annie SW and Merle F. 2014. *Background Paper: Research and Development and Extension Services in Agriculture and Food Security*. ADB Economics Working Paper Series, Asian Development Bank ISSN 1655-5252 Publication Stock No. WPS147021-3.
- Burton E Swanson and Riikka R. 2010. *Strengthening Agricultural Extension and Advisory Systems: Procedures for Assessing, Transforming, and Evaluating Extension Systems Agriculture and Rural Development,* Discussion Paper 45, The International Bank for Reconstruction and Development,The World Bank, NW Washington, DC.
- Dennis PM. 2010. *Building a Project Work Breakdown Structure: Visualizing Objectives, Deliverables, Activities, and Schedules.* ESI International Project Management Series, 1st Edition Auerbach Publications ISBN 9781420069693.
- Singh KM and Meena MS and Swanson BE. 2013. *Extension in India by Public Sector Institutions*: *An Overview*. ICAR-RCER, Zonal Project Directorate, Jodhpur, Patna, University of Illinois.
- Michelle JR, Jane MA, Anne-Maree S, Enly S and Helen T. 2009. *Can agricultural research and extension be used to challenge the processes of exclusion and marginalisation?* http://iari.res.in
- Ralf M and Jonas S. 2014. *Innovative Approaches in Project Management Research*. International Journal of Project Management. **33**(2) November 2014.
- Rodne JT, Martina H, Frank T Anbari and Christophe NB. 2010. *Perspectives on Projects.* Routledge Publishers, ISBN1135848831, 9781135848835.
- *Managing Projects with Openess Part 3.* Document No.16004, Version 1.5 https://idpasc.lip.pt

Weekly Lecture Schedule

Duration (week)	Topic
1	Overview to Extension research - Definition and Models - linear, advisory, facilitation.
2	Advisory services, value chains, supply chains, incubation centres and knowledge management.
3	Types -market led extension, demand driven extension, enterprise extensionMainstreaming extension.
4	Areas of extension research - Policy analysis, gender issues, public and private partnership, product extension, process extension, behaviour change-health security, nutrition security and food security.

Duration (week)	Topics
5	Impact analysis - Technology and training funding agencies and project proposal formats.
6	Research project management practices – project charter and mission.
7	Project Life Cycle, Project Network Diagram.
8	Project progress/ performance measures, project resource loading.
9	Project SOW (statement of work).
10	Project WBS (work breakdown structure)- budgeting.
11	Cost benefit analysis, resource management.
12	Risk Breakdown Structure; SWOT.
13	Project management approaches and tools - Approaches - Result oriented approac.
14	Constructivist approach.
15	Reflexive approach.
16	Tools - PERT, CPM, GANNT.

I. Course Title : Media Application and Product Promotion

II. Course Code : EECM 607

III. Credit Hours : (2+2)

IV. Rationale

Media has the capability of promoting products. Also, media as product and application has potential role in enhancing learning. But, technology alone cannot improve teaching and learning. It must be deeply integrated with subject matter content. Therefore there is a need for a technique within which the learners can meet their needs to learn how to think, their need to develop, their ideas and apply what they learn to solve problems. This calls for active participation of the students and lead to get engaged in critical thinking and problem solving skills. Beyond this, as change agents in future endeavours, they need to be convinced for timely updation of media knowledge, because, in today's world information tracking is totally media based.

V. Aim of the course

- To familiarize students with media applications and interpretation of online analytics due to dissemination
- To provide hands-on-experience in preparation of multimedia products for promotion.

VI. Theory

Unit I: Introduction to media applications

Internet media and globalization - concepts and theories; Technology and culture - debates, regulation, gatekeeping and ethics-case studies.

Unit II: Corporate online promotional strategies

Advertising and marketing; Public communication campaigns and global humanitarianism; Multiplatform journalism; Transnational citizen journalism; Grassroots activism and change.

Unit III: Media prospects of mass communication

Historical development and economic; Social and aesthetic impact on mass culture; Individual and mass consciousness.

Unit IV: Audience research

Definitions; Principles and features; Scope; BARC (Broad Cast Audience Research Council) India; Data management techniques and tools.

Unit V: Software access

Advanced new media; Design and edit software; Open and purchase sources; Application regulations; Ethics.

Unit VI: Product promotion

Search Engine Optimization; Social Media Marketing; E-mail marketing - creation, marketing campaign planning, development and execution; Research.

Unit VII: Social media platforms

Types; Optimization; Product page creation; Analytics.

Unit VIII: Social networking

SNS(Social Networking Sites) in India; Advantages and limitations; Critical analysis of role of SNS in mass communication.

Unit IX: Introduction to SEO

Targeting key words; Integrating search keywords; Search engines and directories; Page wise optimization process; Page title tags; META Description tag; META keywords Tag.

Unit X: Reports

Variables; Time line; Report access protocol; Documentation.

VII. Practical

1. Identify and suggest the suitable keywords for a product
2. Adding keywords to website and blogs
3. Preparing Search Engine Optimization (SEO) friendly content for product website
4. Demonstration to get website listed among top Search in (SEO)
5. Demonstration on off page and on page in SEO
6. Identifying best practices for Social Media Marketing, including platform level best practices
7. Connecting product objectives to appropriate Social Media tactics
8. Creating strong content to engage target audience with marketing message
9. Creating events to manage content distribution
10. Creating Social Media policies that combine business objectives with appropriate use of social media channels and content
11. Creating Fan Pages in Social media platforms
12. Hands-on-experience- learning targeting right audience
13. Hands-on-experience on process of running Facebook ads
14. Creating engaging post and creating brand for business
15. Creating channel on YouTube
16. Updating the profile on YouTube Channel
17. Understanding the Creator Studio of YouTube
18. Types of videos and different platforms of video creation
19. Creating videos- Hands-on-Experience
20. Creating videos- Hands-on-Experience
21. Uploading videos on YouTube
22. Practicing SEO of YouTube

23. Hands-on-experience on Page title tags
24. Hands-on-experience on META Description Tag
25. Hands-on-experience on META Keywords Tag
26. Promotion of videos
27. Promotion of product on YouTube
28. Online orientation to email marketing for product promotion.
29. Hands-on-experience on email marketing for product promotion.
30. Review of analytics of product promotion
31. Presentation of multimedia practice experience
32. End term assessment

VIII. Teaching Methods/ Activities

- Participatory lectures
- Assignment
- Student's Book/Publication Review
- Practice sessions
- Media development and transmission
- Students' presentation

IX. Learning Outcome

After successful completion of the curse the students will be able to:

- Comprehend online and offline media applications
- Recognise effective product promotion platforms
- Write SEO friendly online content for product promotion
- Review analytics of product promotion
- Organise email marketing

X. Suggested Reading

- Dave C and Smith. 2017. *Digital Marketing Excellence*. Taylor & Francis ISBN-10: 1138494232 ISBN-13: 978-1138494237.
- Godse and Godse. 2015. *Graphics and Multimedia for ANNA University*. (V-IT-2013 course) Technical Publications, Third edition ISBN-10: 9333202099 ISBN-13: 978-9333202091.
- Klara N and Ralf S. 2012. *Multimedia Applications*. Springer-verlag Gmbh ISBN: 9783642074103, 3642074103.
- Marshall S and Gohar Khan F. 2017. *Digital Analytics for Marketing*. Routledge Edition. ISBN-10: 1138190683 ISBN-13: 978-1138190689.
- Shajahan. 2010. *Strategic Marketing: Text and Cases Viva Books*. ISBN-10: 8130912694 ISBN-13: 978-8130912691.
- Simon K. 2010. *Digital Marketing Strategy: An Integrated Approach to Online Marketing*. ISBN-10: 0749484225 ISBN-13: 978-0749484224.
- *Convergence in Indian Media: a New Paradigm of ICT* www.researchgate.net/publication

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction to media applications - Internet media and globalization - concepts and theories, Technology and culture - debates, regulation, gatekeeping and ethics-case studies.
2	Corporate online promotional strategies - Advertising and marketing, public communication campaigns and global humanitarianism, Multiplatform journalism, transnational citizen journalism, grassroots activism and change.

Duration (week)	Topics
3	Media prospects of mass communication - Historical development and economic, social and aesthetic impact on mass culture, Individual and mass consciousness.
4	Audience research - Definitions, Principles and features, Scope, BARC (Broad Cast Audience Research Council) India.
5	Data management techniques and tools, Software access - Advanced new media.
6	Design and Edit software, Open and purchase sources.
7	Application regulations and Ethics, Product promotion - Search Engine Optimization.
8	Social Media Marketing, E-mail marketing - Creation, Marketing campaign planning, development and execution.
9	Research perspectives in product promotion, Social media platforms - Types of Social media platforms.
10	Optimization of SM, Product page creation.
11	Analytics of SM, Social networking - SNS (Social Networking Sites) in India.
12	Advantages and limitations, Critical analysis of role of SNS in mass communication.
13	Introduction to SEO (Search Engine Optimization) - Targeting key words, Integrating search keywords.
14	Search engines and directories, Page wise optimization process.
15	Page title tags - META Description Tag, META Keywords Tag, Reports - Variables, Time line.
16	Report access protocol, documentation.

I. Course Title : Advocacy and Behavior Change Management
II. Course Code : EECM 608
III. Credit Hours : 3 (1+2)

IV. Rationale

The holistic objective of the discipline of extension education and communication management is sustainable behaviour change of human beings. Whether organisations or individuals working towards this end believe that social and behavior change communication is key to solving the world's most pressing health and social problems, while advocacy strategies are an important aspect of behaviour change in terms of changing the enabling environment. This course exposes students to logical thinking in planning behaviour change communication programme.

V. Aim of the course

- To familiarise students with the role of advocacy and behavior change management for human development
- To provide contrived experience in application of advocacy and BCC approaches.

VI. Theory

Unit I: Advocacy

Meaning; Purpose and types of Advocacy; Tools; Techniques and approaches of advocacy; Elements of an advocacy strategy.

Unit II: Advocacy planning cycle

Planning advocacy campaigns for different stakeholders relationship between advocacy and development; Programme communication and social mobilization;

Social marketing- models and approaches.

Unit III: Behaviour change communication

Concept; Approaches of BCC - functional approach, information processing approach, consistency approach, behaviour modification approach, health belief model and the bj fogg model of behavior change; Role of learning theories - social cognitive theory, theories of reasoned action and planned behaviour, trans theoretical model of behavior change.

Unit IV: Processes of behaviour change

Strategic issues and BCC (Health/ Environment/ Consumption); Analysis of BCC campaigns for social mobilization and policy change; BCC campaigns in core areas for stakeholders.

Unit V: Evidences of behaviour change

Global programs- evidences of WASH communication, HIV/AIDS communication, obesity communication, diabetic communication, concept of green marketing and cause marketing.

VII. Practical

1. Interaction with Advocacy personnel to comprehend the advocacy approaches- working with HIV/AIDS patients
2. Interaction with Advocacy personnel- working with drug/alcohol addicts
3. Interaction with Advocacy personnel- Family/ Marriage issues
4. Interaction with Advocacy personnel- working with mentally challenged children
5. Preparation and presentation of report
6. Review of research on BCC approaches- Functional approach
7. Review of research on BCC approaches- Information processing approach
8. Review of research on BCC approaches- Consistency approach
9. Review of research on BCC approaches- Behavior modification approach
10. Review of research on BCC approaches- Health Belief model
11. Review of research on BCC approaches-BJ Fogg model of behavior change.
12. Report writing and presentation
13. Case study on Social marketing in India
14. Identification of Niche research in BCC
15. Presentation of researchable issues in BCC
16. End term assessment

VIII. Teaching Methods/Activities

- Participatory lecture
- Online group discussions
- Blog writing
- Research review
- Case study writing and presentation
- Institutional visits

IX. Learning Outcome

After successful completion of the course the students will be able to

- Comprehend the perspectives of advocacy and behaviour change communication
- Explain the theories of BCC and their application in real world
- Review different BCC approaches and prepare case study

- Identify niche research and researchable issues in BCC
- Sensitise towards working with special groups

X. Suggested Reading

- Alan C. 2014. *An Introduction to Social Media Marketing*. Routledge Publishers, ISBN-10: 9780415856171 ISBN-13: 978-0415856171.
- Annette G and Claire B. 2013. *Advocacy and Policy Change Evaluation: Theory and Practice*. 1st Edition, ISBN-13: 978-0804792561 ISBN-10: 0804792569
- John AD. 2013. *Advocacy: Championing Ideas and Influencing Others*. 1st Edition, ISBN-13: 978-0300188134 ISBN-10: 0300188137.
- Nancy R Lee and Philip Kotler. 2011. *Social Marketing: Influencing Behaviors for Good*. Fourth Edition, ISBN-13: 978-1412981491 ISBN-10: 9781412981491.
- McKee Neill, Antje BB and Emily B. 2014. *Social and Behavior Change Communication*. https://doi.org/10.1002/9781118505328.ch17
- Kotler Philip. 2014. *Social Marketing –Strategies for Public Behaviour*. Routledge Publishers, ISBN-10: 9780415856171 ISBN-13: 978-0415856171.
- Sameer D and Nancy RL. 2014. *Social Marketing in India*. Sage Publications, SBN: 9788132113577.
- *Guidelines for Developing Behavioural Change Interventions in the Context of Avian Influenza Health Promotion and Education* (*HPE*). Department of Non-cummunicable Diseases and Mental Health World Health Organization, http://apps.searo.who.int
- *Strategic Communication - For Behaviour and Social Change In South Asia* (2005) The United Nations Children's Fund (UNICEF) Regional Office for South Asia.

Weekly Lecture Schedule

Duration (week)	Topic
1	Advocacy - Meaning and definition of advocacy, Significance of advocacy in community sciences, Purpose and types of advocacy
2	Tools and techniques of advocacy, Approaches of advocacy
3	Elements of an advocacy strategy, Advocacy research and dimensions
4	Advocacy Planning Cycle - Planning advocacy campaigns for different Stakeholders, Relationship between advocacy and development, Critical analysis of Programme communication and social mobilization
5	Social marketing models and approaches, Critical analysisof Social marketing.
6	Research perspectives of advocacy planning cycle, Behaviour Change Communication - Concept of BCC and evolution
7	Approaches of BCC - Functional approach, Information processing approach
8	Consistency approach, Behaviour modification approach
9	Health Belief model, BJ Fogg model of behavior change
10	Role of learning Theories - social cognitive theory, Theories of reasoned action and planned behavior
11	Trans theoretical model of behavior change, Comparative analysis of different models
12	Processes of Behaviour Change - Strategic issues and BCC – Health, Environmentand Consumption, Analysis of BCC campaigns for social mobilization and policy change
13	BCC campaigns in core areas for stakeholders, Stages of behavior change
14	Designing behavior change programme- Steps and outcome, Evidences of behaviour change-Global programs - Evidences of WASH communication
15	Evidences of HIV/AIDS communication, Evidences of obesity communication
16	Evidences of Diabetic communication , Concept of Green marketing and cause marketing

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 6

Community Science
– Food and Nutrition

Preamble
(Food and Nutrition)

Nutrition is well recognized for its central role in national development. The post-graduate curriculum of Food and Nutrition is revised to enable the students to handle the continuous changing nutrition situations of the population and to imply the accurate and scientific knowledge for sustainable handling to induce better health and productivity. The important role of post-graduate students as leaders in extension and community outreach programmes is considered as a need of the hour. The courses are designed to develop a scientific temper among students. Nutrition generates lot of concerns and issues which can be tacked through interdisciplinary approach. The students will study the allied fields along with major courses of basic nutrition with an aim to develop a holistic and multidimensional understanding of the discipline. This course equips the students for skill development, academic understanding, entrepreneurship, community role and employment in various fields of food industry, hospitals, NGOs, etc. Adding the new knowledge to the previous curriculum is very much needed for students to assess the prevailing nutritional situations of a community across age, sex, physiological conditions so that they can suggest the remedial pathways. The students with a good understanding about the role of nutrition in fighting infections and preventing diseases will have better employment opportunities in ever growing health sector.

Nutrition counselling is an upcoming field globally. The major and minor courses will impart high skills in communication, subject knowledge and understanding the client's socio-eco- cultural background to offer curative/ preventive nutritional advice as counsellors. Deep knowledge of food safety and standards along with strong analytical skills in food analysis, food technology and biotechnology may improve the scope for the students for employability in food processing sector. The knowledge of advanced geriatric nutrition will further equip the students to work with elderly population for their better health care. The recent advances in energy metabolism will provide deep insight in human adiposity and the food related disease burden like Type 2 diabetes, heart diseases, cancers, etc.

The courses will include updated information that will enable the students to keep track with agriculture scenario of the country as well as of the entire world to connect with the health status to identify, evaluate and find ways to establish positive interfaces. It is important to equip students with the knowledge of global nutrition problems and prepare them with skills to address the challenges effectively. The students will acquire skills to provide support to vulnerable mother-child duo conducive to development of quality human resource through the advanced courses.

The different entities during rescue operations and how food assistance component has been addressed to meet the needs of stranded population during natural calamities that consistently occur in India such as floods, cyclones, earthquake and droughts have been dealt in the curriculum. A knowledge on the topic will enable the students to act favourably to lessen the miseries of disaster hit population in terms of health and nutrition. A new course on hormones and enzymes gives insight of hormonal and enzymatic dysfunction which may give rise to several lifestyle diseases. In depth knowledge of these two is required to reduce the disease burden. Bioenergetics and regulation of metabolism are taught explicitly so that students are able to understand the increasing prevalence of obesity and related metabolic disorders. Courses on biotechnology, nutrigenomics and food science and technology opens a wide horizon for students to develop novel functional foods with huge potential in local and global markets.

The revision of courses is made to ensure that the students achieve high prominence and excellence in the field of nutrition to become professionals such as educators, researchers, clinical dieticians, health coaches, community health educators, holistic nutritionists rehabilitation counsellors and sports nutritionists.

Modifications Suggested in Courses in the Revised Curricula

M.Sc. (Community Science) in Food and Nutrition

Course Code	Course Title	Credit Hours	Remarks
	Major Courses (20 Credits)		
FN 501*	Macro and Micro Nutrients in Human Nutrition	3(3+0)	Content Modified
FN 502*	Public Health and Nutrition	3(2+1)	Content Modified
FN 503*	Techniques in Food Analysis	3(1+2)	Content Modified
FN 504*	Diet Therapy	3(2+1)	Content Modified
FN 505	Nutrition and Physical Fitness	3(2+1)	Content Modified
FN 506	Developments in Nutrition and Immunity	2(2+0)	Content Modified
FN 507	Clinical Nutrition	3(2+1)	Content Modified
FN 508	Nutrition Counselling	2(0+2)	New
FN 509	Food Safety and Standards	3(2+1)	
FN 510	Nutritional Challenges in Life Cycle	3(2+0)	Content Modified
FN 511	Food Science	3(2+1)	Content Modified
FN 512	Food Processing Technology	3(2+1)	Content Modified
FN 513	Human Physiology	3(3+0)	Content Modified
FN 514	Institutional Food Service Management	2(1+1)	Content Modified
	Minor Courses (08 Credits)		
	Food Science and Technology	3(2+1)	Course numbers will be assigned by the departments that offer the courses. Apart from these courses a student can register any other course offered by any other departments
	Food Biochemistry	3(2+1)	
	Nutritional Biochemistry	3(2+1)	
	Food Microbiology	3(2+1)	
EECM 504	Technology Transfer and Management	3 (1+2)	

Course Code	Course Title	Credit Hours	Remarks
EECM 505	Dynamic Communication Skills	3 (1+2)	
	Supporting Courses (06 Credits)		
	Research Methodology	3(2+1)	Course numbers will be assigned by the departments that offer the courses.
	Statistical methods and application		
	Common Courses (05 Credits)		
	Library and Information Services	1(0+1)	Common to all disciplines. The course numbers will be assigned by the departments that offer the courses
	Technical Writing and Communications Skills	1(0+1)	
	Intellectual Property and its management in Agriculture	1(0+1)	
	Basic Concepts in Laboratory Techniques	1(0+1)	
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)	
FN 591	Seminar	1(1+0)	
FN 599	Thesis/ Research	30	
	Total	**70 Credits**	

*Core courses/ compulsory courses

Ph.D. (Community Science) in Food and Nutrition

Course Code	Course Title	Credit Hours	Remarks
	Major Courses (12 Credits)**		
FN 601*	Macronutrient Metabolism	3(3+0)	Modified
FN 602*	Micronutrient Metabolism	2(2+0)	Modified
FN 603*	Nutrition and Agricultural Interface	3(3+0)	Modified
FN 604	Global Nutritional Problems	2(2+0)	
FN 605	Nutrition in Calamities	2(2+0)	Modified
FN 606	Maternal and Child Nutrition	2(2+0)	
FN 607	Hormones and Enzymes	2(2+0)	New
FN 608	Energy Metabolism	2(2+0)	Modified
FN 609	Application of Biotechnology in Food Science and Nutrition	3(3+0)	Modified
FN 610	Recent Trends in Food Science and Technology	3(3+0)	Modified
	Minor Courses (06 Credits)		
	Food Science and Technology	3(2+1)	Course numbers
	Food Biochemistry	3(2+1)	will be assigned

Course Code	Course Title	Credit Hours	Remarks
	Nutritional Biochemistry Food Microbiology	2(2+0) 3(2+1)	by the departments that offer the courses. Apart from these courses a student can register any other course offered by any other departmentss
EECM 603	Scaling Techniques for Behaviour Research	3 (1+2)	
EECM 605	Sustainable Livelihood Systems	2 (1+1)	

Supporting Courses (05 Credits)

A student can opt any course related to the topic of research offered by other faculties of agriculture university or SWAYAM portal or MOOCS or other online courses up to a maximum of 5 credits.

FN 691	Doctoral Seminar I (Major Field)	1(1+0)	
FN 692	Doctoral Seminar II (Minor Field)	1(1+0)	
FN 699	Research	75	Increased credits for Research
	Total	**100 Credits**	

*Core courses/ compulsory courses.

**Practical sessions in Ph.D. Programme are not suggested by the experts in the field of Food and Nutrition on the grounds detailed below:

1. Sufficient hands-on exposures at UG/PG(M.Sc) level in areas of food & Nutrition covering aspects of nutrient analysis in normal and processed conditions. Such exposures ensure hand holding of related equipment/ instruments, chemicals and methods of analysis. Furthermore, nutritional assessment methods at community level provide ample opportunities to gather the expertise in survey research methods.
2. Exposure to Animal Experiments, however, is limited due to the prevailing ethical issues. If a particular field of research necessitates Animal Experiment, facilities available in established organisation could be linked through meaningful and prior arrangements.
3. In these courses, it is expected that the students take up live case studies with regard to the specificity of the course and report. Preliminary training in dealing with case studies may be imparted by a third party for which some funding may be given by ICAR. The University may offer a common training to students from all faculties through experts within the University set-up. The faculty should lead a thorough discussion of all the cases and a consolidated report may be submitted and sent for publication. In each course, the students spend one credit time during the semester for this exercise.

Course Title with Credit Load
M.Sc. (Community Science) in Food and Nutrition

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FN 501*	Macro and Micro Nutrients in Human Nutrition	3(3+0)
FN 502*	Public Health and Nutrition	3(2+1)
FN 503*	Techniques in Food Analysis	3(1+2)
FN 504*	Diet Therapy	3(2+1)
FN 505	Nutrition and Physical Fitness	3(2+1)
FN 506	Developments in Nutrition and Immunity	2(2+0)
FN 507	Clinical Nutrition	3(2+1)
FN 508	Nutrition Counselling	2(0+2)
FN 509	Food Safety and Standards	3(2+1)
FN 510	Nutritional Challenges in Life Cycle	3(2+0)
FN 511	Food Science	3(2+1)
FN 512	Food Processing Technology	3(2+1)
FN 513	Human Physiology	3(3+0)
FN 514	Institutional Food Service Management	2(1+1)
	Minor Courses (08 Credits)	
	Food Science and Technology	3(2+1)
	Food Biochemistry	3(2+1)
	Nutritional Biochemistry	3(2+1)
	Food Microbiology	3(2+1)
EECM 504	Technology Transfer and Management	3 (1+2)
EECM 505	Dynamic Communication Skills	3 (1+2)
	Supporting Courses (06 Credits)	
	Research Methodology	3(2+1)
	Statistical methods and application	
	Common Courses (05 Credits)	
	Library and Information Services	1(0+1)
	Technical Writing and Communications Skills	1(0+1)
	Intellectual Property and its management in Agriculture	1(0+1)
	Basic Concepts in Laboratory Techniques	1(0+1)
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)
FN 591	Seminar	1(1+0)
FN 599	Thesis/ Research	30
	Total	70 Credits

Course Contents
M.Sc. (Community Science) in Food and Nutrition

I. Course Title : Macro and Micro Nutrients in Human Nutrition

II. Course Code : FN 501

III. Credit Hours : 3(3+0)

IV. Rationale

Proper nutrition is the crux of human health along with safe water, sanitation, immunization, etc. Adequate knowledge about this core course on macro and micronutrients in totality will enable the students to handle the nutrition situations of a population and how to imply the knowledge for sustainable handling to induce better health and productivity. Therefore, the necessity lies in this core course.

V. Aim of the course

- To provide in-depth understanding related to macro and micro nutrients
- To impart knowledge about specific requirements of these nutrients as per age, sex, physiological condition, functions, metabolism sources, deficiency parameters for meaningful handling of normal and problem stricken situations.

VI. Theory

Unit I: Carbohydrates

Body composition; Functions, sources, requirements, digestion and absorption of carbohydrates. Composition, classification and functions of dietary fibre; Role of dietary fibre, resistant starch and fructo-oligosaccharides in various physiological disorders; Glycemic response to carbohydrates.

Unit II: Proteins

Classification, functions, sources, digestion and absorption of proteins; Synthesis of non-essential amino acids in the body; Urea cycle; Protein quality; Relationship between energy and protein requirements; Regulation of food intake; Nutrient adaptation to low intake of energy and protein.

Unit III: Fats

Classification, functions, sources, digestion, absorption and deficiency disorders of lipids and essential fatty acids; Role of omega-3 and omega 6 fatty acids in physiological disorders.

Unit IV: Vitamins, minerals and water

Functions, absorption, requirement, sources, deficiency and toxicity of fat-soluble vitamins - A, D, E and K and water-soluble vitamins- thiamine, riboflavin, niacin, pyridoxine, folate, B_{12}, ascorbic acid, pantothenic acid, biotin and amygdalin; Functions, absorption, requirement, sources, deficiency and toxicity of macro minerals – calcium and phosphorus and micro minerals – iron, zinc, sodium, copper, cobalt, selenium and chromium; Water and electrolyte balance, functions and distribution of water in body, Electrolyte composition of body fluids and electrolyte balance.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Group discussion
- Student presentation

VIII. Learning Outcome

Completion of this course will help the students to:

- Acquire advanced knowledge in macro and micronutrients
- Understand specific nutrient related situations in population
- Apply the techniques as per the demand of the human nutritional profile.
- Utilize the learning techniques in population education/publication

IX. Suggested Reading

- Bamji MS, Rao NP and Reddy V. 2003. *Textbook of Human Nutrition*. 2nd Edition, Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Berdanier CD and Zempleni J. 2009. *Advanced Nutrition: Macronutrients, Micronutrients and Metabolism*. CRC Press, New York.
- Eastwood MA. 1997. *Principles of Human Nutrition*. London; Chapman & Hall.
- FAO. 2004. *Human Energy Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation*. Technical Report Series 1. Food and Agriculture Organization, Geneva.
- FAO. 2007. *Protein and Amino Acid Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation*. Technical Report Series 1. Food and Agriculture Organization, Rome.
- Groff JL and Gropper S. 2012. *Advanced Nutrition and Human Metabolism*. 7th Edition, Yolanda Cossio, New York.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. *Modern Nutrition in Health and Disease*. 11thEdition, LWW, Philadelphia.
- Summathi S. 2017. *Food Chemistry and Nutrition*. BS Publication, Hyderabad.
- Whitney EN and Rolfels CR. 2019. *Understanding Nutrition*. 15th Ed., West Publishing Company, USA.
- Wildman REC and Medeiros DM. 2000. *Advanced Human Nutrition*. CRC Press, Boca Raton, Florida.
- Stipanuk MH and Caudill MA. 2013. *Biochemical, Physiological and Molecular Aspects of Human Nutrition*. 3rd Edition, Elsevier Pub.
- https://www.nutritionintl.org
- https://www.who.int
- https://www.hsph.harvard.edu/nutritionsource
- http://www.nin.res.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Body composition. Functions, sources, requirements, digestion and absorption of carbohydrates.
2	Composition, classification and functions of dietary fibre.
3	Role of dietary fibre, resistant starch and fructo-oligosaccharides in various physiological disorders. Glycemic response to carbohydrates.
4	Classification, functions, sources, digestion and absorption of proteins.
5	Synthesis of non-essential amino acids in the body. Urea cycle.
6	Protein quality.
7	Classification, functions, sources, digestion, absorption and deficiency disorders of lipids and essential fatty acids.
8	Role of omega-3 fatty acids in physiological disorders.

Duration (week)	Topics
9	Relationship between energy and protein requirements. Regulation of food intake. Nutrient adaptation to low intake of energy and protein.
10.	Functions, absorption, requirement, sources, deficiency and toxicity of fat-soluble vitamins - A, D, E and K.
11.	Functions, absorption, requirement, sources, deficiency and toxicity of water-soluble vitamins- thiamine, riboflavin, niacin.
12.	Functions, absorption, requirement, sources, deficiency and toxicity of water-soluble vitamins- pyridoxine, folate, $B_{12.}$
13.	Functions, absorption, requirement, sources, deficiency and toxicity of water-soluble vitamins- ascorbic acid, pantothenic acid and biotin.
14.	Functions, absorption, requirement, sources, deficiency and toxicity of macro minerals – calcium and phosphorus.
15.	Functions, absorption, requirement, sources, deficiency and toxicity of micro minerals – iron, zinc, sodium, copper, cobalt, selenium and chromium.
16.	Water and electrolyte balance, functions and distribution of water in body, Electrolyte composition of body fluids and electrolyte balance.

I. Course Title : Public Health and Nutrition

II. Course Code : FN 502

III. Credit Hours : 3(2+1)

IV. Rationale

This core course on public health nutrition will enable the students with the knowledge in assessment of prevailing nutritional situations of a community across age- sex- physiological conditions. Furthermore, opportunities in analysing Public Health consequences in in-situ conditions will empower the students in planning, executing and evaluating the health and nutrition related development schemes of GOs, NGOs and allied bodies to suggest remedial pathways.

V. Aim of the course

- To provide both theory and practical exposure to the students on the subject of Public Health Nutrition
- To make them skilled in management of adequate nutritional statures of the population conducive to National Development.

VI. Theory

Unit I: Nutritional status assessment

Assessment of nutritional status at individual, household and institutional level: direct and indirect methods; Ecological, socio-cultural, economic and demographic correlations of malnutrition.

Unit II: Nutritional deficiencies and life style disorders

Prevalence, aetiology, biochemical and metabolic changes in protein energy malnutrition, vitamin A deficiency, iron deficiency anaemia, iodine deficiency disorders, diabetes mellitus, cancer, hypertension and other life style disorders.

Unit III: Present scenario of nutritional problems

Major nutritional problems of the state, nation and world; Nutrition intervention-definition, importance, methods of nutrition intervention, monitoring and evaluation; E-surveillance.

Unit IV: Nutritional programmes and polices

National nutritional programmes and policies and nutritional surveillance; National programmes and policies regarding food production and distribution.

VII. Practicals

1-3. Techniques of assessment of nutritional status
4-5. Use of Screening Tools
6-7. Visit to the ongoing public health nutrition programme and report writing.
8-9. Study of existing diet and nutrition practices
10-12. Planning and conducting survey
13-14. Analysing data and writing report
15-16. Development, implementation and evaluation of community nutrition and health programmes

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- On field case identification and analysis
- Project planning and report writing

IX. Learning Outcome

Completion of this course will enable the students to take responsibilities as:

- Nutrition educator
- Health educator
- Extension worker for situational analysis of prevailing public health nutritional problems for cultural adaptation strategies.
- Planner and executor of developmental schemes
- Applied researcher

X. Suggested Reading

- Bamji MS, Kamala K and Brhmam GNV. 2017. *Textbook of Human Nutrition.* 4th Edition, Oxford & IBH.
- Endres JB. 1990. *Community Nutrition Challenges and Opportunities*. Pearson Education Inc. London.
- Frank GC. 2008. *Nutrition: Applying Epidemiology to Contemporary Practice* . 2nd Edition, Jonts and Bartlett Publishers, Sadbury, MA.
- Gopaldas T and Seshadari S. 1987. *Nutrition Monitoring and Assessment*. Oxford University Press.
- Jeannette BE. 1990. *Community Nutrition: Challenges and Opportunities*. 1st Edition, Merrill.
- Jelliffe DB. 1966. *The Assessment of the Nutritional Status of the Community*. WHO, Geneva.
- Longwah T, Ananthan R, Bhaskarachary K and Venkalah K. 2017. *Indian Food Composition Tables*. National Institute of Nutrition, Hyderabad.
- Marie AB and David HH. 2012. *Community Nutrition in Action: An Entrepreneurial Approach*, Cengage Learning Inc. USA.
- McLaren DS. 1977. *Nutrition in the Community*. John Wiley & Sons.
- Park JE and Park K. 2007. *Park's Text Book of Preventive and Social Medicine.* 19th Edition, Banarsidas Bhanot Publishers, Jabalpur.

- Park JE and Park K. 2017. *Park's Textbook of Preventive and Social Medicine.* Banarsidas Bhanot Publ.
- Prabha B. 2017. *Community Nutrition in India.* 1st Edition, Star Publications, Agra.
- Rosalind S Gibson. 2005. *Principles of Nutritional Assessment.* 2nd Edition, Oxford University Press Inc.
- Salil S and Rita SR. 2007. *Textbook of Community Nutrition.* ICAR publication, New Delhi.
- Shukla PK. 1982. *Nutritional Problems of India.* Prentice Hall of India.
- Suryatapa Das. 2018. *Textbook of Community Nutrition.* 3rd Edn., Academic Publishers.
- https://www.india.gov.in/ agriculture
- https://mhrd.gov.in/mid-day-meal
- https://www.harvestplus.org
- https://www.icmr.nic.in/

Weekly Lecture Schedule

Duration (week)	Topic
1	Assessment of nutritional status at individual, household and institutional level: direct and indirect methods.
2	Ecological, socio-cultural, economic and demographic correlations of malnutrition.
3	Prevalence, etiology, biochemical and metabolic changes in Vitamin A deficiency.
4	Prevalence, etiology, biochemical and metabolic changes in Protein Energy Malnutrition.
5	Prevalence, etiology, biochemical and metabolic changes in Iron Deficiency Anaemia.
6	Prevalence, etiology, biochemical and metabolic changes in Iodine Deficiency Disorders.
7	Prevalence, etiology, biochemical and metabolic changes in Diabetes Mellitus.
8	Prevalence, etiology, biochemical and metabolic changes in Hypertension.
9	Prevalence, etiology, biochemical and metabolic changes in Cancer and other life style disorders.
10	Major nutritional problems of the state, nation and world.
11	Nutrition intervention- definition, importance, methods of nutritional intervention, monitoring and evaluation.
12	Methods of nutritional intervention, monitoring and evaluation.
13	E-surveillance.
14	National nutritional programmes and policies and nutritional surveillance.
15	National programmes and policies regarding food production.
16	National programmes and policies regarding food distribution.

I. Course Title : Techniques in Food Anaysis

II. Course Code : FN 503

III. Credit Hours : 3 (1+2)

IV. Rationale

Food analysis is the discipline that deals with the development, application and study of analytical procedures for characterizing the properties of foods and their constituents. It provides analytical data on the quality of a food or product.

V. Aim of the course

- To provide the students an opportunity to develop precision with the principles, techniques and application of different methods analysis for varied food and products.

- To equip the students with knowledge to ascertain quality of the tested food/ products.

VI. Theory

Unit I: Sampling techniques

Preparation of various standard solutions; Sample and sampling techniques; Introduction to standard analytical methods of FSSAI.

Unit II: Analytical techniques

Principle, techniques and applications of colorimeter, spectrophotometer and atomic absorption spectrophotometer, gel filtration and ultra-centrifugation.

Unit III: Photometric methods and electrophoresis

Principle, techniques and applications of fluorimetry, flame photometry and electrophoresis.

Unit IV: Chromatography

Principle, techniques and applications of paper, thin layer, gas liquid and high-pressure liquid chromatography, introduction to animal assay.

VII. Practicals

1-2. Principles and operation of laboratory equipmen
3-6. Determination of moisture content and titratable acidity
7-8. Determination of ash- dry and wet ash
9-10. Determination of reducing sugars and total sugars
11-14. Analysis of protein- Kjeldhal method
15-16. Analysis of amino acids- HPLC
17-20. Analysis of fat - Soxhlet method, Cold extraction method
21-22. Determination of peroxide value and iodine value
23-24. Analysis of crude fibre. Analysis of minerals- sodium and potassium
25-26. Analysis of iron, copper, zinc and lead. Absorption spectrophotometry
27-28. Analysis of phosphorus- Colorimeter method
29-30. Analysis of vitamin C
31-32. Estimation of carotene. Experiments on gel electrophoresis

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- Hands on training

IX. Learning Outcome

Successful completion of this course will enable the students to:

- Utilize the methods and tools to cater the needs of food analysis
- Guide the process of quality control
- Act as trained food analyst

X. Suggested Reading

- AOAC. 1995. *Association of Official Analytical Chemists*. Washington, DC. Gruenwedels DW and Whitakor JR. 1984. *FoodAnalysis: Principles and Techniques*. Vols. I-VIII. Marcel Dekker.
- AOAC International. 2016. *AOAC Official Methods of Analysis*. 20th Edition, Association of Official Analytical Chemists. Washington DC.

- Dennis D Miller. 1998. *Food Chemistry*: *A Laboratory Manual*. John Wiley and Sons Indianapolis.
- Joslyn MA. 1970. *Methods in Food Analysis: Physical, Chemical and Instrumental Methods of Analysis*. Academic Press.
- Kalia M. 2002. *Food Analysis and Quality Control*. Kalyani Publishers, New Delhi.
- Neilsen SS. 2010. *Food Analysis.* 4th Ed., ISBN 978-1-4419-1478-1 Springer Science+ Business Media, LLC, USA.
- Neilsen SS. 2002. *Introduction to Chemical Analysis of Foods*. 1st Ed., J S Offset Printers, Delhi.
- Raghuramulu N, Mahavan and Kalyanasundaram SK. 2003. *A Manual of Laboratory Techniques*. 2nd Edition, NIN Press, Hyderabad.
- Sadasivam A and Manickam A. 2004. *Biochemical Methods*. 2nd Edition, New Age International Publishers, New Delhi.
- Sawhney SK and Singh R. 2000. *Introductory Practical Biochemistry*. Narosa Publishing House, New Delhi.
- Veerakumar L. 2006. *Bio-instrumentation*. MIP Publishers. Chennai.
- Pomeranz Y and Molean CE. 1977. *Food Analysis Theory and Practice*. AVI Publ.
- Wood R, Foster L, Damand A and Key P. 2004. *Analytical Methods for Food Additives*. CRC Press, London.
- https://www.fssai.gov.in
- http://www.fda.gov/food/default.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Preparation of various standard solutions.
2	Sample and sampling techniques.
3	Sample and sampling techniques.
4	Introduction to standard analytical methods of FSSAI.
5	Principle, techniques and applications of colorimeter.
6	Principle, techniques and applications of spectrophotometer.
7	Principle, techniques and applications of atomic absorption spectrophotometer.
8	Principle, techniques and applications of gel filtration.
9	Principle, techniques and applications of ultra-centrifugation.
10	Principle, techniques and applications of fluorimetry.
11	Principle, techniques and applications of flame photometry.
12	Principle, techniques and applications of electrophoresis.
13	Principle, techniques and applications of paper and thin layer chromatography.
14	Principle, techniques and applications of gas liquid chromatography.
15	Principle, techniques and applications of high-pressure liquid chromatography.
16	Introduction to animal assay.

I. Course Title : Diet Therapy

II. Course Code : FN 504

III. Credit Hours : 3 (2+1)

IV. Rationale

Dietetics is a science and art that deals with the optimum nutrition during normal life cycles and its adaptations during ailments. In any situation of life, optimum nutrition can ensure health, endurance, cognition and productivity. As educators/advisors, the professionals need to equip themselves with the knowledge and skills of managing foods particularly during illness as people's mental condition remains at low ebb in ailment.

V. Aim of the course

- To provide both theory and practical knowledge on disease management through appropriate approaches with the most recent scientific input from researchers
- To approach the subject from a multidisciplinary perspective - technical, psycho-social-economic of client, drug diet interaction, etc, enabling the students to become effective member Health Care Team (HCT) in Medical Nutrition Therapy (MNT).

VI. Theory

Unit I: Significance of diet therapy

Importance and scope of diet therapy; Role of dietician in a health care team in hospital and community.

Unit II: Dietary management of nutritional disorders

Newer concepts in dietary management of various nutritional disorders and disease conditions; fevers and infections.

Unit III: Dietary management of diseases

Dietary management during burns, allergy, gastrointestinal disorders, liver diseases, cardiovascular diseases, hypertension, renal disorders, obesity, diabetes, cancer and HIV; Nutrition in critical care.

Unit IV: Nutrigenomics and nutraceuticals

Nutrigenomics. Nutraceuticals. Health foods and supplements; Health foods and supplements; Dietary recommendations for blood donors; Nutrients and drug interaction.

VII. Practicals

1. Formulation of food exchanges
2. Therapeutic modifications of diet in terms of nutrients, consistency and composition
3. Planning and preparation of diet for diabetes

4-5. Planning and preparation of diet for cardiovascular diseases

6-7. Planning and preparation of diet for kidney disorders

8. Planning and preparation of diet for obesity
9. Planning and preparation of diet for cancer patients
10. Planning and preparation of diet for burns patients -first, second and third-degree burns

11-12. Planning and preparation of diet for gastrointestinal disorders

13. Planning of diet for critical care patients
14. Visits to hospital to see preparation of tube feeding diets

15-16. Presentation of case studies

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Case studies
- Hands on training

IX. Learning Outcome

After completion of this course, the students are expected to:

- Appreciate the scientific foundation of disease management through diet
- Utilize the techniques and tools for assessing the vulnerability of a disease situation towards rejection/ acceptance of the diet suggestion
- Confident responsible member of Healthcare team (HCT) as decision maker

X. Suggested Reading

- Cataldo CB, De Brayae LK and Whitney EN. 2012. *Nutrition and Diet Therapy*. 6th Edn.,Wadsworth/Thomson Learning Inc.
- Kathleen ML and JL Raymond. 2016. *Krause's Food and the Nutrition Care Process*. 14th Edition, Saunders, Philadelphia.
- Mazur EE and Litch NA. 2018. *Lutz's Nutrition and Diet Therapy*. 7th Edition, F.A. Davis Company, Philadelphia.
- McIntosh SN. 2016. *Williams' Basic Nutrition and Diet Therapy*. 15th Edition, Mosby, Maryland.
- Schlenker E and Gilbert JA. 2014. *Williams' Essentials of Nutrition and Diet Therapy*. 11th edition, e- book.
- Srilakshmi B. 2019. *Dietetics*. 8th Edition, New Age Internatioanal Publisher.
- Skipper A. 2008. *Advanced Medical Nutrition Therapy Practice*. 1st Edition, Jones & Bartlett Learning, Burlington, Massachusetts.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. *Modern Nutrition in Health and Disease*. 11th Edition, LWW, Philadelphia.
- Whitney E, DeBruyne LK, Pinna K and Rolfes SR. 2011. *Nutrition for Health and Health Care*. 4th Edition.
- https://www.nutritionintl.org
- https://www.hsph.harvard.edu/nutritionsource
- https://www.nutrition.org.uk
- http://www.nutritioncare.org

Weekly Lecture Schedule

Duration (week)	Topic
1.	New concepts in dietary management of various disorders and diseases, protocols for dietary management.
2.	Importance and scope of diet therapy. Role of dietician in a health care team in hospital and community.
3.	Newer concepts in dietary management of fevers and infections.
4.	Dietary management during burns and allergies.
5.	Dietary management during gastrointestinal disorders.
6.	Dietary management during liver diseases.
7.	Dietary management during obesity.
8.	Dietary management during hypertension and cardiovascular diseases.
9.	Dietary management during diabetes.
10.	Dietary management during renal disorders.
11.	Dietary management cancer and HIV.
12.	Nutrition in critical care.
13.	Nutrigenomics and nutraceuticals.
14.	Health foods and supplements.
15.	Dietary recommendations for blood donors.
16.	Nutrients and drug interaction.

I. Course Title : Nutrition and Physical Fitness

II. Course Code : FN 505

III. Credit Hours : 3 (2+1)

IV. Rationale

Physical fitness is a state of health and well-being and more particularly, the capacity to perform satisfactorily in occupations, daily chores and sports. It is generally achieved through proper nutrition, physical exercise and rest. Physical fitness is considered as a measure of body's ability to function efficiently and effectively in work and leisure activities, to be healthy and to resist diseases and to meet emergency situations.

V. Aim of the course

- To provide both theory and practical exposure to understand the concept of physical fitness
- To incorporate recent techniques of body composition and energy metabolism to ascertain the nutritional stature
- To equip the students with the knowledge and capacity to identify, evaluate and evolve ways in addressing various aspects of physical fitness.

VI. Theory

Unit I: Physical fitness and body composition

Overview of nutritional management vis-à-vis body composition and physical fitness; Techniques to assess physical fitness; Body composition in different physiological conditions and factors affecting it; Methods of measuring body composition.

Unit II: Energy balance

Energy metabolism; Factors influencing energy metabolism and physical fitness; Techniques to measure energy expenditure and energy intake.

Unit III: Sports nutrition

Requirement of nutrients for specific sports events; Exercise physiology and biochemistry; Nutrition support before, during and after sports event; Water and electrolyte requirement during exercise and their role in performance; Ergogenic aids; Definition, types and dosage; Doping: Definition, types and consequences; Muscle physiology for performance and fitness; Biomechanics; Physiological testing for fitness and performance; Strength, flexibility, anaerobic power and cardio respiratory fitness.

Unit IV: Nutrition and ageing

Role of nutraceuticals in fitness; Ageing theories; Physiology, mechanism and role of nutrients in arresting ageing process.

VII. Practicals

1-4. Planning diets for general fitness
5-12. Planning and preparation of diets for different sports categories
13-14. Planning nutritional requirements for sports injuries
15. Visit to a sports academy
16. Visit to established fitness centres

VIII. Teaching Methods/ Activities

- Lectures

- Assignment (Writing/Reading)
- Student presentation
- Group activities
- Case studies
- Hands on training

IX. Learning Outcome

On completion of this course, the students will be able to handle responsibilities as:

- Physical fitness educator/ Adviser
- Utilize methods and techniques for vulnerability assessment as per need of the situation
- Experts in Healthcare Team and fitness centres

X. Suggested Reading

- Benardot D. 2005. *Advanced Sports Nutrition.* 2nd Edition, Human Kinetics Publishers, Champaign, IL.
- Baumgartner R. 2006. *Body Composition in Healthy Aging.* Annals of the New York Academy of Sciences.
- FAO. 2004. *Human Energy Requirements. -Report of a Joint FAO/WHO/UNU Expert Consultation.* Technical Report Series 1. Food and Agriculture Organization, Geneva.
- Geetanjali B and Subhadra M. 2018. *Nutritional Guidelines for Sportspersons.* Jaypee Health Books Publishers.
- Geissler C and Powers H. 2009. *Fundamentals of Human Nutrition.* Churchill Livingstone, London.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. *Modern Nutrition in Health and Disease.* Eleventh Edition, LWW, Philadelphia.
- Srilakshmi B, Suganthi V and Kalaivani C Ashok. 2017. *Exercise Physiology Fitness and Sports Nutrition.* New Age International Publishers.
- https://www.who.int
- https://www.hsph.harvard.edu/nutritionsource
- http://www.nutritioncare.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Concept of physical fitness, recent techniques of body composition and energy metabolism.
2	Overview of nutritional management vis-à-vis body composition and physical fitness.
3	Methods of measuring body composition.
4	Body composition in different physiological conditions and factors affecting it.
5	Techniques to assess physical fitness.
6	Energy metabolism. Factors influencing energy metabolism and physical fitness.
7	Techniques to measure energy expenditure and energy intake.
8	Requirement of nutrients for specific sports events.
9	Exercise physiology and biochemistry.
10	Nutrition support before, during and after sports event.
11	Water and electrolyte requirement during exercise and their role in performance.
12	Ergogenic aids: Definition, types and dosage.
13	Doping: Definition, types and consequences. Muscle physiology for performance and fitness.
14	Biomechanics. Physiologic testing for fitness and performance.

Duration (week)	Topic
15	Strength, flexibility, anaerobic power and cardio respiratory fitness Role of nutraceuticals in fitness.
16	Ageing theories Physiology, mechanism and role of nutrients in arresting ageing process.

I. Course Title : Developments in Nutrition and Immunity

II. Course Code : FN 506

III. Credit Hours : 2 (2+0)

IV. Rationale

Immunity is the capability of multi-cellular organism to resist harmful microorganisms from entering it. Good nutrition is essential to build a strong immune system which offers protection from seasonal illness (flu, cold) and other health problems (arthritis, allergies, abnormal cell development, etc.) Students with a good knowledge about role of nutrition in boosting a strong immune system in population will be able to reduce risk factors arising of malnutrition and infection.

V. Aim of the course

- To impart knowledge about role of various macro and micronutrients along with prebiotics, probiotics and phytochemicals in improving immune systems in the population
- To induce understanding about nutrition and immunity in disease management in age- sex groups across all physiological stages.

VI. Theory

Unit I: Immunity and macronutrients

Immunity: definition and history; Classification of immunity and immunological responses; Role of nutrients in immune functions- Carbohydrates, fat and protein; Effect of arginine, glutamine, sulphur amino acids and omega-3 fatty acids on immune system.

Unit II: Immunity and micronutrients

Effect of deficiency and excess of vitamins and minerals on immune cell functions; Effect of malnutrition on immunity; Infections and undernutrition – causes and consequences and role of immunization.

Unit III: Nutrition during infections

Age related immune depression; Role of nutraceuticals and functional foods in immune system; Nutrition, HIV/AIDS and Tuberculosis.

Unit IV: Immunity and chronic diseases

Nutritional immunity and chronic diseases; Probiotics, prebiotics, phytochemicals and immunity; Food allergy.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Written/Reading)
- Students' presentations
- Group discussion

VIII. Learning Outcome

Completion of the course will enable the students to:

- Understand underlying causes of poor immune system
- Appreciate the scientific foundation for better management of risks associated with poor nutrition and immunity
- Act as confident members in healthcare teams
- Utilize information for publication/ education

IX. Suggested Reading

- Calder P and Yaqoob P. 2013. *Diet, Immunity and Inflammation*. Woodhead Publishing Ltd. Cambridge.
- Gershwin ME, German JB and Keen CL. 2000. *Nutrition and Immunology – Principles and Practice*. Humana Press Inc. New York.
- Gershwin ME, Nestel P and Keen CL. 2004. *Handbook of Nutrition and Immunity*. Humana Press Inc. New York.
- Ivan M Roitt and Peter J Deves. 2004. *Essential Immunology*. Blackwell Science Ltd
- Pammi M, Vallejo JG and Abrams SA. 2016. *Nutrition-Infection Interactions and Impacts on Human Health*. CRC Press, Boca Raton, Florida.
- Philip C Calder and Anil D Kulkarni. 2017. *Nutrition, Immunity, and Infection*. CRC press, London
- Shetty PS. 2010. *Nutrition, Immunity and Infection*. CABI Publishers, Oxfordshire, UK.
- https://www.nutritionintl.org
- https://nutrition.org
- https://www.icmr.nic.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Role of nutrients in maintaining and improving the immunity of individuals.
2	Immunity: definition, history and classification of immunity and immunological responses.
3	Role of nutrients in immune functions- Carbohydrates, fats and proteins.
4	Effect of arginine, glutamine, sulphur amino acids and omega-3 fatty acids on immune system.
5	Effect of deficiency and excess of vitamins and minerals on immune cell functions.
6	Effect of malnutrition on immunity.
7	Infections and undernutrition.
8	Causes and consequences and role of immunization.
9	Age related immune depression.
10	Role of nutraceuticals and functional foods in immune system.
11	Nutrition in HIV/AIDS.
12	Nutrition in Tuberculosis.
13	Nutrition, immunity and chronic diseases.
14	Probiotics, prebiotics and immunity.
15	Phytochemicals and immunity.
16	Food allergy.

I. Course Title : Clinical Nutrition

II. Course Code : FN 507

III. Credit Hours : 3 (2+1)

IV. Rationale

Clinical nutrition is nutrition of patients in Health care and refers to the management of patients. It incorporates primarily the scientific fields of nutrition and dietetics. Knowledge of striking a positive energy balance in patients along with providing sufficient amount of other nutrients such as proteins, vitamins, minerals is the basis of patient's Health Care Management.

V. Aim of the course

- To provide both theoretical and applied knowledge on the subject of clinical nutrition for better management of diseases
- To approach various areas of nutrition from a multidisciplinary perspective - biochemical, physiological, pathological and regulatory
- To equip the students to identify the inter-relationship, etiology and management techniques to a specific disease situation including in patients "medical nutrition therapy" understanding to induce situational improvement of health.

VI. Theory

Unit I: Macronutrients

Methods for estimating requirements and recommended allowances of energy, protein, minerals and vitamins for different age groups and physiological state; Growth studies; Depletion and repletion studies; Nutrient balance studies; Use of isotopically labelled nutrients: Nutrient turnover; Obligatory losses of nutrients; National and international recommendations on Nutrient Requirements; Recommendations for Indian by the Indian Council of Medical Research; FAO/ WHO expert committee recommendations; Nutrient interrelationship; therapeutic measures of protein energy malnutrition; Adaptation and chronic energy deficiency; Regulatory processes in chronic energy deficiency; Protein and amino acid turnover; Regulation of amino acid metabolism; Disposal of dietary amino acids and roles of specific organs.

Unit II: Micronutrients

Interrelationship, etiology and preventive measures of vitamin and mineral deficiencies toxicities; Adverse effects of Vitamins and minerals; Upper tolerable levels; Principles and interpretation of clinical laboratory methods with particular emphasis on their interpretation relative to nutritional status and disease; interaction between nutrients, infections and drugs; Functional tests of malnutrition; Nutritional assessment tools in clinical decision making.

Unit III: Nutritional support during disease

Nutritional support, enteral tube feeding, parenteral nutrition, drugs and enteral feeding; Special considerations with nutritional support; Nutrition in surgery and trauma; The stress response to trauma on metabolism; Nutrition support in critically ill patient; Guidelines for use of formula feeds and calculation.

Unit IV: Therapeutic nutrition

Nutrition in GI Diseases; Celiac disease, inflammatory bowel disease, Assessment of liver function - nutritional management in liver disease, acute and chronic pancreatitis, severity scores, nutritional aspects of disease affecting the skeleton, diagnostic imaging, biochemical assessment; Acute and chronic renal failure, nephrotic syndrome, transplantation; Diet and hypertension, stroke, peripheral vascular disease, and chronic heart failure; Wasting syndrome in cancer; Impact of radiation and chemotherapies; Nutritional support on clinical outcomes.

VII. Practicals

1-4. Visit to critical care wards in hospitals for familiarizing with enteral and parenteral feeding methods.
5. Handling and deciphering the medical case sheets.
6-9. Planning enteral feeding, critical care nutritional requirements for different clinical conditions
10-11. Calculating energy, protein, fat and micronutrients after nutritional assessment.
12-13. Presenting case studies of medical cases
14-15. Survey of various enteral feed formulations for different clinical conditions
16. Report writing

VIII. Teaching Methods/Activities

- Lectures
- Assignment (writing/reading)
- Students' presentation
- Group activities
- Case studies in medical setup.
- Hands on training

IX. Learning Outcome

After successful completion of this course, the students will be able to

- Appreciate scientific understanding of the clinical situation of a patient and suggesting complementary nutrition therapy for its management
- Utilize methods and tools related to nutrition assessment and advocacy strategies along with Health Care Team
- Utilize knowledge for scientific Publication
- "Care Education" for target groups
- Utilize the knowledge to act as technical expert in R&D projects

X. Suggested Reading

- Connie WB and Christine SR. 2016. *Handbook of Clinical Nutrition and Ageing*. Humana Press.
- FAO. 2004. *Human Energy Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation*. Technical Report Series 1. Food and Agriculture Organization, Geneva.
- Gibney MJ, Macdonald IA and Roche HM. 2011. *Nutrition and Metabolism*. Wiley-Blackwell Publishing Company, Boston.
- Gibney MJ, Elia M, Ljungqvist O and Dowsett J. 2013. *Clinical Nutrition*. Wiley-Blackwell Publishing Company, Boston.
- Heimburger DC and Ard JD (2006) *Hand Book of Clinical Nutrition*. Mosby Pub.
- Joshi YK. 2009. *Basics of Clinical Nutrition*. 2nd Edition, Jaypee Brothers Medical Publishers Private Limited, New Delhi.
- Macdonald IA and Michael J Gibney MJ. 2011. *Nutrition and Metabolism*. Wiley-Blackwell Publishing Company, Boston.
- Narasinga Rao BS and Sivakumar B. 2010. *Nutrient Requirements and Recommended Dietary Allowances*. 2nd Edition, National Institute of Nutrition, Hyderabad.
- Marian M and Susan R. 2009. *Clinical/Nutrition for Oncology Patients*. Jones and Bartlett Pub.
- Scott AS and George LB. 1997. *Nutrition Support-Theory and Therapeutics*. Chapman and Hall Series, International Thomson Publications.
- Sharon RR , Kathryn P and Whitney E. 2017. *Understanding Normal and Clinical Nutrition*. Cengage Learning.
- Width M and Reinhard T. 2017. *The Essential Pocket Guide for Clinical Nutrition*. LWW Pub.

- Wayne EB. 2005. *Clinical Nutrition Case Studies*. Cengage Learning.
- Vishwanath S. 2017. *Introduction to Clinical Nutrition*. CRC Press.
- http://www.nutritioncare.org
- https://nutrition.org
- http://www.nutritionlink.org/

Weekly Lecture Schedule

Duration (weeks)	Topic
1.	Methods for estimating requirements and recommended allowances of energy, protein, minerals and vitamins for different age groups and physiological state.
2.	Growth studies. Depletion and repletion studies. Nutrient balance studies.
3.	Use of isotopically labelled nutrients: Nutrient turnover. Obligatory losses of nutrients.
4.	National and international recommendations on nutrient requirements. Recommendations for Indian by the Indian Council of Medical Research. FAO/ WHO expert committee recommendations.
5.	Nutrient interrelationship; therapeutic measures of protein energy malnutrition. Adaptation and chronic energy deficiency. Regulatory processes in chronic energy deficiency.
6.	Protein and amino acid turnover. Regulation of amino acid metabolism. Disposal of dietary amino acids and roles of specific organs.
7.	Interrelationship, etiology and preventive measures of vitamin and mineral deficiencies toxicities. Adverse effects of vitamins and minerals. Upper tolerable levels.
8.	Principles and interpretation of clinical laboratory methods with particular emphasis on their interpretation relative to nutritional status and disease; interaction between nutrients, infections and drugs.
9.	Functional tests of malnutrition. Nutritional assessment tools in clinical decision making.
10.	Nutritional Support, Enteral tube feeding, Parenteral nutrition, drugs and enteral feeding.
11.	Special considerations with nutritional support, Nutrition in surgery and trauma. The stress response to trauma on metabolism.
12.	Nutrition support in critically ill patient. Guidelines for use of Formula feeds and calculation.
13.	Nutrition in GI Diseases, celiac disease and inflammatory bowel disease. Assessment of liver function-nutritional management in liver disease, acute and chronic pancreatitis, Severity scores.
14.	Nutritional aspects of disease affecting the skeleton. Diagnostic imaging, biochemical assessment. The Kidney- Acute, chronic renal failure, Nephrotic syndrome, transplantation.
15.	Diet and hypertension, stroke, peripheral vascular disease and chronic heart failure.
16.	Wasting syndrome in cancer. Impact of radiation and chemotherapies. Nutritional support on clinical outcomes.

I. Course Title : Nutrition Counselling
II. Course Code : FN 508
III. Credit Hours : 2 (0+2)

IV. Rationale

Nutrition counselling is an ongoing process in which nutrition professional works with an individual to assess his/her usual dietary intake to support growth, development and maintenance conducive to good health in normal and ailing conditions. As counsellor, it requires high skill in communication, subject knowledge and understanding the client's socio-eco- cultural background to offer curative/ preventive nutritional advice.

V. Aim of the course

- To provide ample hands on training to develop skills in communication, application of subject knowledge and understanding client's need and offer curative/ preventing dietary plan in medical or non-medical set-ups
- Tol approach the counselling techniques from and multidimensional perspective i.e. personal, medical, socio-eco cultural good habits and causative factors that contribute to the development of situations affecting normal health of population
- To create effective nutrition counsellors for addressing health and nutritional challenges of population.

VI. Practicals

1-2. Development of resources and dietary guidelines for counselling
3-4. Procedures of nutritional counselling in clinical practice
5-12. Preparing nutritional and dietary care plans for individuals and groups
13-16. Records required for follow up study, group discussion and motivation as tools to bring attitudinal changes in food selection and preparation
17-18. Exercises on writing scientific facts in simple manner for the people
19-22. Diet campaigns, exhibitions, demonstrations and workshops
23-28. Setting up counselling unit. Counselling in outpatient wards in local hospitals
29-30. Simulation techniques for counselling in selected settings
31-32. Use of dietary apps for counselling and assessing food intake

VII. Teaching Methods/ Assignments

- Hands on training
- Group activities
- Project planning and report writing
- Case studies

VIII. Learning Outcome

After successful completion of this practical course, students will be able to:

- Act as confident nutrition counsellor in given setup
- Utilize methods and techniques to correct nutrition related health problems and suggest adaptive strategies in the context of social milieu
- Utilize the scientific knowledge for benefit of the community through population education/ publication
- Act as resource person in handling R&D projects

IX. Suggested Reading

- Aronson V. 1989. *The Dietetic Technician-Effective Nutrition Counselling*. John Wiley and Sons Florida.

- Betsy H and Judith BA. 2014. *Nutrition Counselling and Education Skills for Dietetics Professional*. 6th Edition, LWW, Philadelphia.
- Devito JA. 2015. *Human Communication: The Basic Course*. Pearson, New York.
- Gable J. 2016. *Counselling Skills for Dietitians*. John Wiley and Sons Florida.
- Kathleen DB, Doreen Land Carol AS. 2001. *Basic Nutrition Counselling Skill Development*. Brooks Cole Pub.
- Kathleen DB, Doreen L and Carol AS. 2014. *Nutrition Counselling and Education Skill Development*. CENGAGE Learning Custom Pub, USA.
- King K and Klawitter B. 2007. *Nutrition Therapy. Advanced Counselling Skills*. 3rd Edition, LWW, Philadelphia.
- Mahan LK and Escott S. 2016. *Krause's Food & Nutrition Therapy*. 14th Edition, Saunders, Philadelphia.
- Midwinter R and Dickson J. 2015. *Embedding Counselling and Communication Skills - A Relational Skills Model*. Routledge.
- Snetselaar L. 2009. *Nutrition Counselling Skills for the Nutrition Care Process*. 4th Edition Jones Bartlett Publishers, Sudbury, Massachusetts.
- https://nutrition.org
- http://www.nutritionlink.org
- http://www.fao.org/docrep/X2550E/X2550e04.htm

I. Course Title : Food Safety And Standards

II. Course Code : FN 509

III. Credit Hours : 3 (2+1)

IV. Rationale

Food safety involves the prevention of the adverse effects of chemical substances of food on human beings and means to overcome toxic effect through appropriate processing techniques. It is important to derive maximum benefits of consumed food as far as practicable toxin free.

V. Aim of the course

- To provide both theoretical and practical exposure to the students on the subject of food safety including types of toxin and methods of removal of these in terms of human health
- To approach the related topics ranging from types, causative factors, signs and symptoms of food toxicity, removal and potential containments
- To induce sufficient knowledge regarding national and international food safety standards.

VI. Theory

Unit I: Xenobiotics

Toxicologically relevant principles of the cell and molecular biology; Dynamics and kinetics of xenobiotics; Environmental pollutants entering the food chain.

Unit II: Food poisoning

Introduction and significance of food toxicology; Food poisoning – types, causative factors, signs and symptoms and preventive measures; Naturally occurring food toxins, their harmful effects and methods of removal.

Unit III: Microbial and chemical toxins

Microbial toxins and food intoxication – source of contamination, effects on health, preventive measures and methods of inactivation and destruction; Chemical toxins –

pesticides, insecticides, metallic and others and their residual effects, preventive measures and methods of removal.

Unit IV: Food safety laws and standards

Food packaging material – Potential contaminants from food packaging material; Food safety laws and standards: FSSAI, FPO, ISI, Agmark, Codex Alimentarius, ISO mark for vegetarian and non-vegetarian foods, eco-friendly products and others in operation.

VII. Practicals

1-2. Basic chemical diagnostics of poisonings based on the samples from dead animal's organs and feed
3-7. Methods of identification and quantification of poisons isolation from biological materials
8-9. Principles of sampling and sending biological materials for toxicological analysis
10. Basis of intravital laboratory diagnostics of acute and chronic poisonings
11. Evaluation of toxic effects concerning the degree and the time of exposure to a xenobiotic
12-13. The determination of cholinesterase activity in the whole blood, in blood plasma and in red blood cells after the exposure to organophosphate and carbaminate insecticides
14. Evaluation of the effect of an antidote
15. Identification of nitrite and nitrate in water and in vegetables
16. Evaluation of nitrite and nitrate effect on haemoglobin.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- On field case identification and analysis
- Hands on training

IX. Learning Outcome

Successful completion of this course will enable the students to:

- Be an expert on the subject relating key learnings as food safety officer/ extension worker/ food inspector
- Utilize learning in scientific Publications/ population education

X. Suggested Reading

- Concon JM. 2000. *Food Toxicology- Principles and Concepts - Part A and B.* Marcel-Dekker Inc. New York.
- Helferich W and Winter CK. 2001. *Food Toxicology*. CRC Press, Boca Raton, Florida.
- Pussa T. 2013. *Principles of Food Toxicology*. CRC Press, Boca Raton, Florida.
- Timbrell J. 2001. *Introduction to Toxicology*. 3rd Edition, Informa, London.
- Vought JB and Henderson MK. 2000. *Principles of Sampling and Sending Biological Materials for Toxicological Analysis - Unit II Biomarkers Practical Aspects*. IARC publication, WHO, Geneva.
- https://www.fssai.gov.in
- http://www.fda.gov/food/default.htm

Weekly Lecture Schedule

Duration (weeks)	Topic
1	Toxicologically relevant principles of the cell and molecular biology.
2	Dynamics and kinetics of xenobiotics.
3	Environmental pollutants entering the food chain.
4	Introduction and significance of food toxicology.
5	Food poisoning – types and causative factors.
6	Food poisoning- signs and symptoms and preventive measures.
7	Naturally occurring food toxins, their harmful effects.
8	Naturally occurring food toxins- methods of removal.
9	Microbial toxins and food intoxication – source of contamination and effects on health.
10	Microbial toxins and food intoxication- preventive measures and methods of inactivation and destruction.
11	Chemical toxins – pesticides, insecticides, metallic and others and their residual effects.
12	Chemical toxins – Preventive measures and methods of removal.
13	Food packaging material- Potential contaminants from food packaging material.
14	Food laws and standards: FPO and ISI.
15	Agmark, Codex Alimentarius and ISO.
16	Mark for vegetarian and non-vegetarian foods, eco-friendly products and others in operation.

I. Course Title : Nutritional Challenges in Life Cycle

II. Course Code : FN 510

III. Credit Hours : 3 (3+0)

IV. Rationale

Nutrition is crucial for the fulfilment of human rights especially those of the most vulnerable groups i.e. infants, children less than 5 years of age, girls and women who constitute the foundation of human development and national prosperity. Knowing the nutritional challenges during various stages of life cycle can reduce susceptibility to infection, morbidity, disability and mortality, thereby, enhancing cumulative lifelong learning capacities and adult productivity.

V. Aim of the course

- To give an exposure to the students with an in-depth basic knowledge regarding nutritional challenges of vulnerable groups during various stages of life cycle
- To approach the areas from various angles like nutritional needs of fetus, mothers (expectant and lactating), adolescents, adults and geriatrics in terms of cognitive learning abilities and to remain healthy and productive
- To equip students to identify, evaluate and evolve management techniques to address nutritional challenge.

VI. Theory

Unit I: Importance of maternal nutrition

Nutritional needs during first 1000 days; Influence of maternal nutritional status on outcome of pregnancy: birth weight of infant and lactation performance.

Unit II: Human milk

Psycho-physiology of lactation; Milk synthesis and secretion; Maternal needs during lactation; Composition of colostrum and mature human milk; Milk of mothers of preterm babies; Milk of animal and formula feeds; Non-nutritional factors of human milk - immunological factors, enzymes and hormones; Human milk banking.

Unit III: Nutrition during childhood, adolescence and adulthood

Nutritional needs of the children and adolescents; Common childhood ailments and dietary considerations; Growth spurt and nutrition; Adolescent fads influencing nutrition, food preferences and nutritional problems; Nutritional requirements in adulthood; Malnutrition, mental development, learning abilities and behavior.

Unit IV: Geriatric nutrition

Overview of ageing process; Nutritional variables related to the ageing process; Physiology of aging; Biological markers of aging; Sociology of aging; Nutritional requirements and deficiencies in elderly; Medications and psychiatric problems in elderly; Immunopathological diseases and aging; Parkinson and Alzheimer syndrome; Care of the elderly; Care-givers and community services.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Student presentation
- Group activities

VIII. Learning Outcome

Successful completion of this course will enable the students to

- Appreciate the scientific understanding of mitigating nutritional challenges and relating key learning as professional expert in the area
- Utilize methods and hand tools for vulnerability assessment and designing adaptation strategies
- Utilize knowledge in scientific publication/ population education
- Be an expert in community health and R&D projects

IX. Suggested Reading

- Bales CW, Ritchie CS. 2013. *Handbook of Clinical Nutrition and Aging.* 2nd Edition, Springer Science & Business Media, Humana Press Inc. New York.
- Cataldo CB, De Brayae LK and Whitney EN. 2012. *Nutrition and Diet Therapy.* 6th Edn., Wadsworth/Thomson Learning Inc.
- Chernoff R. 2003. *Geriatric Nutrition: The Health Professional's Handbook.* 2nd Edition, Jones & Bartlett Learning, Burlington, Massachusetts.
- Kleinman RE. 2008. *Paediatric Nutrition Handbook.* 6th Edition, American Academy of Paediatrics Committee on Nutrition.
- Sachdev HPS and Choudhury P. 2004. *Nutrition in Children - Developing Country Concerns.* B I Publications.
- Schlenker E and Gilbert JA. 2014. Williams' *Essentials of Nutrition and Diet Therapy.* 11th Edition, e- book.
- Sharbaugh C and Brown JE. 2013. *Nutrition Through the Life Cycle.* 5th Edition, Wadsworth Co Inc. Belmont, CA.
- Srilakshmi B. 2019. *Dietetics.* 8th Edition, New Age Internatioanal Publisher.
- Whitney E, DeBruyne LK, Pinna K and Rolfes SR. 2011. *Nutrition for Health and Health Care.* 4th Edition.

- World Health Organization. 2005. *WHO Library Cataloguing-in-Publication Data. Nutrition in Adolescence –Issues and Challenges for the Health Sector*. WHO, Geneva.
- https://www.who.int
- http://www.nutritionlink.org
- https://www.icmr.nic.in

Weekly Schedule

Duration (week)	Topic
1	Nutritional needs of the foetus during different stages of fetal cell growth
2	Maternal nutritional needs
3	Influence of maternal nutritional status on outcome of pregnancy: birth weight of infant and lactation performance.
4	Psycho-physiology of lactation. Milk synthesis and secretion.
5	Maternal needs during lactation.
6	Composition of colostrum and mature human milk. Milk of mothers of preterm babies. Milk of animal and formula feeds.
7	Non-nutritional factors of human milk -immunological factors, enzymes and hormones.
8	Human milk banking.
9	Nutritional needs of the children and adolescents.
10	Common childhood ailments and dietary considerations.
11	Growth spurt and nutrition. Adolescent fads influencing nutrition, food preferences and nutritional problems.
12	Nutritional requirements in adulthood. Malnutrition, mental development, learning abilities and behaviour.
13	Overview of ageing process. Nutritional variables related to the ageing process. Physiology of aging. Biological markers of aging. Sociology of aging.
14	Nutritional requirements and deficiencies in elderly. Medications and psychiatric problems in elderly.
15	Immuno-pathological diseases and aging. Parkinson and Alzheimer syndrome.
16	Care of the elderly. Care-givers and community services.

I. Course Title : Food Science

II. Course Code : FN 511

III. Credit Hours : 3 (2+1)

IV. Rationale

Food is an integral part of everyone's life. This course will empower the students to understand the science factors of food, effects of different processing methods on its nutritional qualities and how to conserve nutrients to the best benefits of the consumers.

V. Aim of the course

- To expose the students in understanding the changes in foods during various processing methods in laboratory setups
- To equip the students in understanding the desirable and undesirable effects of food treatments and identify the best ones for the benefit of consumers as food or trade.

VI. Theory

Unit I: Evaluation of food

Colloidal chemistry as related to foods; Evaluation of food by subjective and objective methods.

Unit II: Characteristics of sugars and starches

Carbohydrates in foods sources; Characteristics of sugar; Starches - types, sources, uses and chemical characteristics; Factors effecting viscosity of starch paste; Characteristics of cellulose and pectin; Gums in foods; Effect of cooking and processing techniques on carbohydrates; Batters and dough- types, properties.

Unit III: Processing of cereals, legumes and animal foods

Preparation of gluten structure; Dough changes in baking; Protein in foods: Plant and animal protein; Chemical and physical properties related to protein foods; Effect of cooking and processing techniques on animal foods – meat, fish, poultry, eggs, milk and milk products; Effect of cooking and processing of plant foods – cereals, millets, legumes, nuts and oilseeds;

Unit IV: Processing of fruits and vegetables

Classification and importance of fruits and vegetables; Composition of fruits and vegetables. Effect of cooking and other processing methods on the nutritive value of fruits and vegetables; Food pigments; Browning reactions in fruits and vegetables; Classification and importance of beverages; Definition, classification, uses and legal aspects of food additives; Classification, nature and uses of leavening agents.

VII. Practicals

1. Microscopic structure of different starch granules
2. Evaluation of food by subjective and objective methods

3-4. Changes in colour, texture and flavour of foods due to processing

5. Product preparation using leavening agents
6. Physicochemical evaluation of grains like length, breadth, L/B ratio, bulk density, cooking properties, 1000 grains weight
7. functional properties of grains - gelatinization, water absorption capacity, oil retention capacity and water retention capacity

8-9. Sugar cookery

10. Smoking temperature of fats and oils
11. Factors effecting absorption of fats
12. Deep fat fried food preparation
13. Changes in cookery- meat, fish, poultry
14. Coagulation of egg, poached egg, omelette, custard, cake
15. Emulsion - mayonnaise preparation
16. Soaking, germination and fermentation of pulses

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Hand on experience

IX. Learning Outcome

After completion of this course, the students are expected to:

- Appreciate the scientific foundation of food and its application to the benefits of human health
- Perform as Food Analyst
- Become Food Entrepreneurs
- Act as Health/ Nutrition advisor

X. Suggested Reading

- Belle Lowe. 2019. *Experimental Cookery from the Chemical and Physical Standpoint*. Facsimile Pub.
- Potter NN and Hotchkiss JH. 2007. *Food Science*. 5th Edition, CBS, New Delhi.
- Roday S. 2018. *Food Science and Nutrition*. 3rd Edition, Oxford University Press, UK.
- Sharma A. 2005. *Textbook of Food Science and Technology*. 3rd Edition, CBS, New Delhi.
- Stone H. 2004. *Sensory Evaluation Practices* (*Food Science and Technology*). 3rd Edition, Academic Press, Cambridge.
- Subbalakshmi G and Udipi SA. 2006. *Food Processing and Preservation*. New Age International, New Delhi.
- Sofia Jan. 2013. *Elements of Food Science*. New India Publishing Agency,New Delhi ISBN: 979-93-81450-24-6.
- Vaclavik VA and Christian EW. 2014. *Essentials of Food Science*. 4th Edition, Springer-Verlag, New York.
- https://www.ift.org
- https://www.foodsciencematters
- https://www.ifst.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Colloidal chemistry as related to foods.
2	Evaluation of food by subjective and objective methods.
3	Carbohydrates in foods sources.
4	Characteristics of sugar.
5	Starches-types, sources, uses and chemical characteristics.
6	Factors effecting viscosity of starch paste.
7	Characteristics of cellulose and pectin. Gums in foods.
8	Effect of cooking and processing techniques on carbohydrates. Batters and dough-types, properties.
9	Preparation of gluten structure. Dough changes in baking.
10	Protein in foods: Plant and animal protein. Chemical and physical properties related to protein foods.
11	Effect of cooking and processing techniques in Animal foods – meat, fish, poultry, eggs, milk and milk products.
12	Effect of cooking and processing of plant foods – cereals, legumes, nuts and oilseeds.
13	Classification and importance of fruits and vegetables. Composition of fruits and vegetables.
14	Effect of cooking and other processing methods on the nutritive value of fruits and vegetables. Food pigments. Browning reactions in fruits and vegetables.
15	Classification and importance of beverages. Definition, classification, uses and legal aspects of food additive.
16	Classification, nature and uses of leavening agents.

I. **Course Title** : **Food Processing Technology**
II. **Course Code** : **FN 512**
III. **Credit Hours** : **3(2+1)**

IV. Rationale

Almost all foods consumed need processing from field to plate. While some processing is applicable to day- to- day life to consume safe and healthy foods, most of the perishable foods require special techniques to conserve nutrients alongside increasing shelf life. Knowledge of the subject is an integral part for food entrepreneurs.

V. Aim of the course

- To give exposure of the subject, with the newer techniques in food processing procedures ranging from preliminary steps to the packaging aspects of different foodstuff for safe consumption and business
- To equip students to identify and application of processing methods suitable to meet the purpose of the consumer.

VI. Theory

Unit I: Food processing techniques

Principles underlying food processing operations including thermal, radiation, refrigeration freezing and dehydration; Effect of processing on physiochemical characteristics; Principles underlying pressure modified processing (high hydrostatic pressure, hyperbaric processing, vacuum cooling, hypobaric storage).

Unit II: Processing technologies for plant foods

Processing technology for preservation and production of variety food products during storage, handling and processing of cereals/millets and legumes, oilseeds, fruits and vegetables; Food preservation by Hurdle technology and canning technology.

Unit III: Processing technologies for animal foods

Processing technology for milk and milk products, egg, meat, poultry and fish, convenience foods and processed foods; Technologies underlying mutual supplementation, enrichment and fortification, fermentation, malting and germination; Food additives commonly used in food industries for colour, flavour and as preservatives; Nanomaterials as food additives.

Unit IV: Quality control in food processing

Quality control in food industry - raw materials and finished products; Waste management and sanitation in food industries; Packaging - self-cooling self-heating packaging, micro packaging, antimicrobial packaging and water-soluble packaging.

VII. Practicals

1. Effect of blanching on enzymatic activity and volume occupation
2. Effect of refrigeration and freezing on quality of fruits and vegetables
3. Dehydration of fruits and vegetables
4. Canning of fruits and vegetables

5-6. Preparation of fruit candy, squash, nectar, malt beverages and quality evaluation with respect to FPO

7. Clarification of juice using various methods (chemical, enzyme and fining agents)

8-9. Malting of green gram, moth bean- enzymatic activity determination

10. Preparation of *Paneer* and curd and its quality evaluation
11. Quality evaluation of egg and fish
12. Effect of chemical preservation on storage quality of food (bread, cake).
13. Storage of nuts and oil seeds under vacuum packaging
14. Packaging of fruits and vegetables for transportation distance market using corrugated fibre boxes
15. Transportation of fresh fruits and vegetables using cushioning system and fibre board
16. Visit to food processing unit

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- Hands on training

IX. Learning Outcome

This course will help students to

- Utilize the scientific knowledge to become food processing entrepreneur
- Utilize the acquired knowledge for being an expert in any Processing Unit
- Assist in ascertaining quality control of a consumed food in any given situation

X. Suggested Reading

- Brennan JG. 2006. *Food Processing Handbook*. Wiley-VCH
- Clark S, Jung S and Lamsal B. 2014. *Food Processing - Principles and Applications.* 2nd Edition, Wiley-Blackwell Publishing Company, Boston.
- Fellows PJ. 2000. *Food Processing Technology*. Woodhead Publishing Ltd.
- Fellows PJ. 2017. *Food Processing Technology, Principles and Practice.* 4th Edition, Woodhead Publishing Ltd. Cambridge.
- Hartel R W and Heldman D. 2012. *Principles of Food Processing*. Aspen Publishers Inc. New York.
- Owens G. 2001. *Cereals Processing Technology*. Woodhead Publishing Ltd.
- Sivshankar B. 2002. *Food Processing and Preservation.* Prentice-Hall of India Pvt. Ltd. Delhi.
- Subbalakshmi. 2001. *Food Processing and Preservation*. New Age International Publishers, New Delhi.
- Vaclavik V. 2018. *Dimensions of Food.* CRC Press.
- https://www.ift.org
- https://www.foodsciencematters
- https://www.ifst.org

Weekly Lecture Schedule

Duration (week)	Topic
1.	Principle underlying food processing operations including thermal, radiation, refrigeration, freezing and dehydration.
2.	Effect of processing on physiochemical characteristics.
3.	Principles underlying pressure modified processing (high hydrostatic pressure, hyperbaric processing, vacuum cooling, hypobaric storage).
4.	Processing technology for preservation and production of variety food products during storage, handling and processing of cereals, legumes and oilseeds.
5.	Processing technology for preservation and production of fruits and vegetables.
6.	Food preservation by Hurdle technology.
7.	Food preservation by canning technology.

Duration (week)	Topic
8.	Processing technology for milk and milk products, egg, meat, poultry and fish.
9.	Processing technology for convenience foods and processed foods.
10.	Technologies underlying in mutual supplementation, enrichment and fortification.
11.	Technologies underlying fermentation, malting and germination.
12.	Food additives commonly used in food industries for colour, flavour and as preservatives.
13.	Nanomaterials as food additives.
14.	Quality control in food industry - raw materials and finished products.
15.	Waste management and sanitation in food industries.
16.	Packaging - self-cooling self-heating packaging, micro packaging, antimicrobial packaging and water-soluble packaging.

I. Course Title : Human Physiology

II. Course Code : FN 513

III. Credit Hours : 3 (3+0)

IV. Rationale

Physiology is the scientific study of the function and mechanism which work within a living system. Human Physiology seeks to understand the mechanisms that work to keep the human body alive and functioning through scientific enquiry to keep humans healthy and productive. Changes in Physiology in human can impact vital body functions.

V. Aim of the course

- To give theoretical concepts to complex physiological systems of the human body through scientific enquiry into the nature of mechanical, physical and biochemical function of humans, their organs and cells of which they are composed
- To approach the subject area from variegated angles to equip the students with the knowledge of importance of normal and altered picture of biological markers and suggest remedies.

VI. Theory

Unit I: Circulatory system

Overview of anatomy and functions of human body; Reticuloendothelial system- functions, classification; Lymphatic system- functions, circulation; Circulatory system- blood and composition blood cells, development and function of blood cells, blood clotting, blood grouping and haemoglobin, Heart - anatomy, cardiac cycle, blood pressure and factors affecting blood pressure.

Unit II: Respiratory system

Respiratory system- anatomy, physiology and mechanism of respiration, regulation of respiration; Digestive system- anatomy of gastrointestinal tract and accessory organs, digestion and absorption of food, regulation of appetite.

Unit III: Excretory system

Excretory system- anatomy and functions of kidney, formation, composition and excretion of urine; Endocrine glands, mode of action of hormones.

Unit IV: Reproductive system

Reproductive system- structure and functions of male and female reproductive organs; Anatomy and functions of nervous and musculoskeletal system.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities

VIII. Learning Outcome

This course will help students to:

- Apply knowledge in understanding interrelationship between physiology and nutrition.
- Enable to act as a reliable team member in Healthcare team in medical and non-medical setups.
- Apply the acquired techniques for population education

IX. Suggested Reading

- Chaterjee CC. 2012. *Human Physiology Vol. I and Vol. II.* CBS Publications.
- David F, Stacia BM and Charles LS. 1993. *Human Physiology- Foundations and Frontiers.* 2nd Edn., Mosby Pub.
- Donnersberger AB and Scott AL. 2005. *Laboratory Textbook of Anatomy and Physiology*. 8th Edition, Jones and Bartlett Learning, Burlington, Massachusetts.
- Jain AK. 2009. *Human Physiology for BD.* 3rd Edition, Avichal Publishing Company, New Delhi.
- Hall JE. 2016. *Gayton and Hall Text Book of Medical Physiology*. 13th Edition, Elsevier India.
- Marieb EN. 2004. *Human Anatomy and Physiology 6th Edition*. Pearson Education, Inc. London.
- Waugh A and Grant A. 2014. *Ross and Wilson Anatomy and Physiology in Health and Illness.* 6th Edition, Elsevier Ltd. Churchill Livinstone, London.
- http://novella.mhhe.com/sites/0073525707/information_center_view0/custom_publishing_primis.html
- https://jsums.instructure.com/courses/2144344/pages/welcome-to-holes-human-anatomy-and-physiology-11-slash-e

Weekly Lecture Schedule

Duration (week)	Topic
1	Overview of anatomy and functions of human body.
2	Reticuloendothelial system- functions, classification.
3	Lymphatic system- functions, circulation.
4	Circulatory System- blood and composition blood cells, development and function of blood cells.
5	Blood clotting, blood grouping and haemoglobin.
6	Heart – anatomy and cardiac cycle.
7	Blood pressure and factors affecting it.
8	Respiratory system- anatomy and physiology.
9	Mechanism of respiration and its regulation.
10	Digestive system- anatomy of gastrointestinal tract and accessory organs.
11	Digestion and absorption of food, regulation of appetite.
12	Excretory system- anatomy and functions of kidney.

Duration (week)	Topics
13	Formation, composition and excretion of urine.
14	Endocrine glands, mode of action of hormones.
15	Reproductive system- structure and functions of male and female reproductive organs.
16	Anatomy and functions of nervous and musculoskeletal system.

I. Course Title : Institutional Food Service Management

II. Course Code : FN 514

III. Credit Hours : 2 (1+1)

IV. Rationale

Institutional food Service Management denotes the entities that provides meals at educational institutes, hospitals, care homes, hotels, public and private cafeteria, etc. Students equipped with updated knowledge in this area will help them to act as an expert to suggest quality food to the customer as per their needs.

V. Aim of the course

- To equip the students with the multi-dimensional knowledge associated with institutional food service in a given setup
- To enable them in planning, execution and control of the management of institutes with ease and profit.

VI. Theory

Unit I: Food service management

Types of food services - organization and management. Tools of management; FSSAI and CODEX guidelines.

Unit II: Record keeping

Personnel management; Books, records and record keeping; Cost control in food services; Menu planning; HACCP.

Unit III: Quantity food production

Meal services management; Types of services; Quantity food production; Principles involved in development of recipes in large scale cooking; Standardization of recipes; Utilization of left-over foods.

Unit IV: Planning of food service unit

Types of kitchens; Planning of layout and equipment for food services; Sanitation and hygiene in handling foods; Personnel hygiene and its importance; Organisation of spaces.

VII. Practicals

1-2. Standardization of basic recipes: planning and preparation
3. Modification in basic recipes
4. Use of left-over foods
5-6. Visit to different types of food service institutions and study the organization, physical plan and layout, food service equipment, sanitation and hygiene.
7-10. Practical experience in organization and management of a college cafeteria/ hotels
11-12. Setting of canteens with formal and informal table setting

13. Scale production of standardised recipes
14-15. Menu planning for snack bars, canteens, residential hostels and hospitals
16. Cost analysis

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Hands on training

IX. Learning Outcome

This course will help students to:

- Act as front office managers
- Skilled in centralized/ decentralized service providers in medical/ care homes
- Skilled chef and service providers

X. Suggested Reading

- Arora RS. 2012. *Banquet and Catering Management*. Abhijeet Publications.
- Beckley JH, Herzog LJ and Foley MM. 2017. *Accelerating New Food Product Design and Development*. 2nd Edition, John Wiley and Sons Inc. Hoboken, New Jersey.
- Carpenter RP, Lyon DH and Hasdell TA. 2002. *Guidelines for Sensory Analysis in Food Product Development and Quality Control*. 2nd Edition, Aspen Publishers Inc. New York.
- Earle M and Earle RL. 2008. *Case Studies in Food Product Development*. Woodhead Publishing Limited and CRC Press, New York.
- Harish Bhat. 2008. *Hotel Management*. Crescent Publishing Corporation.
- Moskowitz HR, Straus T and Saguy S. 2009. *An Integrated Approach to New Food Product Development*. CRC Press, Boca Raton, Florida.
- Mudit Bhajwani. 2007. *Food Service Management: Principles and Practice*. Rajat publications, New Delhi.
- Nancy LS. 2007. *Catering Management*. John Wiley & Sons.
- Puckett RP. 2012. *Food Service Manual for Health Care Institutions*. 4th Edition, John Wiley and Sons Inc. Hoboken, New Jersey.
- Sethi M. 2018. *Catering Management- An Integral Approach*. 3rd Edition, New Age International, New Delhi.
- https://www.ferrerofoodservice.com
- https://www.foodservicedirector.com
- Vaclavik V (2018) *Dimensions of Food*. CRC Press.

Course Title with Credit Load
Ph.D. (Community Science) in Food and Nutrition

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
FN 601*	Macronutrient Metabolism	3(3+0)
FN 602*	Micronutrient Metabolism	2(2+0)
FN 603*	Nutrition and Agricultural Interface	3(3+0)
FN 604	Global Nutritional Problems	2(2+0)
FN 605	Nutrition in Calamities	2(2+0)
FN 606	Maternal and Child Nutrition	2(2+0)
FN 607	Hormones and Enzymes	2(2+0)
FN 608	Energy Metabolism	2(2+0)
FN 609	Application of Biotechnology in Food Science and Nutrition	3(3+0)
FN 610	Recent Trends in Food Science and Technology	3(3+0)
	Minor Courses (06 Credits)	
	Food Science and Technology	3(2+1)
	Food Biochemistry	3(2+1)
	Nutritional Biochemistry	2(2+0)
	Food Microbiology	3(2+1)
EECM 603	Scaling Techniques for Behaviour Research	3 (1+2)
EECM 605	Sustainable Livelihood Systems	2 (1+1)
	Supporting Courses (05 Credits)	
	A student can opt any course related to the topic of research offered by other faculties of agriculture university or SWAYAM portal or MOOCS or other online courses up to a maximum of 5 credits.	
FN 691	Doctoral Seminar I (Major Field)	1(1+0)
FN 692	Doctoral Seminar II (Minor Field)	1(1+0)
FN 699	Research	75
	Total	100 Credits

*Core courses/ compulsory courses

Course Contents
Ph.D. (Community Science) in Food and Nutrition

I. Course Title : Macronutrient Metabolism

II. Course Code : FN 601

III. Credit Hours : 3(3+0)

IV. Rationale

Food intake is sporadic: for most people it occurs in three major boluses each day. Energy expenditure, however, is continuous, with variations during the day that bears no resemblance to the energy intake pattern. Macronutrients are the three sources of energy which are variably stored and assimilated from food each day. A basic understanding of this fact will help the students to address the need of efficient energy metabolism in people to maintain energy balance for health. Furthermore, it will help to guide people how to lessen the food related disease burden like obesity, Type 2 diabetes, heart disease, etc.

V. Aim of the course

- To give a strong theoretical base to the students with reference to metabolism of macronutrients
- To approach the related areas from a multidimensional perspective—digestion, absorption, assimilation and metabolism in relation to normal health maintenance and preventing disease onsets
- To equip the students to identify, stratify and manage the risks associated with energy metabolism.

VI. Theory

Unit I: Macronutrients

Digestion, absorption and metabolism of carbohydrates, proteins and lipids; Inborn errors of metabolism; Degenerative diseases - diabetes, obesity, atherosclerosis, hyperlipidaemia and hypertension; Glucose homeostasis determined by insulin/ glycogen ratio; low carbohydrates diet and its metabolic consequences.

Unit II: Dietary fibre

Glycaemic Index and load; Dietary fibre and its impact in various physiological disorders; Hypoglycaemic action of foods.

Unit III: Proteins

Classification of protein, new discoveries in protein and their functions (protein in immune system, biological buffers and carriers); Evaluation of protein quality- *in vitro* and *in vivo* methods, animal and human bioassays; Amino acid pool, protein turnover in man with special reference to body size, age and various nutrition and pathological conditions; Novel food sources of protein; Role of hormones in protein metabolism; Effect of dietary protein on cardiovascular disease and cholesterol metabolism; Adaptation of body to low intake of energy and protein.

Unit IV: Lipids

Hypolipidemic action of MUFA, PUFA and oxidation products of cholesterol; Effect of saturated fatty acids and trans fatty acids in lipid metabolism, role of reversal diet in cardiovascular disorders; Causes, prevention and treatment of hyperlipidaemia.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Student presentation
- Online Group Discussion

VIII. Learning Outcome

After successful completion of this course, the students will be able to

- Appreciate the scientific knowledge in the process of energy metabolism
- Utilize the methods and tools for the management of hypo/hyper metabolic stages
- Utilize knowledge for scientific deliberations
- Act as Clinical Nutritionist in medical set-ups
- Expert Member of Health Care Team (HCT)
- Researcher in related R&D Projects

IX. Suggested Reading

- Akoh CC and Min DB. 2002. *Food Lipids - Chemistry, Nutrition and Biotechnology*. Marcel Dekker Inc. New York.
- Dickens F. 1981. *Carbohydrate Metabolism and its Disorders Vol. III*. Academic Press, Cambridge.
- FAO WHO/UNU ý(2004ý) *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation*. Geneva: World Health Organization. FAO Food and Nutrition Technical Report Series 1.
- FAO WHO/UNU. ý2007. *Protein and Amino Acid Requirements in Human Nutrition: Report of a Joint FAO/WHO/UNU Expert Consultation, Geneva*. Word Health Organization. Technical Report Series 935. http://www.who.int/iris/handle/10665/43411.
- Nelson D L and Cox MM. 2017. *Lehninger Principles of Biochemistry*. 7th Edition. WH Freeman, New York.
- Stipanuk MH and Caudill MA. 2013. *Biochemical, Physiological and Molecular Aspects of Human Nutrition*. 3rd Edition. Elsevier Pub.
- https://www.who.int
- http://www.fao.org/home/en
- https://www.nutrition.org.uk

Weekly Lecture Schedule

Duration (week)	Topic
1	Carbohydrates -digestion, absorption and metabolism. Proteins - digestion, absorption and metabolism. Lipids- digestion, absorption and metabolism.
2	Inborn errors of metabolism. Diabetes.
3	Obesity.
4	Atherosclerosis.
5	Hyperlipidaemia.
6	Hypertension.
7	Glucose homeostasis determined by insulin/glycogen ratio. Low carbohydrates diet and its metabolic consequences.
8	Glycaemic Index and load. Dietary fiber and its impact in various physiological disorders

Duration (week)	Topic
9	Hypoglycemic action of foods. Classification of protein
10	New discoveries in protein and their functions in immune system, biological buffers and carriers.
11	Evaluation of protein quality- *in vitro* and *in vivo* methods, animal and human bioassays. Amino acid pool.
12.	Protein turnover in man with special reference to body size, age and various nutrition and pathological conditions. Novel food sources of protein.
13.	Role of hormones in protein metabolism. Effect of dietary protein on cardiovascular disease and cholesterol metabolism. Adaptation of body to low intake of energy and protein.
14.	Hypolipidemic action of MUFA, PUFA and oxidation products of cholesterol.
15.	Effect of Saturated fatty acids and trans fatty acids in lipid metabolism. Role of reversal diet in cardiovascular disorders.
16.	Causes, Prevention and treatment of hyperlipidemia.

I. Course Title : Micronutrient Metabolism

II. Course Code : FN 602

III. Credit Hours : 2(2+0)

IV. Rationale

Micronutrients are required by human and other organisms all over life in small quantities to coordinate a wide range of physiological functions. While vitamins are chiefly necessary for energy production, immune functions, blood clotting, etc. the minerals play important role in growth, bone health, fluid balance, etc. An advanced understanding of the metabolism aspects of these nutrients will enable the students to guide the population in encouraging proficient metabolic stages in humans to address the public health nutritional problems.

V. Aim of the course

- To give a strong theoretical understanding of the essentiality of micronutrient sufficiency to aid metabolic processes in relation to health and disease onset
- To enhance the knowledge of recent advances in micronutrient nutrition that will help the students to plan and execute policies in micronutrient malnutrition in population.

VI. Theory

Unit I: Vitamins

History, chemistry, distribution and functions of vitamins; Absorption, transportation, metabolism of vitamins; Nutritional requirements of vitamins; Deficiency manifestations of water soluble vitamins; Deficiency manifestations of fat soluble vitamins; Causes of vitamin deficiencies in India; Hypervitaminosis of water-soluble vitamins; Hypervitaminosis of fat-soluble vitamins; Vitamin fortification and supplementation; Methods of assay of vitamins; Interaction with other nutrients, antagonists and analogues of vitamins; Assessment of vitamin status of population.

Unit II: Minerals

Causes of macro and micro mineral deficiencies in India; Chronology, chemistry and distribution of minerals; Functions, absorption, transport and metabolism of minerals; Deficiency manifestations of minerals; Nutritional requirements of minerals; Methods of assay of minerals; Interactions of minerals with other nutrients, antagonists and analogues of minerals; Assessment of mineral status of population; Mineral fortification and supplementation; Metaloenzymes. Antioxidants and their relationship with aging, cancer and various non-communicable diseases.

Unit III: Heavy metal toxicity

Harmful effects of major mineral pollutants on health - mutagenicity, carcinogenicity and heavy metal toxicity; Heavy metal toxicity;

Unit IV: Trace elements

Trace minerals - their chronology, chemistry, distribution. Functions of trace minerals. Absorption and metabolism of trace minerals. Requirements of trace minerals. Deficiency manifestation and interaction of trace minerals. Use of mineral isotopes/ tracers in nutritional studies.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

VIII. Learning Outcome

After successful completion of this course, the students will be able to

- Appreciate the scientific knowledge in the process of various physiological functions of human body
- Utilize the methods and tools for the management of hypo/hyper metabolic stage
- Utilize knowledge for scientific deliberations
- Act as Clinical Nutritionist in medical setups
- Expert Member of Health Care Team (HCT)
- Researcher in related R&D Projects

IX. Suggested Reading

- FAO/WHO. 2004. *Vitamins and Minerals in Human Nutrition. A report of joint FAO/WHO Expert Consultation.* 2nd Edition, World Health Organization and Food and Agriculture Organization of the United Nations.
- Garland CF, Garland FC, Gorham ED, Lipkin M, Newmark H, Mohr SB and Holick MF. 2006. *The Role of Vitamin D in Cancer Prevention. American Journal of Public Health*. 96(2), 252–261.
- Groff JL and Gropper S. 2012. *Advanced Nutrition and Human Metabolism*. 7th Edition, Yolanda Cossio, New York.
- Guardia M and Garrigues S. 2015. *Hand Book of Mineral Elements in Foods*. John Wiley & Sons Inc. Hoboken, New Jersey.
- Rizvi S, Raza, ST, Ahmed F, Ahmad A, Abbas S and Mahdi F. 2014. *The Role of Vitamin E in Human Health and Some Diseases. Sultan Qaboos University Medical Journal*, 14(2), 157–165.
- Schwalfenberg GK. 2017. *Vitamins K1 and K2: the emerging group of vitamins required for human health. Journal of Nutrition and Metabolism*. https://doi.org/10.1155/2017/6254836.
- https://www.who.int

- https://nutrition.org
- https://www.gainhealth.org

Weekly Lecture Schedule

Duration(Week)	Topic
1	History, chemistry, distribution and functions of vitamins.
2	Absorption, transport, metabolism of vitamins.
3	Nutritional requirements of vitamins.
4	Deficiency and manifestations of water soluble and fat soluble vitamins.
5	Causes of vitamin deficiencies in India. Hypervitaminosis of water-soluble and fat-soluble vitamins.
6	Vitamin fortification and supplementation.
7	Methods of assay of vitamins. Interaction with other nutrients, antagonists and analogues of vitamins. Assessments of vitamin status of population.
8	Causes of macro and micro mineral deficiencies in India. Chronology, chemistry and distribution of minerals.
9	Deficiency manifestations of minerals. Nutritional requirements of minerals.
10	Methods of assay of minerals. Interactions of minerals with other nutrients, antagonists and analogues of minerals.
11	Assessment of mineral status of population. Mineral fortification and supplementation.
12	Metaloenzymes. Harmful effects of major mineral pollutants on health – mutagencity, carcinogenicity. Heavy metal toxicity.
13	Heavy metal toxicity.
14	Antioxidants and their relationship with ageing and cancer. Antioxidants and their relationship with various non – communicable diseases. Trace minerals - their chronology, chemistry, distribution and functions. Absorption and metabolism of trace minerals.
15	Functions and Requirements of trace minerals. Absorption and metabolism of trace minerals.
16	Deficiency manifestation and interaction of trace minerals. Use of mineral isotopes/ tracers in nutritional studies.

I. Course Title : Nutrition and Agricultural Interface

II. Course Code : FN 603

III. Credit Hours : 3(3+0)

IV. Rationale

There is a clear potential for the agriculture sector to play a critical role in enhancing food and nutrition security and health of population. Agriculture and nutrition are closely linked. Producing foods that are acceptable, accessible and affordable can make population healthy and productive, thus making a virtuous cycle. If this cycle becomes vicious, the turn-over will become negative. This course will enable the students to keep tract with agriculture scenario of a place and connect with the health status to identify, evaluate and find ways to establish positive interfaces.

V. Aim of the course

- To give a clear understanding of interlinking agricultural production and nutritional status of the population
- To assist the students to identify and evaluate the agriculture in terms of nutrition nexus and its effective management.

VI. Theory

Unit I: Food production and consumption

Food situation in India and in the world; Food production and consumption trends; Food balance sheets; Role of nutrition in agricultural planning and national development.

Unit II: Food distribution

Linkages between agricultural practices and food production, distribution and nutritional status; Factors affecting food distribution at macro and micro level; Per capita food availability and consumption; Food and Nutrition security at national and household level; Role of agriculture in enhancing food security; Food crop failure and malnutrition.

Unit III: Farming systems

Poverty and vicious cycle of low food production; Effect of food production and economic policies on food availability; Impact of physical resources, farming systems, cropping system, inputs and manipulation, agricultural marketing system, post-harvest processing of foods on food and nutrition situation; Implementation of nutrition policy.

Unit IV: Agricultural programmes

Sustainable food systems, nutritional impact of agricultural programmes, food price control and consumer subsidy; Contribution of National and International organization in agricultural development.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

VIII. Learning Outcome

After successful completion of this course, the students will be able to

- Understand linkage between agriculture and nutrition
- Apply the knowledge in planning and implementation of agriculture and nutrition related policies
- Act as expert in developmental programmed of GOs and NGOs

IX. Suggested Reading

- FAO. 2017. *The State of Food and Agriculture - Leveraging Food Systems for Inclusive Rural Transformation.* Food and Agriculture Organization, Rome.
- FAO. 2017. *The State of Food Security and Nutrition in the World.* Food and Agriculture Organization, Rome.
- GOI. 2016. *Agricultural Statistics at a Glance.* Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation and Farmers Welfare Directorate of Economics and Statistics, Government of India.
- GOI. 2017. *Agriculture - Statistical Year Book India.* Ministry of Statistics and Programme Implementation, Government of India.
- GOI. 2011. *Census of India.* Government of India.
- GOI. 2018. *A Reference Manualby Publication Division.* Ministry of Information about Broadcasting, Govt. of India.
- https://www.who.int

- http://www.fao.org/home/en
- https://www.india.gov.in/ agriculture
- https://mhrd.gov.in/mid-day-meal

Weekly Lecture Schedule

Duration(Week)	Topic
1	Food situation in India and in the world
2	Food production and consumption trends. Food balance sheets.
3	Role of nutrition in agricultural planning and national development
4	Linkages between agricultural practices and food production, distribution and nutritional status
5	Factors affecting food distribution at macro and micro level. Per capita food availability and consumption
6	Per capita food availability and consumption
7	Food and Nutrition security at national and household level
8	Role of agriculture in enhancing food security. Food crop failure and malnutrition
9	Poverty and vicious cycle of low food production. Effect of food production and economic policies on food availability
10	Impact of physical resources, farming systems, cropping system and inputs and manipulation on food and nutrition situation
11	Impact of agricultural marketing system, post-harvest processing of foods on food and nutrition situation
12	Nutrition policy implementation
13	Sustainable food systems
14	Nutritional impact of agricultural programmes
15	Food price control and consumer subsidy
16	Contribution of National and International organization for agricultural development

I. Course Title : Global Nutritional Problems

II. Course Code : FN 604

III. Credit Hours : 2(2+0)

IV. Rationale

Global Nutrition Report of 2018 by WHO states that malnutrition is still rampant affecting most of world's population at some point in their life cycle from infancy to old age. No country is untouched. Malnutrition is a universal issue holding back development with unacceptable human consequences. Yet the opportunity to end malnutrition has never been better. Malnutrition is responsible for more ill-health than any other cause. It deems necessary for the students to equip thems with the knowledge of the nutrition related global problems and prepare thems with skills to address the challenges effectively.

V. Aim of the course

- To make the students knowledgeable about the world scenario of prevailing malnutrition in variegated forms and measures being adopted at international/ national levels
- To give opportunity to the students to identify, analyse and suggest coping strategies at global, national, regional and community levels.

VI. Theory

Unit I: Food consumption

Food consumption pattern of underdeveloped, developing and developed countries.

Unit II: Nutritional deficiency diseases

An overview of world nutrition situation and assessment of problems of developing and developed countries in light of prevalence, aetiology, indicators and preventive measures.

Unit III: Health programmes

Nutrition and health programmes to alleviate malnutrition, role of national and international organizations.

Unit IV: Health care polices

Impact of health care polices and delivery systems; Micronutrients, food fortification and supplementation.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group work/ group discussion

VIII. Learning Outcome

A successful scholar with this knowledge will be able to

- Appreciate the scientific foundation of risk management associated with malnutrition and relate the key learning to the job of a professional
- Utilize methods and tools to assess the nutritional scenario and plan out suitable interventions

IX. Suggested Reading

- Babu SC, Gajanan SN and Hallam JA. 2017. *Nutrition Economics-Principles and Policy Applications*. Science Direct. Elsevier.
- FAO. 2017. *Regional Overview of Food Security and Nutrition in Asia and the Pacific*. Food and Agriculture Organization, Rome.
- Park JE and Park K. 2007. *Text Book of Preventive and Social Medicine*. Barnasi Das Bhanot Publishers, Jabalpur.
- Semba RD and Bloem MW. 2008. *Nutrition and Health in Developing Countries*. 2nd Edition. Humana Press Inc. New York.
- Temple NJ and Steyn N. 2016. *Community Nutrition for Developing Countries*. AU Press, Athabasca University, Canada and UNISA Press, University of South Africa.
- https://www.who.int
- http://www.fao.org/home/en
- https://www.harvestplus.org
- https://www.hsph.harvard.edu/nutritionsource

Weekly Lecture Schedule

Duration(Week)	Topic
1	An overview of world nutrition situation.
2	Overview of global nutritional problems.
3	Global nutrition intervention programmes.
4	Food consumption pattern of underdeveloped countries.

Duration (week)	Topic
5	Food consumption pattern of developing countries.
6	Food consumption pattern of developed countries.
7	Prevalence and etiology of nutritional problems of developing countries.
8	Indicators of nutritional problems of developing countries.
9	Preventive measures of nutritional problems of developing countries.
10	Prevalence and etiology of nutritional problems of developed countries.
11	Indicators and preventive measures of nutritional problems of developed countries.
12	Nutrition and health programmes to alleviate malnutrition.
13	Role of national organizations in combating nutritional problems.
14	Role of international organizations in combating nutritional problems.
15	Impact of health care polices and delivery systems.
16	Micronutrients food fortification and supplementation.

I. Course Title : Nutrition in Calamities

II. Course Code : FN 605

III. Credit Hours : 2(2+0)

IV. Rationale

Calamities, natural, viz., flood, earthquake, draught) or man-made, viz., riots, war, wrong policies always affect nutritional status of population which may be short-termed or long-termed depending upon the severity of the disaster. A knowledge on the topic will enable the students to act favourably for the favours of the victims to lessen the miseries in terms of health and nutrition.

V. Aim of the course

- To give theoretical base to the scholars in the management of food and nutritional security during a disaster. This course will cover areas of food and water supply, precautions against food shortage, adequate feeding especially of vulnerable groups, control of communicable diseases, health and hygiene, etc. during a calamity
- To equip the students with the knowledge of providing effective support systems according to the need of calamity.

VI. Theory

Unit I: Calamities and undernutrition

Starvation in emergencies arising out of drought, floods, earth quakes, locust, war, wrong policies and poverty and climatic changes, conflict and global economic volatility, historical perspectives.

Unit II: Food needs during emergencies

Effect of inanition, short, medium and long- term emergencies on food and nutrient intake, precautions against food shortage; Population groups most vulnerable to under nutrition; Food needs at national level during normal emergencies.

Unit III: Nutritional deficiency diseases

Major nutritional deficiency diseases in emergencies, mobilization of local resources, general fund distribution, mass and supplementary feeding, therapeutic feeding, social funds; Nutritional Indices and reference standards; Preventing and handling donations in emergencies.

Unit IV: Hygiene and sanitation

Control of communicable diseases, public health and hygiene problems during emergencies.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

VIII. Learning Outcome

After successful completion of the course, the students will be able to:

- Assist in preparedness and disaster risk management
- Assist in taking care of vulnerable population
- Assist in nutrition risk assessment as extension professional

IX. Suggested Reading

- FAO. 2018. *Climate Change Challenge Badge.* 2nd edition. Food and Agriculture Organization of United Nations, Rome.
- Gibney MJ. 2004. *Public Health Nutrition.* Blackwell Science, Oxford.
- Park K. 2007. *Text book of preventive and Social Medicine* 19th Edition. Banarsidas Bhanot Publishers, Jabalpur, India.
- Spark A. 2007. *Nutrition in Public Health: Principles, Policies and Practice.* CRC Press, New York.
- WHO. 2000. *The Management of Nutrition in Major Emergencies.* World Health Organization, Geneva.
- https://www.who.int
- http://www.fao.org/home/en
- https://ndma.gov.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Latest advances in management of food and nutrition in emergent situation.
2	Starvation in emergencies- historical perspectives.
3	Starvation in emergencies arising out of war, wrong policies, poverty and climatic changes.
4	Starvation in emergencies arising out of conflict and global economic volatility.
5	Starvation in emergencies arising out of drought, floods, earthquakes and locust.
6	Population groups most vulnerable to under nutrition.
7	Food needs at national level during normal emergencies.
8	Effect of inanition, short, medium and long- term emergencies on food and nutrients intake.
9	Precautions against food shortage.
10	Major nutritional deficiency diseases in emergencies.
11	Mobilization of local resources, general fund distribution, social funds.
12	Mass and supplementary feeding programmes during emergencies.
13	Therapeutic feeding programmes during emergencies.
14	Nutritional Indices and reference standards.
15	Communicable diseases and their control during emergencies.
16	Public health and hygiene problems during emergencies.

I. Course Title : Maternal and Child Nutrition

II. Course Code : FN 606

III. Credit Hours : 2(2+0)

IV. Rationale

Inadequate maternal and child nutrition is the underlying cause of considerable deaths in the third world countries. The one who survives does not grow to its full potential, remains unproductive and a burden to the society. As professionals, the students need to develop skills to provide support to this most vulnerable mother-child duo conducive to development of quality human resource.

V. Aim of the course

- To impart in-depth knowledge about why this vulnerable group needs special attention in terms of nutrition and other health care areas. This course will emphasize topics like nutritional challenges, physiological changes, IYCF guidelines, feeding of children with special needs, interventions, etc.
- To make students knowledgeable to identify risks and stratify coping strategies.

VI. Theory

Unit I: Nutrition and reproduction

Nutrition challenges, physiological changes, teenage pregnancy and gestational diabetes, nutrient needs, factors affecting nutrition of the women and children.

Unit II: Nutritional deficiencies

Needs and problems of lactating women, fetal malnutrition and low birth weight, nutrition and parasites, children with special needs, Protein energy malnutrition, vitamin A, iron, vitamin D, calcium and other common deficiencies, significance of stem cell and cord blood.

Unit III: Feeding practices

Formula feeding and supplements, lactation and breast feeding in the community, HIV and breast feeding; drug abuse and breast feeding. Human milk banks, IYCF guidelines, WHO breast feeding recommendations

Unit IV: Overnutrition and undernutrition

International programs regarding child and maternal health initiative to prevent overnutrition and undernutrition.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group Work/ Group Discussion

VIII. Learning Outcome

Successful completion of this course will enable the students to:

- Appreciate the scientific knowledge and relate them to actual work situation to evade long term health crisis of the concerned
- Utilize the methods and tools to assess nutritional demands and suggest coping strategies
- Utilize the knowledge for scientific publication/ population education.
- Act as scientist in related R&D projects

IX. Suggested Reading

- Brown JE. 2016. *Nutrition through the Life Cycle*. 6th Edition. Cengage Learning, Boston.
- Ehiri J. 2009. *Maternal and Child Health - Global Challenges, Programs and Policies*. Springer Nature, Switzerland.
- Gluckman P, Hanson M, Seng CY and Bardsley A. 2015. *Nutrition and Lifestyle for Pregnancy and Breastfeeding*. Oxford University Press, UK.
- Morgan JB and Dickeson JWT. 2003. *Nutrition in Early Life*. John Wiley and Sons Ltd. Chichester.
- https://www.unicef.org
- https://www.india.gov.in/ agriculture
- https://mhrd.gov.in/mid-day-meal

Weekly Lecture Schedule

Duration (week)	Topic
1	Nutrition and reproduction.
2	Nutrition challenges, physiological changes.
3	Teenage pregnancy and gestational diabetes.
4	Nutrient needs, factors affecting nutrition of the women and children.
5	Needs and problems of lactating women.
6	Foetal malnutrition and low birth weight.
7	Nutrition and parasites.
8	Children with special needs.
9	Protein energy malnutrition, vitamin A, iron, vitamin D, calcium and other common.
10	Significance of stem cell and cord blood.
11	Formula feeding and supplements.
12	Lactation and breast feeding in the community.
13	HIV and breast feeding; drug abuse and breast feeding.
14	Human milk banks, IYCF guidelines.
15	WHO breast feeding recommendations.
16	International programs regarding child and maternal health initiative to prevent over weight human nutrition.

I. Course Title : Hormones and Enzymes

II. Course Code : FN 607

III. Credit Hours : 2(2+0)

IV. Rationale

Hormones are chemical messengers providing signals to the cells for performing various functions while enzymes as catalysts enhance the rate of reaction in the body. There are few chances of occurring disease due to enzyme dysfunction however, hormonal dysfunction may give rise to lifelong diseases. Both are important biochemical materials for all living beings. Knowledge on the topic will help the students in ascertaining an effective diet counselling to address health problems linked with hormones and enzymes.

V. Aim of the course

- To learn in detail about the role of hormones and enzymes in human physiology and relate this information to the context of normal health and diseased state like diabetes, hypertension, renal and gastro intestinal disorders, etc. and suggesting relevant dietary managements

- To equip the students with relevant knowledge of effective dietary management of a given disease condition due to hormonal and enzymatic imbalance.

VI. Theory

Unit I: Hormones

History, chemistry, endocrine and exocrine secretion of hormones, organs of secretion, metabolism, mechanism of action, regulation and sites of action, biological effects and interaction.

Unit II: Enzymes

Enzyme pathways in normal functions of the heart, pancreas, gastrointestinal and hepatic functions and kidneys.

Unit III: Metabolic disorders

Altered hormone and enzymatic pathways in obesity, reproductive functions, renal disorders, gastrointestinal disorders.

Unit IV: Degenerative diseases

Altered hormone and enzymatic pathways in hypertension, cardiovascular diseases, diabetes and cancer.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online group work/ group discussion

VIII. Learning Outcome

After successful completion of this course, a scholar will be able to:

- Utilize the scientific foundation to act as an expert of Health Care Team in medical set-ups
- Act as Clinical Nutritionists
- Act as expert in related R&D projects

IX. Suggested Reading

- Berg JM. 2007. *Biochemistry*. 6thEdition. W. H. Freeman and Company, New York.
- Henry HL and Norman AW. 2014. *Hormones*. 3rd Edition. Academic Press, Cambridge.
- Kleine B and Rossmanith WG. 2016. *Hormones and the Endocrine System*. Springer Nature, Switzerland.
- Palmer T and Bonner PL. 2007. *Enzymes*. 2nd Edition. Woodhead Publishing, Cambridge.
- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry*. 7th Edition. W.H. Freeman Company, New York.
- https://www.nutrition.org.uk
- http://www.nutritioncare.org
- https://nutrition.org

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Histor and chemistry of hormones.
2	Endocrine and exocrine secretion of hormones, organs of secretion.
3	Metabolism, mechanism of action, regulation and sites of action of hormones.
4	Biological effects and interaction of hormones.
5	Enzyme pathways in normal functions of the heart and pancreas.
6	Enzyme pathways in normal functions of the gastrointestinal and hepatic functions.

Duration (weeks)	Topics
7	Enzyme pathways in normal functions of the kidneys.
8	Altered hormone and enzymatic pathways in diseases-hypertension.
9	Altered hormone and enzymatic pathways in cardiovascular diseases.
10	Altered hormone and enzymatic pathways in diabetes.
11	Altered hormone and enzymatic pathways in obesity.
12	Altered hormone and enzymatic pathways in metabolic disorders.
13	Altered hormone and enzymatic pathways in reproductive functions.
14	Altered hormone and enzymatic pathways in renal disorders.
15	Altered hormone and enzymatic pathways in gastrointestinal diseases.
16	Altered hormone and enzymatic pathways in cancer.

I. Course Title : Energy Metabolism

II. Course Code : FN 608

III. Credit Hours : 2(2+0)

IV. Rationale

Energy metabolism is complex process of deriving energy from the nutrients. Imbalance in energy metabolism may be devastating for human health. It is important to understand bioenergetics to overcome the issued related to these imbalances. The understanding of the role of energy metabolism in regulation of hunger to manage body weight and other non-communicable disease by the students will help them to manage obesity related diseases.

V. Aim of the course

- To impart in depth knowledge to the students with new developments in the area of energy metabolism and its relation to human health
- To learn the concept of bioenergetics, thermogenesis, metabolic regulation and hunger for its application in preventing adiposity.

VI. Theory

Unit I: Bioenergetics

Scope and application of bioenergetics for human nutrition; Energy stores in man; Components of energy; Basal metabolism, energy cost of various activities; Factors affecting energy expenditure.

Unit II: Energy expenditure

Direct and indirect methods of assessing energy expenditure; Factors affecting energy requirements; Assessment of energy requirements.

Unit III: Regulation of metabolism

Thermogenesis, metabolic regulation; Weight control and obesity-role of adipose tissues; Effect of hormones on energy metabolism.

Unit IV: Hunger

Mechanism of hunger; Psychological and physiological factors associated with adiposity.

VII. Teaching Methods/Activities

- Lectures

- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

VIII. Learning Outcome

Successful completion of this course will enable the students to:

- Apply the knowledge of bioenergetics in weight management
- Use methods and tools of measuring energy expenditure
- Correlate eating behaviours of people for planning appropriate meals/diets to prevent adiposity

IX. Suggested Reading

- Donohoue PA. 2010. *Energy Metabolism and Obesity*. Humana Press Inc. New York.
- Driskell JA and Wolinsky I. 2007. *Sports Nutrition: Energy Metabolism and Exercise.* 2nd Edition. CRC Press, New York.
- Korbonits M. 2008. *Obesity and Metabolism*. Karger Publishers, London.
- Rathore AK. 2015. *Bioenergetics, Physiology and Biostatistics*. Discovery Publishing House, New Delhi.
- Scott B. 2008. *A Primer for the Exercise and Nutrition Sciences: Thermodynamics, Bioenergetics, Metabolism*. Humana Press Inc. New York.
- http://www.nutritionlink.org
- https://www.icmr.nic.in
- http://www.nin.res.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Scope and application of bioenergetics for human nutrition.
2	Energy stores in man. Components of energy.
3	Basal metabolism.
4	Energy cost of various activities.
5	Factors affecting energy expenditure.
6	Direct methods of assessing energy expenditure.
7	Indirect methods of assessing energy expenditure.
8	Factors affecting energy requirements.
9	Assessment of energy requirements.
10	Thermogenesic.
11	Metabolic regulation.
12	Weight control.
13	Role of adipose tissues in obesity.
14	Effect of hormones on energy metabolism.
15	Mechanism of hunger.
16	Psychological and physiological factors associated with adiposity.

I. Course Title : Application of Biotechnology in Food Science and Nutrition

II. Course Code : FN 609

III. Credit Hours : 3 (3+0)

IV. Rationale

The role of food biotechnology is important in product development. Knowledge of biotechnology will help to develop foods with enhanced taste, shelf life, nutrition and quality. Novel food products with desirable characteristics that are safe, nutritious and suitable in different physiological conditions can be developed by the application of biotechnology. Biotechnology can be an important area of application to manage hunger from population.

V. Aim of the course

- To understand the role of food biotechnology in quality food production for mass feeding
- To equip the students with knowledge of application of biotechnology in the process of food product development.

VI. Theory

Unit I: Food science and biotechnology

History, processes and products of biotechnology, application of biotechnology in production of nutritious foods.

Unit II: Product development

Role of biotechnology in enzymology and product development, fermentation process, fruit juice extraction, genetic improvement of food grade microorganisms.

Unit III: Nutraceuticals

Nutritional significance of food products developed by biotechnological techniques.

Unit IV: Constraints in food biotechnology

Scientific, technological and resource constraints in biotechnology; important factors affecting development in biotechnology.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

VIII. Learning Outcome

Successful completion of this course will enable the students to:

- Utilize the knowledge in modifying foods for therapeutic purpose
- Serve as investigative dietitian in developing novel food products in food industry

IX. Suggested Reading

- Nestle M. 2003. *Safe Food: Bacteria, Biotechnology and Bioterrorism*. University of California Press Ltd., London.
- Panesar PS and Marwaha. 2014. *Biotechnology in Agriculture and Food Processing: Opportunities and Challenges*. CRC Press, Boca Raton, Florida.
- Shetty K, Paliyath G, Pometto A and Levin RE. 2011. *Food Biotechnology*. 2nd Edition, CRC Press, New York.
- Ravishankar Rai V. 2015. *Advances in Food Biotechnology*. Wiley-Blackwell Publishing Company, Boston.
- https://www.bio.org

Weekly Lecture Schedule

Duration (weeks)	Topic
1	History of biotechnology.
2	Processes and products of biotechnology.

Duration (weeks)	Topic
4	Application of biotechnology in production of nutritious foods.
6	Role of biotechnology in enzymology.
7	Product development.
8	Fermentation process.
9	Fruit juice extraction.
10	Genetic improvement of food grade microorganisms.
12	Nutritional significance of food products developed by biotechnological techniques.
14	Resource constraints on biotechnology.
15	Technological constraints on biotechnology.
16	Important factors affecting development in biotechnology.

I. Course Title : Recent Trends in Food Science and Technology

II. Course Code : FN 610

III. Credit Hours : 3(3+0)

IV. Rationale

Environment and food can influence individual's health due to interaction between genes and food components that can cast positive or negative impact on human health. Nutrigenomics relates human genome with response of body to the food. In depth study of recent advances in the field of food analysis and food fortification is imperative to reduce double burden of malnutrition. With the use of application of food science and technology, the novel foods can be formulated which are safe, wholesome and nutritious.

V. Aim of the course

- To acquaint the students with latest advances in food science and technology to meet nutritional challenges
- To understand the integration of genomic science with nutrition
- To understand the physical, chemical and biological makeup of food and ways of food processing and packaging.

VI. Theory

Unit I: Macro and micronutrients

Recent advances in the field of carbohydrates, lipids, proteins, vitamins and minerals in relation to food science; Nutrigenomics, incorporating genetics into dietary guidance.

Unit II: Food analysis

Recent advances in the field of food analysis and food fortification.

Unit III: Advanced techniques

Membrane technology: micro-filtration, ultra-filtration, nano-filtration, reverse osmosis and their applications in food industry; Supercritical fluid extraction- concept and extraction methods; Microwave and radio frequency processing- mechanism and application in food processing; Hurdle technology- concept and its applications.

Unit IV: Foods of future

Food processing and product development; regulating; food processing and preservation through Total Quality Management (TQM) and Hazard Analysis and

Critical Control Points (HACCP); Genetically Modified Foods (GM) foods and their health implications, functional foods and organic foods.

VII. Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

VIII. Learning Outcome

Successful completion of this course will enable the students to:

- Understand the recent advances in technologies used in food industry
- Gain in knowledge of genetically modified, safe and nutritious food products to maintain and improve human health
- Serve as novel therapeutic food designer in pharmaceutical/nutraceutical companies

IX. Suggested Reading

- Clark S, Jung S and Lamsal B. 2014. *Food Processing - Principles and Applications*. 2ndEdition, Wiley-Blackwell Publishing Company, Boston.
- deMan JM, Finley JW, Hurst WJ and Lee CY. 2018. *Principles of Food Chemistry*. 4th Edition, Springer International Publishing, New York.
- Fellows PJ. 2017. *Food Processing Technology*. 4th Edition, Woodhead Publishing Ltd. Cambridge.
- Hartel RW and Heldman D. 2012. *Principles of Food Processing*. Aspen Publishers Inc. New York.
- Ward JD and Ward LT. 2012. *Principles of Food Science*. Goodheart-Willcox Publisher, Illinois.
- https://www.gainhealth.org
- https://foodprocessingindia.co.in
- http://agronfoodprocessing.com

Weekly Lecture Schedule

Duration (week)	Topic
1.	Recent advances in the field of carbohydrates, lipids and proteins in relation to human nutrition.
2.	Recent advances in the field of vitamins and minerals in relation to human nutrition.
3.	Nutrigenomics.
4.	Incorporating genetics into dietary guidance
5.	Recent advances in the field of food analysis
6.	Recent advances in the field of food fortification.
7.	Membrane technology: micro-filtration, ultra-filtration.
8.	Reverse osmosis and their applications in food industry.
9.	Supercritical fluid extraction- concept and extraction methods.
10.	Microwave and radio frequency processing- mechanism and application in food processing.
11.	Hurdle technology- concept and its applications.
12.	Foods of future; special nutrients.
13.	Food processing and product development.
14.	Regulating food processing and preservation through Total Quality Management (TQM).
15.	Hazard Analysis and Critical Control Points (HACCP).
16.	Genetically Modified Foods (GM) foods and their health implications, functional foods and organic foods.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 6

Community Science
– Human Development and Family Studies

Preamble

Human Development and Family Studies (HDFS) students acquire knowledge to explore the ways in which people develop physically, emotionally, socially and intellectually within the framework of family and society and learn strategies for promoting growth and development in family systems. The face and pace of systematic investigation has accelerated markedly, in all disciplines and the product of research has changed in both quality and quantity. Owing to wide-ranging transition in psychological structures, social systems and family relations, a more specific radical transformation has occurred over the past decade in how we view human development and family studies in the changing ecological settings and complexities of life. Accordingly, research in Human Development is moving away from research focused on development at particular stages (early childhood, adolescence, middle age, older adulthood) and from separate fields of inquiry to a more inclusive, integrative, and interdisciplinary approach to the study of human development across the entire life span. Some problems considered to be of major importance a decade ago receive less attention today, rather other areas of HDFS that had previously been only minor foci of study have become central today.

With this backdrop, Post Graduate curriculum of HDFS has been extensively updated, reshaping previous course contents and developing some new ones after giving due consideration to the needs and requirements of stakeholders thus rendering it suitable for students to pursue for optimal placements. The basic objectives of this updated/ revamped curriculum are the same as they were earlier, but effort has been made to offer the students a broader and deeper understanding and more extended knowledge of the scientific basis of various developmental processes in various ecological settings across cultures. The redesigned courses will help in understanding and critically analyzing the adopted practices in trend to know what is best and what is obsolete for human development. It can prove panacea for many developmental delays, irregularities as well as ills and evils faced by society. The increased number of courses and research credits give massive support to this aspect.

The PG courses are not only meant to give freedom to choose the courses of their interest to enhance their knowledge and abilities in various domains of human development and family studies but also enhance their professionalism, entrepreneurship skills, creativity, innovation, employability, job avenues and develop their confidence to become job providers than job seekers. These courses support and are in line with the objectives of this new educational policy and Skill India. The courses will help in capacity building of the students to develop their managerial and entrepreneurial skills so that they can organize and manage various types of institutions for children, adolescents and elderly which are the need of the day. The courses on HDFS equip the students to engage themselves as child, school and family counsellors, personality development trainers, parent coaches and motivational speakers for public sector and private corporate houses, make them entitled to work with various national and international organizations or to undertake their own enterprise. The main purpose of this new curriculum is to focus on the overall development and performance of students, as it is believed that if their performance over takes their ambitions, it gets lot of success to them.

Modifications Suggested in Courses in the Revised Curricula

M.Sc. (Community Science) in Human Development and Family Studies

Course Code	Course Title	Credit Hours	Remarks
	Major Courses (20 Credits)		
*HDFS 501	Theories of Human Development	3 (3+0)	Course content modified
*HDFS 502	Dynamics of Human Development	3 (3+0)	Contents modified and change in title
*HDFS 503	Methods and Techniques of Assessment in Human Development	3 (2+1)	Contents modified and change in title
*HDFS 504	Innovative Programmes in Early Childhood Development and Education	3 (2+1)	Contents modified
HDFS 505	Gender Issues in Human Development and Relationships	3 (2+1)	Contents modified and change in title
HDFS 506	Adult Development	2 (2+0)	New Course added
HDFS 507	Management of Differently Abled	3 (2+1)	Contents modified and change in title
HDFS 508	Adolescent Development and Challenges	3 (2+1)	Contents modified and change in title
HDFS 509	Guidance and Counselling	3 (2+1)	Contents modified
HDFS 510	Interventions for Differently Abled Children	2(1+1)	New course added
HDFS 511	Family Ecology	2 (2+0)	New Course added
HDFS 512	Family and Cultural Diversities	2(2+0)	New course added
HDFS 513	Family Therapy	3 (2+1)	Contents modified

Course Code	Course Title	Credit Hours	Remarks
	Minor Courses (08 Credits)		
FN 502	Public Health and Nutrition	3(2+1)	Proposed minor courses from subjects closely related to a student's major subject.
FN 505	Nutrition and Physical Fitness	3(2+1)	
FN 510	Nutritional Challenges in Life Cycle	3(2+0)	Apart from these courses a student can register any other course offered by any other departments
FN 513	Human Physiology	3(3+0)	
EECM 501	Global Extension Systems	2 (2+0)	
EECM 502	Development Communication	3 (2+1)	
EECM 508	Educational Technology	3 (2+1)	
EECM 509	Group Dynamics	2 (2+0)	
EECM 512	Gender Sensitization for Empowerment		2 (2+0)
	Supporting Courses (06 Credits)		
	Research Methodology	3 (2+1)	Course numbers will be assigned by the departments that offer these courses
	Statistical Methods and Application	3 (2+1	
	Common Courses (05 Credits)		
	Library and Information Services	1(0+1)	Common to all disciplines. The course numbers will be assigned by the departments that offer these courses
	Technical Writing and Communications Skills	1(0+1)	
	Intellectual Property and its management in Agriculture	1(0+1)	
	Basic Concepts in Laboratory Techniques	1(0+1)	
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)	
HDFS 591	Master's Seminar	1 (0+1)	
HDFS 599	Research	30	Increased credits for research
	Total	**70 Credits**	

*Core courses/ compulsory courses

Ph.D. (Community Science) in Human Development and Family Studies

Course Code	Course Title	Credit Hours	Remarks
	Major Courses (12 Credits)		
*HDFS 601	Advanced Human Development	3(3+0)	Contents and title modified
*HDFS 602	Ecology and Human Development	3(3+0)	Contents and title modified
*HDFS 603	Programme Development for Vulnerable Families	3(2+1)	Contents modified
HDFS 604	Strategic Developmental Intervention	3(2+1)	Contents modified
*HDFS 605	Family Studies	3(3+0)	Contents and title modified
HDFS 606	Adulthood and ageing	3(3+0)	Contents and title modified
HDFS 607	Mental Health	3(3+0)	New course
HDFS 608	Qualitative Research Methods	2(1+1)	Contents modified
	Minor Courses (06 Credits)		
CS/PGS 601	Research and Publication Ethics	2(1+1)	Proposed minor courses from subjects closely related to a student's major subject. Apart from these courses a student can register any other course offered by any other departments
EECM 602	Impact Assessment of Development Programmes	3(1+2)	
EECM 603	Scaling Techniques for Behavioural Research	3(1+2)	
EECM 608	Advocacy and Behavior Change Management	3 (1+2)	
FN 606	Maternal and Child Nutrition	2(2+0)	
FN 604	Global Nutritional Problems	2(2+0)	
FN 605	Nutrition in Calamities	2(2+0)	

Supporting Courses (05 Credits)

A student can opt any course related to the topic of research offered by other faculties of agriculture university or SWAYAM portal or other online courses up to a maximum of 5 credits.

HDFS 691	Doctoral Seminar I	1 (0+1)	
HDFS 692	Doctoral Seminar II	1 (0+1)	
HDFS 699	**Doctoral Research**	**75**	Increased credits for Research
	Total	**100 Credits**	

*Core courses/ compulsory courses

Course Title with Credit Load
M.Sc. in Human Development and Family Studies

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
*HDFS 501	Theories of Human Development	3 (3+0)
*HDFS 502	Dynamics of Human Development	3 (3+0)
*HDFS 503	Methods and Techniques of Assessment in Human Development	3 (2+1)
*HDFS 504	Innovative Programmes in Early Childhood Development and Education	3 (2+1)
HDFS 505	Gender Issues in Human Development and Relationships	3 (2+1)
HDFS 506	Adult Development	2 (2+0)
HDFS 507	Management of Differently Abled	3 (2+1)
HDFS 508	Adolescent Development and Challenges	3 (2+1)
HDFS 509	Guidance and Counselling	3 (2+1)
HDFS 510	Interventions for Differently Abled Children	2(1+1)
HDFS 511	Family Ecology	2 (2+0)
HDFS 512	Family and Cultural Diversities	2(2+0)
HDFS 513	Family Therapy	3 (2+1)
	Minor Courses (08 Credits)	
FN 502	Public Health and Nutrition	3(2+1)
FN 505	Nutrition and Physical Fitness	3(2+1)
FN 510	Nutritional Challenges in Life Cycle	3(2+0)
FN 513	Human Physiology	3(3+0)
EECM 501	Global Extension Systems	2 (2+0)
EECM 502	Development Communication	3 (2+1)
EECM 508	Educational Technology	3 (2+1)
EECM 509	Group Dynamics	2 (2+0)
EECM 512	Gender Sensitization for Empowerment	2 (2+0)
	Supporting Courses (06 Credits)	
	Research Methodology	3 (2+1)
	Statistical Methods and Application	3 (2+1)
	Common Courses (05 Credits)	
	Library and Information Services	1(0+1)
	Technical Writing and Communications Skills	1(0+1)
	Intellectual Property and its management in Agriculture	1(0+1)

Course Code	Course Title	Credit Hours
	Basic Concepts in Laboratory Techniques	1(0+1)
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)
HDFS 591	Master's Seminar	1 (0+1)
HDFS 599	Research	30
	Total	**70 Credits**

*Core courses/ compulsory courses

Course Contents
M.Sc. in Human Development and Family Studies

I. Course Title : Theories of Human Development

II. Course Code : HDFS 501

III. Credit Hours : 3 (3+0)

IV. Rationale

Theories act as vital tools in the study of human development and provide orderly, meaningful direction to research and out-reach programmes. Children are complex beings and to understand them, it is significant to be familiar with the basis of their development in all aspects i.e. biological, psychological, social and cognitive. No single theory has been able to explain all these aspects. The study of multiple theories helps advance knowledge, since researchers are continuously trying to explore, support and integrate the different points of view.

V. Aim of the course

- To equip the students with the concepts, theoretical framework and critical review of different theories of human development .
- To give orientation towards comparative analysis of theories and their educational implications.

VI. Theory

Unit I: Psycho-dynamic theories

Meaning, types and functions of developmental theories. Theoretical perspectives and approaches- Psycho-dynamic theories- Psycho-analytic theory of Sigmund Freud – life history of Sigmund Freud, key concepts of psycho analytic theory, laws of psychological energy, three components of personality and their operational principles. Structural model of personality. Psycho-sexual stages and their impact on process of personality development. Contribution and criticism of Freudian theory. Neo-Freudians. Psycho-social theory of Erik Erikson – concept of development and basis of development, psycho-social stages of life.

Unit II: Maturation and cognitive theories

Maturational and biological approach- Arnold Gessell's theory of maturation. Cognitive Development theory of Jean Piaget – concepts, cognitive mechanism, cognitive structure, different stages of cognitive development, thought process and implications of the theory. Piaget's contribution to field of education. Neo-Piagetians- Fischer, Robert Case, Robert Sieglar and Bruner. Socio-cultural theory of Lev Vygotsky. Information processing theories.

Unit III: Behavioural and ecological systems theories

Behavioural approach of Watson. Stimulus Response theory by Sears, Skinner and Pavlov. Social- Learning and Social Cognition theory by Albert Bandura and its application in human development. Ecological Systems theory of Urie Bronfrenbrenner - concepts, systems and implications in understanding human development. Contribution of ecological systems theory in guiding families and teachers. Language development theory of Naom Chomsky.

Unit IV: Attachment, self and moral theories

Attachment theories by John Bowlby and Ainsworth. Maslow's Need Hierarchy model. Self Theories- Models of Morris Rosenberg and Cooppersmith. Moral development theories of Lawrence Kohlberg and Jean Piaget. Comparative analysis of theories and their application. Integrated approach to theory building.

VII. Teaching Methods/ Activities

- Lecture cum discussion
- Assignments
- Student presentation
- Content analysis of the seminal work of different theorists
- Classroom discussion
- Video clips/ films
- Quiz and debate
- Incentives

VIII. Learning Outcome

After completion of the course, the students will

- have an overview of theories of human development, learn to critically evaluate these theories and recognize their merits.
- understand the scientific process of human development and learn to know the application of different theories in this process.

IX. Suggested Reading

- Baldwin AL. 1980. *Theories of Child Development*. John Wiley & Sons, New Jersey.
- Craig. 1985. *Theories of Human Development*. 2nd Ed., John Wiley & Sons, New Jersey.
- Grain WC. 1980. *Theories of Development: Concepts and Application*. Englewood Cliffs, Bergon, New Jersey.
- Hall CS. 1998. *Theories of Personality*. 4th Ed., John Wiley, New Jersey.
- Miller PH. 2016. *Theories of Developmental Psychology*. Worth Publishers, New York.
- Newman B and Newman R. 2007. *Theories of Human Development*. Rutledge, New Jersey.
- Sailkind NJ. 2004. *An Introduction to Theories of Human Development*. Sage Publications, New Delhi.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Introduction to the course. Meaning, types and functions of developmental theories. Theoretical perspectives and approaches.
2	Psycho-dynamic theories- Psychoanalytic theory of Sigmund Freud – Life history of Sigmund Freud. Key concepts of Freud's theory of Psychoanalysis, personality components, operational principles of different components and structural model of personality.
3	Freudian theory- Stage approach to nature and process of personality development, implications and criticism of Freudian theory. Neo-Freudians.
4	Psycho-social theory of Erik Erikson – his life history, key concepts, stages of life span development, Erikson's model of Psycho-social development.
5	Maturational and biological approach. Arnold Gessell's theory of maturation.
6	Cognitive Development theory of Jean Piaget – Key concepts, cognitive mechanism.
7	Cognitive Development theory of Jean Piaget – stages and implications. Piaget's contribution to education.

Duration (weeks)	Topics
8	Neo-Piagetians- Fischer, Case and Bruner. Socio-cultural theory of Lev Vygotsky. Information Processing theories.
9	Behavioural approach of J.B. Watson, Stimulus Response theory by Thorndike, Sears, Skinner and Pavlov.
10	Social Learning theory by Albert Bandura. Application of behaviourism, learning and social cognition in human development.
11	Ecological Systems theory of Urie Bronfrenbrenner - concepts, systems and implications in understanding human development and guiding families and teachers
12	Language development theory of Naom Chomsky. Attachment theories by John Bowlby and Ainsworth.
13	Moral development theories of Lawrence Kohlberg and Jean Piaget.
14	Maslow's Need Hierarchy Model.
15	Self Theories- Models of Morris Rosenberg and Coopersmith.
16	Comparative analysis of theories and their application. Integrated approach to theory building.

I. Course Title : Dynamics of Human Development

II. Course Code : HDFS 502

III. Credit Hours : 3 (3+0)

IV. Rationale

Nature and nurture play key role in human development. It is necessary for the students to understand the role of genetic endowment and environmental experiences of an individual in the course of human development. The knowledge of latest trends in the dynamic process of human development and the issues that emerge in it due to ever changing socio-cultural and economic environments becomes important .

V. Aim of the course

- To impart information to students regarding advanced concepts of human development, current trends and issues of development.
- To provide indepth understanding of the developmental concepts and processes in human life span.

VI. Theory

Unit I: Nature vs. Nurture

Human development – basic concepts and issues. Genetic foundation, genetic code, chromosomal abnormalities. Role of epigenesis and canalization in growth and development. Interface between heredity and environment. Genetic research and its influence on child's development. Current research findings on pre-natal development and neo-natal stages – developmental sequence, prenatal environmental influences, developmental threats and DNA methylation.

Unit II: Cognitive development

Brain development- key concepts and process of development. Models of intelligence. Cognitive development during early years - perceptual capacities, attention, memory, imitation, early learning, conditioning and assessment. Role of early deprivation and enrichment in cognition. Information processing. Social cognition, emotional intelligence, metacognition and self regulation and their contribution to human mind and behavior. Gardner's Model of Multiple Intelligence.

Unit III: Psycho-social Issues

Language development and its components - pre-linguistic development, phonology, semantics and bilingualism. Socialization practices and influencing factors. Cultural influence on child outcomes. Exposure to media and technology and role of parents and institutions. Impact of socio-emotional deprivation on different stages of development. Vulnerability and resilience, risk and protective factors. Personality changes and self perceptions through different stages of development. Integrated view of human development.

Unit IV: Current and classic research trends in human development

Seminal work of Sigmund Freud, Erikson, Piaget, Uri Bronfenbrenner and Margaret Mead. Design and field work of "Six cultures project". Current research trends in physical, intellectual, psycho- social and moral development of children from birth to adolescence.

VII. Teaching Methods/ Activities

- Lecture cum discussion
- Assignments
- Students' presentation
- Content analysis of the seminal work of Developmental psychologists
- Video clips/ films
- Quiz and debate
- Incentives

VIII. Learning Outcome

After completion of the course, the students will

- Understand the role of heredity and environmental influence in human development.
- Appreciate and recognize the interdependence of various aspects of human development across lifespan.
- Get oriented to the current researchable issues in human development.

IX. Suggested Reading

- Berk EL. 2017. *Development Through the Life Span*. 7th Ed., Pearson Education, Atlantic.
- Bronfenbrenner V. 1979. *The Ecology of Human Development*. Cambridge, Harvard.
- Feldman RS. 2017. *Development Across the Life Span*. Pearson, London, England.
- Garbarino J. 1982. *Children and Families in the Social Environment*. Aldine, New York.
- Kail R and Cavaraugh JC. 2016. *Human Development - A Life Span View*. Cenage Learning, Boston.
- Papalia DE and Olds SW. 2008. *Human development*. 11th Ed., McGraw Hill, New York
- Santrock JW. 2006. Life Span Development. Mc Graw Hill, New York.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Human development perspective- basic concepts and issues. Introduction to genes and environment. Genetic foundation, genetic code, chromosomal abnormalities.
2	Role of epigenesis and canalization in growth and development. Interface between heredity and environment. Genetic research and its influence on child's development.

Duration (week)	Topics
3	Current research findings on pre-natal development and neo-natal stages – developmental sequence, prenatal environmental influences, developmental threats and DNA methylation.
4	Brain development across life span- key concepts and process of development. Structure of cognition. Models of intelligence. Cognitive abilities and development during early years - perceptual capacities, attention, memory, imitation, early learning, conditioning, and assessment.
5	Role of early deprivation and enrichment in cognition. Information processing.
6	Social cognition, emotional intelligence, metacognition and self regulation and their contribution to human mind and behavior.
7	Gardner's Model of Multiple Intelligence.
8	Language development and its components - pre-linguistic development, phonology, semantics and bilingualism.
9	Socialization practices and influencing factors. Influence of cultural factors on child outcomes.
10	Exposure to media and technology and role of parents and institutions.Impact of socio-emotional deprivation on different stages of development. Vulnerability and resilience, risk and protective factors.
11	Personality changes in self perceptions through different stages of development. Integrated view of human development.
12	Current research trends in physical, motor and intellectual development in early childhood.
13	Presentation and group discussion on Seminal work of Sigmund Freud
14	Presentation and group discussion on Seminal work of Erik Erikson
15	Presentation and group discussion on Seminal work of Jean Piaget and Margaret Mead
16	Presentation and discussion on Seminal work of Uri Bronfenbrenner.

I. Course Title : Methods and Techniques of Assessment in Human Development

II. Course Code : HDFS 503

III. Credit Hours : 3(2+1)

IV. Rationale

It is imperative to have knowledge of various methods and techniques of assessment in human development for scientific understanding and analysis of developmental status of individuals for their need based guidance and education. In order to gather required information about the individuals, it makes pertinent to have an insight into the strengths, weaknesses of various research tools and hands-on training in application of these, so as to make assessments in a dependable manner.

V. Aim of the course

- To apprise the students with different methods and techniques of assessment in human development.
- To develop skills in psychological test administration, scoring, analysis, interpretation and report writing.

VI. Theory

Unit I: Developmental assessment, methods and techniques.

Assessment –Concept, functions, characteristics, steps and rationale of assessment.

History of tests and measurements. Different methods of child study/ developmental assessment. Techniques of measurement and their significance in measuring different aspects of human development. Role of assessment in intervention.

Unit II: Types of measures & methods

Scientific methods-definition, importance, goals and steps. Essential criteria of Scientific methods -reliability, validity control, item analysis. Use of objective measures and methods. Types of tests – individual and group tests. Projective techniques. Psychometrics, Sociometry. Types of scales –nominal, ordinal, interval and ratio scale

Unit III: Development of tests/ scales

Developmental Assessment from birth to early childhood. Tests for infants and children. APGAR scoring of new borns. Physical growth assessment. Anthropometric evaluation of nutritional status. Measurement of intelligence. Assessment of personality, aptitude, attitude and environment. Development of test/scale, steps, guidelines and standardization procedure – various methods of calculation of validity and reliability. Variables- extraneous, confounding, researcher variables and participant variables affecting internal validity. Threats to internal validity.

Unit IV: Ethical issues and barriers

Ethical issues in the assessment of human development. Special consideration in assessing young children. Ethical issues and barriers in assessment of infants and young children. Assessment of children with special needs. Interpretation and use of assessment information. Trends and challenges in assessment of human behavior.

VII. Practical

1. Visit to neonatal unit to observe the neonates and to observe their assessment of APGAR score by pediatricians.
2. Physical Growth assessment and nutritional status of children of different age groups.
3. Review of available developmental screening and diagnostic tests for infants, toddlers and pre-school children.
4. Review of available screening and diagnostic tests for school age children and adolescents.
5. Developmental assessment of infants by using Bayley's Scale of Infant Development (BSID)
6. Interpretation of results and report writing
7. Administration of psychological tests for measuring cognitive abilities and intelligence.
8. Administration of psychological tests for assessment of socio-emotional development of children and adolescents.
9. Administration of psychological tests for personality assessment.
10. Administration of psychological tests for assessment of language development of children.
11. Assessment of home environment using HOME (Home Observation and Measurement of Environment) inventory for different age groups of children/ Indian Home Inventory/ Family Environment Scale.
12. Interpretation of results and report writing on home environment
13. Development of scale or check lists on selected areas of development.
14. Standardization of the developed test, scoring and interpretation of results.
15. End term assessment

VIII. Teaching Methods/ Activities

- Lectures cum discussion
- Demonstrations on various methods and techniques of developmental assessment
- Case studies and discussion
- Demonstrations and hands on experience on various psychological tests, administration, scoring, interpretation of results and effective counselling
- Organizing Child Development Assessment Camps (CDAC) for giving hands on training

IX. Learning Outcome

After completion of the course, the students will

- Learn different methods and techniques of assessment of various aspects of human development.
- Gain practical experience of handling various psychological tests – administration, scoring, interpretation of results and report writing.
- Learn basics of developing testing material/ tools.

X. Suggested Reading

- Anastasi A. 1988. *Psychological Testing*. 6th Ed., McMillan Publishing Company, New York.
- Bailey DB and Worley M. 2003. *Assessing Infants and Preschoolers with Handicaps*. Merrill Publishing Company, Delhi.
- Gregory RJ. 2004. *Psychological Testing - History, Principles and Applications*. 4th Ed., Pearson Education, Atlantic.
- Gumbiner J. 2003. *Adolescent Assessment*. John Wiley & Sons, New Jersey.
- Kumar R. 2014. *Research Methodology - A Step by Step Guide for Beginners*, 4th Ed., Sage Publications, New Delhi.
- Miller LA, Macintire SA and Lovler RL. 2012. *Foundations of Psychological Testing - A Practical Approach*. 4th Ed., Sage Publications, New Delhi.
- Shaughnessy JJ and Zechmeister EB. 2014. *Research Methods in Psychology*. 10th Ed., McGraw - Hill Publishing Company, New York.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Concept, functions, characteristics, steps and rationale of assessment.
2	History of tests and measurements. Importance of assessment for intervention.
3	Different methods of developmental assessment/ child study.
4	Different Techniques of measurement and their significance in measuring different aspects of human development.
5	Scientific Methods-definition, importance, goals and steps. Essential criteria of Scientific methods. Concept of reliability, validity, item analysis. Different methods of calculating reliability.
6	Types of validity - face, content, concurrent & predictive and construct validity . Difference between test validity & test reliability. Validity & reliability in qualitative research
7	Item analysis – Item difficulty, item discrimination, item response theory, item analysis of speed tests, cross validation and assessment of item bias.
8	Methods of test classification. Types of tests – individual and group tests. Performance tests. Projective techniques. Psychometrics, Sociometry. Types of scales –nominal, ordinal, interval & ratio scale.
9	Developmental assessment from birth to early childhood. APGAR scoring of new borns. Neuro-behavioral assessment of new born infant. Physical growth assessment. Anthropometric evaluation of nutritional status. Early childhood assessment. Tests for infants and children

Duration (week)	Topics
10	Measurement of intelligence. Assessment of aptitude, attitude and personality. Environmental assessment.
11	Development of test/scale- need, significance, steps, guidelines for composing test items, writing effective items, writing administration instructions, instructions for test take, scoring instructions.
12	Standardization - establishing validity & reliability of the instrument. Variables- extraneous, confounding, researcher variables & participant variables affecting internal validity. Threats to internal validity.
13	Ethical issues in the assessment of human development. Special considerations in assessing infants and preschoolers. Special consideration in assessing young children.
14	Principles of assessment for young children. Ethical issues and barriers in child assessment. Assessment of children with special needs.
15	Interpretation of assessment information and use of assessment information for planning instructional programme.
16	Trends and challenges in assessment of human behavior - current changes in assessment, issues and trends in assessment, computerized testing. Web based assessment, implications for future.

I. Course Title : Innovative Programmes in Early Childhood Development and Education

II. Course Code : HDFS 504

III. Credit Hours : 3 (2+1)

IV. Rationale

Early childhood care and educational experiences play a pivotal role in human development. As change agents, early childhood educators and professionals need to enrich themselves with the advances and innovations that are taking place in the domain of early childhood development and education for strategic planning and execution of child care, development and educational programmes for fostering child development.

V. Aim of the course

- To orient students about the need and scope of innovative programmes in early childhood development and education.
- To develop the abilities in students for planning and executing innovative early childhood development and education programmes for enhancing wholesome development of young children

VI. Theory

Unit I: Innovative programmes in early childhood development and education

Need and scope for innovative programmes for early childhood development and education (ECDE). Innovative pedagogical approaches in early childhood development and education. Developmental patterns of children in early years. Current innovative programmes at State, National and International level. Innovative learning settings in classrooms of early child development and education centres. Usage of virtual and digital classrooms in Child Development and Education Centres

Unit II: Innovative programmes for child development

Methods and principles of designing, execution, monitoring and evaluation of programmes and activities in early childhood care and education centres. Innovative programmes for fostering physical, motor, cognitive, speech and language, creativity, socio- emotional and moral development of children.

Unit III: Stimulatory learning environment

Stimulatory learning environments at home and early childhood child care and education centres and at centres for children with special needs. Current and conventional practices of stimulatory learning. Innovative ideas for planning and execution of customized programmes/ activities for gifted children and differently able children.

Unit IV: Social support network systems

Innovative programmes for involving families in early childhood development and education centres. Challenges of family involvement. Development of social support network systems for inclusion of differently able children

VII. Practical

1. Visits to observe early childhood care, education and development centers using varied pedagogical approaches in urban/ rural settings and study their programme and activities.
   i. Creche/ day care centre and Urban Nursery school
   ii. Visit to Aanganwadi centre and rural nursery school
2. Critical analysis and report presentation
3. Class room discussions on different types of virtual and digital classrooms
4. Designing innovative activities for young children - Physical and motor development
5. Designing innovative activities for young children - Cognitive and language development
6. Designing innovative activities for young children - Social, emotional and moral development
7. Execution of designed innovative activities.
8. Evaluation of the designed innovative activities as per their effectiveness and implementation potential
9. Conducting survey to assess parental needs on knowledge of innovative activities.
10. Designing need based parent education programmes
11. Organization of parent education programme
12. Conducting need assessment study to find out the training needs of ECCE staff
13. Planning of workshop/training for ECCE personnel
14. Conducting workshop/training for ECCE personnel
15. End term assessment

VIII. Teaching Methods/ Activities

- Lectures and discussions
- Showing educational video films.
- Field visits to early childhood care and education centers
- Demonstrations of innovative programmes
- Designing innovative programmes, their implementation and analysis of developmental outcome of children.
- Market survey of available educational play material

- Visit to child libraries.
- Web/ Internet surfing & report presentations

IX. Learning Outcome

After successful completion of this course, students are enabled to:

- Design innovative child development and education programmes.
- Evaluate early childhood programmes, understand and differentiate the mundane and innovative programmes being run early childhood development and education centeres.
- Utilize the knowledge and skills acquired in it for establishing innovative child care & education institutions as a worthy enterprise with win-win principle (employment for self and others too).

X. Suggested Reading

- Deiner PL. 2006. *Inclusive Early Childhood Education*. Cengage Learning Press.
- Jaipaul I Roopnarian and James EJ. 2008. *Approaches to Early Childhood Education*. Pearson Education, Atlantic.
- Kaul V. 1997. *Early Childhood Education Programmes*. NCERT, Delhi.
- Saraswathi TS. 1988. *Issues in Child Development - Curriculum and Other Training and Employmen*t. Spmaiya.
- Shiradhonkar K and Patnam V. 2019. *Understanding and Developing Creativity*. New Academic Publications, New Delhi.
- Sinclair H. 2004. *Standards for Early Childhood Programmes in Centre based Child Care.* Govt. of New Found Land and Labrador. Dept. of Health and Community Services.
- Soni R. 2015. Theme Based Early Childhood Care And Education Programme - A Resource Book. NCERT, New Delhi.
- Wiltshire M. 2010. *Understanding the High Scope Approach, Early Years Education in Practice.* Taylor and Francis.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Need and scope for innovative programmes for early child care, development and education centers. Principles of pedagogy in early child care, development and education centers. Innovative pedagogical approaches in early child care, development and education centers.
2	Physical and motor development patterns during early childhood. Cognitive development pattern during early childhood. Speech and language development patterns of early childhood. Socio-emotional and moral development patterns during early childhood.
3	Current innovative programmes of State and National level for early child care, development and education.
4	Innovative learning settings in classrooms of early child development and education centers. Usage of virtual and digital classrooms in Child Development and Education centers
5	Methods and principles of designing, executing, monitoring and evaluation of early child care, development and education centers.
6	Innovative integrated programmes with special focus on enhancing physical and motor development of children. Innovative integrated programmes with special focus on fostering intellectual development of children.
7	Innovative integrated programmes with special focus on fostering speech & language development of children. Innovative integrated programmes with special focus on promoting socio- emotional and moral development of children.

Duration (week)	Topics
8	Innovative integrated programmes with special focus on inculcating moral values in children. Need and benefits of inclusive early childhood education.
9	Stimulatory learning environments at home and early childhood child care and education centers. Creating Stimulatory learning environments at centers for children with special needs.
10	Current and conventional practices of stimulatory learning. Innovative ideas for planning and execution of customized programmes/ activities for gifted children and differently able children.
11	Significance of customized programmes for differently able children and challenges in it. Precautions to be taken while customizing programmes for differently able children and challenges in it.
12	Innovative programmes for differently able children at State and National level and their effectiveness.
13	Innovative programmes for differently able children at international level. Innovative ideas for planning and execution of customized programmes for gifted children and their effectiveness.
14	Innovative ideas for planning and execution of customized programmes for differently able children and challenges in it.
15	Innovative programmes for involving families in early childhood development and education centers and challenges in it. Innovative programmes for involving families in early childhood development and education centers.
16	Social support network systems for execution of innovative early childhood care development and education centers. Social support network for planning and execution of innovative programmes for developmentally differently able children in ECDE centers.

I. Course Title : Gender Issues In Human Development and Relationships

II. Course Code : HDFS 505

III. Credit Hours : 3 (2+1)

IV. Rationale

Gender stereotypes have been existing in different cultures, though, at various degrees. In rapidly changing socio-cultural and economic scenario, gender issues in human development and relationships have become a very sensitive and vital issue for protection of human rights and dignity. It is important to enlighten students about the various aspects of gender studies and its repercussion on human development, behaviour, relationships, family functioning and societal values.

V. Aim of the course

- To orient the students regarding the gender issues in human development and family relationships.
- To impart experiences regarding gender issues, family practices and biases prevalent in Indian Society.

VI. Theory

Unit I: Gender perspectives and theories

Concept of gender- biological and socio-cultural connotations. Historical perspectives. Gender differences in human development. Gender theories- Gender Orientation theory of Sandra Bem. Gender Schema theory, theory of Ego Development and Gender. Gender Stratification theory by Blumberg. Gender Identity Formation theory.

Unit II: Gender discrimination, gap and parity

Gender equality and development. Gender inequalities in human development– dimensions, causes and consequences. Gender discrimination indicators- global gender gaps. Gender Development Index, Global Gender Gap Index and Gender Parity Index. Demographic challenges to family ecology- gender role socialization.

Unit III: Gender violence and empowerment

Gender violence- dowry harassment and deaths, suicides, prostitution, sexual harassment and exploitation and prevention. Family violence, amniocentesis, female feticide, infanticide, eve teasing. Gender empowerment strategies- working towards family solidarity and social well-being. Gender main streaming- concept, policy of United Nations, objectives, requirements and principles. Empowering lives of women by controlling – patriarchy system, women's sexuality, fertility, labour, lack of visibility. Gender budgeting.

Unit IV: Changing trends in status of women

Status of women in India. Various plans and policies designed for achieving gender equality. Changing trends in gender role orientation- early civilization, pre-independence, post independent India, contemporary times, socio economic impact on the family and society, cultural impact on the family. Gender role portrayal in mass media. Gender stereotyping in schools. Gender issues at workplace.

VII. Practical

1. Gender analysis of mass media: Print media and E-media
2. Report writing
3. Study of adopted socialization practices for children of both genders
4. Report writing
5. Case studies of three generations on dynamics of gender orientation
6. Report presentation and discussion
7. Case studies of three generations on dynamics of Gender roles and responsibilities.
8. Report presentation and discussion
9. Views of adolescents on their gender role orientation- designing questions .
10. Survey through questionnaire
11. Report presentation and discussion
12. Case studies on changing trends of roles and responsibilities of women and men
13. Report writing
14. Visits to women welfare Govt. organizations/ agencies/ NGOs
15. Presentation of report and class discussion.
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures.
- Viewing of educational video films.
- Case studies on women and men in different occupations- issues & challenges.
- Intergenerational case studies of families.
- Interviews with lawyers of women welfare courts.

- Field visits to Govt and Non- Govt institutions.
- Analysis of mass media narratives.

IX. Learning Outcome

After successful finishing of this course,

- Students become capable of recognizing gender related issues, problems and challenges in society, it's influencing factors and solutions.
- Students are able to design and organize effective programmes for protection of rights and dignity of women in families, society and workplace.

X. Suggested Reading

- Banddarage A. 1997. *Women Population and Global Crisis - A Political and Economical Analysis*. Zed books, London.
- Barnett RC, Biner L and Baruch GK. 1987. *Gender Stress*. The Free Press, New York.
- Chanana K. 1989. *Gender and the Household Domain*. Sage Publications, New Delhi.
- Kapadia S and Gala J. 2015. *Gender Across Cultures: Sex and Socialization in Childhood.* Sage Publications, New Delhi.
- Kumar CS. 2017. *Gender Socialization and The Making of Gender in The Indian Context*. Sage Publications. New Delhi.
- Menon L. 1997. *Gender Issues and Social Dynamics*. Kanishka Publishers and Distributors, New Delhi.
- Sudha DK. 2000. *Gender Roles*. A.P.H. Publishing Corporation, New Delhi.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Concept of gender- biological and socio-cultural connotations. Historical perspectives.
2	Gender differences in human development.
3	Gender theories- Gender Orientation theory of Sandra Bem. Gender Schema Theory, theory of Ego Development and Gender.
4	Gender Stratification theory by Blumberg. Gender Identity Formation theory.
5	Gender equality and development. Gender inequalities in human development– dimensions, causes and consequences.
6	Gender discrimination indicators- global gender gaps. Gender Development Index, Global Gender Gap Index and Gender Parity Index.
7	Demographic challenges to family ecology- gender role socialization.
8	Gender violence- dowry harassment and deaths, suicides, prostitution, sexual harassment and exploitation and prevention.
9	Family violence, amniocentesis, female feticide, infanticide, eve teasing.
10	Gender empowerment strategies- working towards family solidarity and social well-being.
11	Gender main streaming- concept, policy of United Nations, objectives, requirements and principles.
12	Empowering lives of women by controlling – patriarchy system, women's sexuality, fertility, labour, lack of visibility. Gender budgeting.
13	Status of women in India and various plans and policies designed for achieving gender equality.
14	Changing trends in gender role orientation- early civilization, pre-independence, post independent India, contemporary times, socio economic impact on the family and society, cultural impact on the family.
15	Gender stereotyping in schools and gender issues at workplace. Gender role portrayal in mass media
16	Wrap up

I. **Course Title : Adult Development**

II. **Course Code : HDFS 506**

III. **Credit Hours : 2 (2+0)**

IV. **Rationale**

Adulthood is a critical period in the life course involving vibrant transitions in roles and responsibilities in biological, psychological, social, carrier and economic spheres. If adults make needed adjustments and alterations in life, there will be sustainable, happy and healthy society. Students get oriented to adulthood concerns, issues, challenges and different ways to cope up with them.

V. **Aim of the course**

- To acquaint the students with developmental perspectives in relation to adult life stages and theoretical perspectives of the ageing process.
- To develop an understanding of the changes and adjustments at various stages of adulthood aging.

VI. **Theory**

Unit I: Theoretical and ecological perspectives of adult development

Adulthood- transition to adulthood, stages of adulthood. Psychosocial theories of ageing - Erikson's Psychosocial theory, Identity Process Theory, Activity Theory, Socio-emotional Selectivity Theory. Theoretical perspectives in adult development - Bio-psychosocial perspective, Ecological perspective, Life Course perspective. Klaus Riegel's Dimensions of Development Theory. Four principles of adult development and aging.

Unit II: Models and stereotypes in adulthood

Models of development- biological model of aging, psychological models of adulthood development, socio-cultural models of development, nature and nurture in adulthood-individual and environment interactions. Reciprocity in development. Themes and issues in adult development and aging. Ageism and stereotyping the elderly.

Unit III: Developmental changes during adulthood

Developmental changes in adulthood – biological changes, cognitive changes, sensory changes, psychological and social interactional changes associated with aging. ageing and health. Factors affecting health. Lifestyle and health. Key concepts in health and prevention of chronic diseases, physical and neuro-cognitive disorders and others. Risk factors and preventive measures, supportive services.

Unit IV: Adulthood Adjustment

Demographics of an ageing population. Gender differences in aging. Menopause and its effects on women. Cessation of sexual prowess and its effect on men. Issues and adjustments related to occupation, self and family. Retirement, leisure and adjustment. Causes of morbidity and mortality across the life cycle. Human longevity - the influence of genetic and environmental factors. Death, dying and bereavement. Attitude towards death, grief and bereavement.

VII. **Teaching Methods/ Activities**

- Lecture cum discussion
- Interviews with individuals in different phases of adulthood.
- Adult case study analysis- report presentation.

- Related video clips and films.
- Assignments and class reports on current research trends.

VIII. Learning Outcome

After successful completion of this course, students are able to

- Realize age related transitions and challenges in life of adults and measures to cope up with them.
- Understand gender related developmental perspectives in adulthood and build up empathy to guide them well.

IX. Suggested Reading

- Dacey JS and Travers JF. 2002. *Human Development - Across the Lifespan*. McGraw Hill, Boston.
- Dandekar K. 1996. *The Elderly in India*. Sage Publications, New Delhi.
- Hayslip B and Panek P. 1989. *Adult Development and Aging*. Harper & Row.
- Hurlock EB. 2003. *Developmental Psychology - A Life Span Approach*. Tata McGraw Hill, New Delhi.
- Kail RV and Cavanaugh JC. 2004. *Human Development - A Life-Span View*. Thomson Wadsworth, United States.
- Kimmel DC. 1990. *Adulthood and Aging*. John Wiley & Sons, New York.
- Leme BH. 1995. *Development in Adulthood*. Allyn & Bacon.
- Newman BM and Newman PR. 2003. *Development Through Life: A Psycho Social Approach*. Cengage Learning, Boston.
- Sigelman CK. 1999. *Life Span Human Development*. 3rd Ed., Brooks/Cole Publishing Company, London.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Adulthood – Definition, phases/ stages of Adulthood, related concepts of biological, psychological, social, legal, and functional age, characteristics of emerging adulthood, physical and social indicators of adulthood.
2	Psychosocial theories of ageing - Erikson's Psychosocial Theory. Identity Process theory, Activity theory, Socio- emotional Selectivity theory.
3	Theoretical perspectives in adult development - Bio-psychosocial perspective. Ecological Perspective, Havighurst's Developmental Tasks Theory, Jane Loevinger's theory of Ego Development.
4	Theories of Aging, theories of successful Aging, biological theories of ageing - programmed theories, evolutionary theories and random damage theories.
5	Life-Course Theories - Erik Erikson's Eight Stages of Life, Klaus Riegel's Dimensions of Development Theory. Four Principles of Adult Development and Aging.
6	Models of development- biological model of ageing in adulthood, psychological models of development in adulthood. Socio-cultural models of development.
7	Nature and nurture in adulthood. Individual–environment interactions, reciprocity in development.
8	Themes and issues in adult development and aging. Ageism & Stereotyping the elderly.
9	Theoretical perspectives on developmental changes in adulthood. Changes at different stages of adulthood – biological changes, cognitive changes- ageing and memory, ageing and intelligence, sensory changes, psychological and social interactional changes associated with aging.
10	Aging and health. Factors affecting health.

Duration (weeks)	Topics
11	Lifestyle changes needed for secure health, Key concepts in health and prevention– cardiovascular diseases, cancer, disorders of the musculoskeletal system, diabetes, neuro-cognitive disorders and others.
12	Risk factors and preventive measures, supportive services.
13	Demographics of an ageing population. Gender differences in aging. Menopause and its effects on women. Cessation of sexual prowess among men and its effects.
14	Issues and adjustments related to occupation, self and family. Retirement, leisure and adjustment.
15	Causes of morbidity & mortality across the life cycle.
16	Human longevity -the influence of genetic & environmental factors. Death, dying and bereavement. Attitude towards death, grief and bereavement.

I. Course Title : Management of Differently Abled

II. Course Code : HDFS 507

III. Credit Hours : 3 (2+1)

IV. Rationale

Despite advanced scientific technologies in health and education domains, the number and types of differently abled persons is still alarming. It is necessary for students to learn about persons with various different ablilities, their causes, characteristics, needs, management, assistive technologies and rights. This input is required for the effective guidance and counseling of such individuals, their families and teachers. This course is useful for making efforts for prevention, management and rehabilitation of differently able.

V. Aim of the course

- To orient the students to the etiology and developmental characters of differently abled individuals and develop empathy for working with differently abled persons.
- To develop knowledge and skills in students about how to conduct case studies and surveys of differently abled individuals, analyzing and report writing about it.

VI. Theory

Unit I: Classification and statistics of differently abled

Concept and classification of differently abled individuals. Their current statistics. It's implications on the quality of life. Social, emotional, and economic aspects of exceptionality for both children and families. Multi disciplinary view of differently abled individuals.

Unit II: Characteristics, etiology and issues of differently abled

Different abilities- mental deficiency, learning disabilities, visual impairment, hearing impairment, communication disorders, neurological disorders - definition, types, characteristics, etiology, prevalence in India for all above different abilities. Associated psychological and behavioural problems, educational provisions, management considerations and remedial programmes for different types of special needs.

Unit III: Educational & vocational interventions for differently abled

Physical impairment or loco-motor disabilities (Orthopedic and neurological impairment)- definition, classification, assessment and etiology. Psychological and behavioural characteristics of physically challenged children. Educational and vocational interventions. Remedial programmes for physically challenged. Psycho-social disturbances and social maladjustment - definition, classification, types, characteristics and etiology of emotionally disturbed and socially maladjusted. Management considerations and remedial programmes for psycho-socially disturbed and socially maladjusted. Gifted children - definition, types, characteristics, assessment and prevalence in India. Inclusive education and special programmes for the gifted.

Unit IV: Government support services

Preventive measures. Assistive technologies for different developmental challenges. Inclusive education policies and programmes for differently abled persons. Government provisions, concessions, facilities, rights and legislations for differently abled. Community based rehabilitation. Rehabilitation Council of India. National and International agencies for differently abled individuals.

VII. Practical

- Case studies of differently abled persons- etiology, characteristics, assessment of their different Abilities
  - Mentally subnormal children
  - Visually impaired children
  - Hearing impaired children
  - Speech impaired children
  - Orthopedically handicapped
  - Learning disabled children
  - Gifted children

2. Collaborative work with professionals in development of intervention packages for differently abled children (for any one category)
3. Conducting home based interventions
4. Conducting center based interventions at schools/ child clinics/ pediatric wards/ special schools and so on.
5. Report writing and presentation
6. Collaborative work with professionals in development of intervention packages for differently abled children (for any second category)
7. Conducting home based interventions
8. Conducting center based interventions at schools/ clinics/ pediatric wards/ special schools, etc.
9. Report writing and class presentation
10. End term assessment

VIII. Teaching Methods/ Activities

- Lectures.
- Field visits to various institutions of differently abled.
- Viewing of related educational video films-report writing and discussion.
- Case studies –Analysis & discussion.
- Demonstrations of special accessories & materials.
- Study and analysis of reports.
- Demonstrations on planning, execution and evaluation of intervention packages.

IX. Learning Outcome

After successful completion of this course, students become

- Sensitive and empathetic to the needs, conditions and circumstances of differently abled.
- Capable of conducting case studies and planning and executing activities for differently abled.

X. Suggested Reading

- Achenbach TM. 1982. *Developmental Psychopathology*. 2nd Ed., John Wiley, New York.
- Berdine WH and Blackhurst AE. 1985. *An Introduction to Special Education*. 2nd Ed., Harper Collins, Lexington.
- Hallahan DP and Kauffman JM. 1991. *Introduction to Exceptional Children*. Allyn and Bacon, Boston.
- Hegarty S. 2002. *Education and Children with Special Needs*. Sage Publications, New Delhi.
- Kar C. 1996. *Exceptional Children - Their Psychology and Education*. Sterling Publication, New York.
- Kirk SA. 1972. *Educating Exceptional Children*. Houghton Mifflin Company, Boston.
- NIMH. 1999. *School Readiness for Children with Special Needs*. National Institute for the Mentally Challenged Children, Secunderabad.
- Prasad J and Prakash R (1996). *Eduaction of Handicapped Children, Problems and Solution*. Kanishka Publications. New Delhi.
- Saini S and Vig D (2008). *Special Children - Behaviour, Needs and Management*. Swami Printers, Ludhiana.

Weekly Lecture Schedule

Duration(Weeks)	Topics
1	Classification of differently abled individuals. Their current statistics. Implications of special needs on quality of life.
2	Social, emotional, and economic aspects of exceptionality for both children and families. Preventive measures.
3	Multi disciplinary view of differently abled individuals in their care and coping with them. Screening and early identification. Methods and benefits
4	Mental deficiency (low intelligence or *mental retardation*), etiology, characteristics, associated psychiatric problems, special education and welfare services for their management. Managing child in school.
5	Learning disabilities (LD) – definition, causes, types and characteristics. Educational considerations, remedial programmes and managing LD students in schools.
6	Visual impairments - development of visual skills, common visual defects among partially blind. Causes and characteristics. Vision tests. Educational provisions and management considerations.
7	Special education and welfare services for their management. Remedial programmes for visually impaired.
8	Hearing impairment- etiology, early identification and characteristics of hearing impaired. Psychological and behavioural characteristics, special education and welfare services for their management.
9	Communication (speech & language) disorders – speech production, language & communication development. Classification of speech defects, identification and causes.
10	Psychological and behavioural characteristics associated with communication disorders. Educational provisions and management considerations. Remedial programmes for speech problems.
11	Physical impairment or loco-motor disabilities (Orthopedic and neurological impairment)- definition, classification, assessment and etiology. Psychological and behavioural characteristics of physically challenged children. Educational and vocational interventions. Remedial programmes for physically challenged.

Duration (weeks)	Topics
12	Psychosocially disturbed (emotionally disturbed and socially maladjusted) - definition, classification, types, characteristics and etiology of emotionally disturbed and socially maladjusted. Management considerations and remedial programmes for psychosocially disturbed and socially maladjusted.
13	Gifted children - definition, types, characteristics, assessment, prevalence in India. Inclusive education and special programmes for the gifted.
14	Preventive measures. Assistive technologies for different types of challenges. Inclusive education. Community based rehabilitation.
15	Government policies and provisions for differently abled. Concessions, facilities, rights and legislations.
16	Rehabilitation Council of India. National and International agencies for differently abled individuals.

I. Course Title : Adolescent Development and Challenges

II. Course Code : HDFS 508

III. Credit Hours : 3 (2+1)

IV. Rationale

India has more than half of its population below the age of 25 yrs. Adolescence is an age of opportunity. Due to rapid physical, psycho-social changes, adolescents are inclined to be at risk to storm and stress, peer pressure and encounter various challenges. If their development, education, economic empowerment and stability are well taken care, it becomes easy to maintain peace and prosperity in the country. The adolescents need to be studied intensely for proper understanding of the development and challenges of this phase of life, so that they can be guided well.

V. Aim of the course

- To acquaint the students with the important developmental issues and challenges.
- To educate about the contemporary issues in adolescent development and challenges.

VI. Theory

Unit I: Theoretical perspectives of adolescents

Adolescence – definition, significance of the stage. Theoretical perspectives on adolescence – biological, psycho-analytical, psycho-social, social-cognitive and cultural. Physical and sexual development in adolescence - physical transition from child to adult, adolescent growth spurt, puberty causes and changes, psychological impact of puberty, early and late maturation and its psychological implications, adolescent sexuality, causes and correlates of physical development.

Unit II: Cognitive and communication development during adolescence

Cognitive and intellectual development during adolescence- the formal-operational stage, hypothetico-deductive reasoning, thinking like a scientist, complexities of adolescent thoughts, information-processing view of adolescent cognitive development, gender differences in mental abilities. Language development during adolescence- later syntactic development, semantics and meta-linguistic awareness, development of communication skills, learning in school and vocational development.

Unit III: Psycho-social and personality development

Psychosocial development during adolescence- emotional changes, problems, emotional regulation and stability, self-understanding. Role of family, peers, school in psychosocial development. Work, career, heterosexual relationships in adolescence. Personality development- Erikson's theory, identity crisis, identity diffusion, identity foreclosure, identity moratorium, self-concept, gender-role stereotyping. Moral development during adolescence and value orientation. Environmental learning, interactional and cultural context in moral development.

Unit IV: Different challenges of adolescence

Vocational preferences. Transition to adulthood- conflicts with special reference to contemporary socio-cultural changes. Challenges of adolescence- sexuality, aggression, delinquency, AIDS, substance abuse, alcoholism, personality disorders, depression, suicide, eating disorders, health problems, psychological problems, social problems- dating and relationships. Integration of self and psycho-sexual resolution. Resolving identity crisis- reorganization of social life relationship with peers and parents, heterosexual relationships. Risk and resilience during adolescence. Risk and protective factors. Challenges in adolescent's life in the 21st century. Challenges and opportunities for adolescent research. Programs and policies.

VII. Practicals

1. Case studies- interviewing early and late adolescents on issues, problems, pubertal changes, friendships, career aspirations, self and social awareness, mass media references
   - Development of case study format
   - Conducting case study of early adolescent girl and early adolescent boy
   - Conducting case study of late adolescent girl and late adolescent boy
2. Report writing and presentation of case studies
3. Assessment of intellectual abilities of adolescents and class room discussion.
4. Assessment of psycho-social development patterns of adolescents and class room discussion.
5. Depiction of adolescents in mass media: Content analysis of media-
   - Feature films
   - Television serials
   - Literature-magazines, newspapers, advertisements.
6. Report writing and presentation
7. Survey in rural/ semi-urban/ urban communities on challenges faced by adolescents and their Parents.
8. Survey in rural/ semi-urban/ urban communities on challenges faced by teachers of Adolescents
9. Analysis of survey results for adolescent challenges and their need assessment.
10. Planning intervention education programmes for adolescents.
11. Organising intervention education programmes for adolescents about their developmental changes, needs and coping up strategies.
12. End term assessment

VIII. Teaching Methods/ Activities

- Lecture-cum-discussion.
- Adolescent interviews: concerns and challenges.
- Viewing related amazing video clips.
- Class reports on interesting case studies reported in mass media.

- Survey- educational & vocational interests, values and aspirations of adolescents.
- Demonstrations of tests- IQ, EQ,GQ and personality.

IX. Learning Outcome

After successful finishing of this course, students are able to

- Appreciate the scientific foundation of adolescent development and challenges.
- Utilize their knowledge and available services for planning and executing programmes for raising awareness of adolescents about their self care and development.

X. Suggested Reading

- Berk LE and Meyers AB. 2010. *Infants, Children, and Adolescents.* 7th Ed., Prentice Hall, PTR.
- Conger JJ. 1977. *Adolescence and Youth: Psychological Development in a Changing World.* Harper & Row, New York.
- Hazen EP, Goldstein MA and Goldstein MC. 2011. *Mental Health Disorders in Adolescents: A Guide for Parents, Teachers, and Professionals.* Rutgers University Press: New Brunswick, NJ.
- Hurrelmann K and Hamilton SF. 1996. *Social Problems and Social Contexts in Adolescence.* Aldine De Gruyter: New York.
- Seifert KL, Hoffnung RJ and Zack IZ. 1999. *Child and Adolescent Development.* Cengage Learning, Belmont, CA, USA.
- Shaffer DR and Kipp K. 2010. *Developmental Psychology: Childhood and Adolescence.* Wadsworth, Cengage Learning, Belmont, CA, USA.
- Spielhagen FR and Schwartz PD. 2013. *Adolescence in the 21st Century: Constants and Challenges.* Information Age Publishing, Amazon Kindle.

Weekly Lectute Schedule

Duration (weeks)	Topics
1.	Adolescence – definition, importance of the stage, adolescence in perspectives, adolescents today.
2.	Theoretical perspectives on adolescence- biological, psychoanalytical, social-cognitive and cultural.
3.	Physical, motor and sexual development- motor development in adolescence, physical transition from child to adult, adolescent growth spurt, sexual maturation, adolescent sexuality.
4.	Causes and correlates of physical development. Psychological impact of puberty, psycho-social implications of early and late maturation.
5.	Cognitive and intellectual development during adolescence- the formal-operational stage, hypothetico-deductive reasoning, thinking like a scientist, complexities of adolescent thoughts, information-processing view of adolescent cognitive development, sex differences in mental abilities.
6.	Language development during adolescence- later syntactic development, semantics and meta-linguistic awareness, development of communication skills.
7.	Learning in school, vocational and career development
8.	Psychosocial development -emotional changes, problems and emotional regulation, self-understanding. Role of family, peers, school, work and career, heterosexual relationships in psychosocial development. Environmental learning, interactional and cultural context in psychosocial development
9.	Personality development- Erikson's theory, identity crisis, identity diffusion, identity foreclosure, identity moratorium, self-concept, gender-role stereotyping

10. Moral development during adolescence and value orientation. Environmental learning, interactional and cultural context in moral development. Vocational preferences, training and work, transition to adulthood- conflicts with special reference to contemporary socio – cultural changes.
11. Challenges of Adolescence- sexuality, aggression, delinquency, AIDS, substance abuse, alcoholism, personality disorders, depression, suicide, eating disorders, health problems, psychological problems
12. Social problems- dating and relationships. Integration of self and psycho-sexual resolution and resolving identity crisis- reorganization of social life relationship with peers and parents, heterosexual relationships.
13. Risk and resilience in adolescence. Risk and protective factors. Transition to adulthood- conflicts with special reference to contemporary socio-cultural changes
14. Challenges in adolescent's life in the 21st century
15. Challenges and opportunities for adolescent research. Programs and policies
16. Researchable and current issues in adolescent development

I. Course Title : Guidance and Counselling

II. Course Code : HDFS 509

III. Credit Hours : 3 (2+1)

IV. Rationale

Family systems, roles and responsibilities are under great transformation, which has lead the society towards various problems and challenges. Rapidly changing socio-cultural & economic scenario has affected family systems. As a result, families are encountering for its sustainability and in discharging its role and responsibilities. Child guidance and family counseling is a big boon in uprooting/ solving problems and empowering families to encounter their challenges through professional services for leading quality and successful life.

V. Aim of the course

- To acquaint the students about guidance and counselling.
- To orient the students about different techniques of guidance and counselling for different problems.

VI. Theory

Unit I: Areas and types of guidance and counselling

Guidance and Counselling – Meaning, history, goals, levels and techniques. Areas of guidance and Counselling. Types of guidance and counseling services - educational, vocational, personal, marriage and family, leisure time. Assessment and diagnostics in counselling.

Unit II: Contemporary trends and ethical issues

Counselling and therapy relationships. Counselling children - goals, child-counsellor relationships. History about counselling children. Contemporary issues. Play therapy. Integrated counselling for children. Guidance and counselling in schools and colleges. Group guidance. Couple, pre-marital, marriage and family counselling. Current trends in counselling, computerized therapy programs. Research trends in guidance and counseling in India and abroad.

Unit III: Essentials of conducting guidance and counselling sessions

Competencies and role of guidance and counselling professionals. Modes and methods of counselling. Essentials of conducting guidance and counselling session. Understanding the process of guidance and counseling. Ethical issues in guidance and counselling. Knowledge and skills to handle assessment tools. Effective communication and documentation skills. Networking with allied professionals and institutions. Counselling with special concerns, Children with developmental challenges, ambivalent and oppositional type, crisis counselling, guidance in adolescence, counselling elderly.

Unit IV: Approaches and theories of counselling

Approaches and theories of counselling: Affective Counselling theory- concept, key principles. Humanistic approaches- Roger's Client centered approach, Gestalt approach. Psychoanalytic -Psychodynamic approaches by Sigmund Freud, Carl Jung, Alfred Adler and Melanie Klien. Skinner's Behaviouristic approach, Bandura's Behaviour Modification approach. Rational emotive behaviour therapy. Reality therapy. Beck's Cognitive –Behaviour approach.

VII. Practicals

1. Compiling research reviews on various aspects of guidance and counselling.
2. Preparing a checklist to observe and analyze guidance and counselling centers – their organizational structure, objectives, types of services provided, available facilities, staff competencies and problems experienced by them, etc.
3. Survey of guidance and counselling centers by using prepared observation check list.
4. Visit to observe and conduct interviews to get information about the counselling services provided by these institutions such as-Women welfare & child development
5. Family court
6. Women cell, etc.
7. Preparation and presentation of report
8. Visit to observe career guidance centers
9. Feed back of the clients towards the services, financial management/budget, support of other professionals/agencies to different types of centers.
10. Simulation exercises of guidance and counselling children and parents.
11. Content analysis of problems addressed by the leading counselling centers.
12. Content analysis of prevailing psychosocial problems reported in print and electronic media.
13. Identification of characteristics and skills of the counsellors by watching recorded videos on child and adolescent counselling.
14. Understanding techniques used by counsellors by watching recorded videos on child and parent guidance, child counselling, adolescent counselling, couple counselling.
15. Writing reports on films and videos related to the course and its presentation.
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies of guidance & counselling institutions/ clinics–analysis & discussion.
- Viewing related video clips-report writing and discussion.

- Field visits to different guidance and counselling centers/ institutions.
- Interviews with clients of such centers and counselors.
- Observations and analysis of profile & issues of clients.

IX. Learning Outcome

After successful completion of this course, students

- Learn about essentials and skills of child guidance and family counselling.
- Appreciate different approaches to child guidance and family counselling.
- Understand the various needs of families and children for giving appropriate guidance and counselling services.

X. Suggested Reading

- Anthony DJ. 2006. *Mental Disorders Encountered in Counselling*. Anuragha Publications, Chennai.
- Barker M, Vossler A and Langdridge D. 2010. *Understanding Counselling and Psychotherapy*. Sage Publications, New Delhi.
- Cooper S. 2005. *Counselling, Inception, Implementation & Evaluation*. Infinity Books, New Delhi.
- Gunner J. 1984. *Counselling and Therapy for Children*. The Free Press, New York.
- Hough M. 2014. *Counselling Skills and Theory*. Hodder Education, Oxon, UK.
- Ivey AE, Ivey MB and Downing LS. 1987. *Counseling and Psychotherapy - Interpreting, Skills Theory and Practice*. Prentice Hall.
- Timulak L (2011). *Developing your Counselling and Psychotherapy Skills and Practice,* 1st Ed., Sage publications, New Delhi.
- Welfel E R and Patterson L E (2004). *The Counseling Process - A Multitheoretical Integrative Approach*. Thomson Brooks/Cole, Australia.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Counselling- definitions, difference between guidance and counselling. Goals, stages and conditions for guidance and counselling, levels of counselling, types of counselling. History of Counselling, evolution of guidance and counselling movement in India.
2	Counselling strategies and techniques. Role of Assessment and diagnosis in counselling.
3	Areas of counselling- school counselling, college counselling, career counselling, vocational counselling, social guidance and counselling, mental health. Counselling and therapy relationships.
4	Current trends in counseling, computerized therapy programs. Counselling children – history, goals for counselling children, child counsellor relationship.
5	Types of guidance and counselling services - educational, vocational, personal, marriage and family, leisure time. Couple counselling, premarital and marital counselling, family counselling.
6	Research trends in guidance and counselling in India and abroad. Counselling children – goals of child counselling. Child- counsellor relationships. History of child counselling.
7	Contemporary issues in counselling children. Play therapy - Goals, theories and Working with children and their parents.Child Counselling skills, play therapy, use of media, strategies and activities. Child counselling. Counselling process, general model for counselling.Integrated counselling for children – child counselling, observation, active listening, dealing with resistance & transference, self destructive behavior patterns.

Duration (weeks)	Topics
8	Guidance and counselling in schools and colleges. Group guidance.Student counselling – counselling and psychotherapy, objectives of student Counselling.
9	Group guidance – definition, importance, objectives and advantages of group guidance. Tools and techniques, career conferences, vocational, recreational, educational, occupational information.
10	Competencies and role of guidance and counselling professionals. Modes and methods of counselling. Essentials of conducting guidance and counselling session. Understanding the process of guidance and counselling.
11	Ethical issues in counselling. Knowledge and skills to handle assessment tools.
12	Effective communication and documentation skills. Networking with allied professionals and institutions.
13	Counselling special groups. Counselling children with developmental challenges. Counselling ambivalent, different and oppositional type children. Crisis counselling - death, financial, suicidal, academic failure, illness, etc. Guidance for adolescence. Counselling elderly.
14	Approaches and theories of counselling: Affective Counselling theory- concept, key principles. Humanistic approaches- Roger's Client centred approach, Gestalt approach.
15	Psychoanalytic -Psychodynamic approaches by Sigmund Freud, Carl Jung, Alfred Adler and Melanie Klien. Skinner's Behaviouristic approach, Bandura's Behaviour Modification approach.
16	Rational emotive behaviour therapy. Reality therapy. Beck's Cognitive–Behaviour approach.

I. Course Title : Interventions for Diffrerently Abled Children

II. Course Code : HDFS 510

III. Credit Hours : 2 (1+1)

IV. Rationale

Differently able children and their families encounter various physical, psychological, educational and career problems. They are in need of expertise support and guidance to develop right attitudes towards their differently abled children and skills for their effective care and management of. Timely and early interventions for differently abled children yield analyzing results. This course is useful for the students specializing in human development as they need to have knowledge and skills for planning & executing interventions for the rehabilitation and mainstreaming differently abled children.

V. Aim of the course

- To make the students aware about significance and strategies of imparting intervention for differentally abled children.

VI. Theory

Unit I: Significance and types of intervention services

Intervention services- concept, need and significance. Prevention of avoidable health problems. Early intervention –concept, need and significance. Therapies and services-types and contents. Family centred, Child focused intervention, supportive and structured intervention. Speech therapy, occupational therapy, play based intervention.

Unit II: Intervention Strategies and steps

Guidelines for intervention programmes for differently abled. Problems and strategies. Process and steps of intervention- identification, assessment and diagnosis of differently abled and at-risk children, planning and designing intervention, implementation and evaluation. Curriculum planning for differently abled children.

Unit III: Development of intervention programme

Developing need based intervention programmes and strategies for different categories of developmentally challenged children and their parents. Understanding key elements for successful interventions- tailoring for individual needs, providing normality and integration, provision of optimal environment for developmental progress, environmental compatibility and remedial services.

Unit IV: Executing intervention and multi disciplinary approach

Executing child and parent focused interventions and evaluating its effectiveness. Multi disciplinary approach-significance, strategies to include parents and community and overcoming barriers. Planning interventions for inclusion. Involving parents and community.

VII. Practicals

1. Identification of families having children with specific disability
2. Based on selected families, developing need assessment checklist of differently abled children and their families.
3. Need assessment of differently abled children and their families, report presentation and enlisting the needs of family and differently abled child care & development.
4. Designing and developing intervention modules/ programme based on needs of differently abled children and their families.
5. Presentation of intervention modules/ programme, its evaluation and enhancement.
6. Intervention programme: Material selection from department and market survey of required Material/ toys/ tools/ books, etc.
7. Presentation of student's ideas for development of educational and development oriented material/ tools for intervention, discussion on it and finalizing the intervention material and tools.
8. Understanding and experiencing purchase procedure for required material- Seeking permissions of the authorities for purchases, drawing advances (Money indent), submission of vouchers and entry of material in registers.
9. Preparation and up gradation of intervention activities, material and tools.
10. Part-1: Implementation and monitoring of intervention programme in families of differently abled child
11. Part-II: Implementation and monitoring of intervention programme in families of differently abled child.
12. Part-III: Implementation and monitoring of intervention programme in families of differently abled child.
13. Part-IV: Implementation and monitoring of intervention programme in families of differently abled child.
14. Evaluation of effectiveness of intervention programme in catering the identified needs of families and their differently abled children.

15. Conducting parents/ community workshops for publicity of benefits of need based intervention programmes for creating awareness and motivation in families for the welfare of differently abled children.
16. End term assessment.

VIII. Teaching Methods/Activities

- Lectures.
- Case studies –success stories .
- Viewing of amazing intervention video clips.
- Review reports on different types of interventions.
- Field visits to Govt. and Non- Govt. institutions implementing various intervention programmes.
- Demonstrations on preparation & use of innovative learning & teaching materials.

IX. Learning Outcome

After successful completion of this course, students are well equipped to

- Understand the dos & don’ts in designing & executing interventions for the welfare and enhancing of differently abled children.
- Analyze the government programmes and home environments differently abled children and suggest concrete measures for improvement in it.

X. Suggested Reading

- Chadha A. 2001. *A Guide to Educating Children with Learning Disabilities*. Vikas Publishing House, New Delhi.
- Chadha A. 2005. *Teaching Visually Impaired Children – Module 1*. Unistar Books, Chandigarh.
- Gutpa R K. 2005. *Disability In Indian Context - A Teacher’s Role*. Unistar Books, Chandigarh.
- Khatib J and Khadi P. 2011. *Emotional Behaviouir of Mentally Challenged Children Attending Special Schools: Parental Educational Intervention*. UAS, Dharwad.
- Manga SK. 2009. *Educating Exceptional Children - An Introduction to Special Education*. PHI Learning, New Delhi.
- Panda KC. 1997. *Education of Exceptional Children*. Vikas Publishing House. New Delhi.
- Sahu BK. 2002. *Education of the Exceptional Children*. Kalyani Publishers, New Delhi.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Concept, need and significance of intervention services. Prevention of avoidable health problems.
2	Early intervention –concept, benefits, eligibility criteria for early intervention. Role of early intervention specialist
3	Therapies and services- types and contents. Family centred, Child focused intervention, Supportive and structured. Play based intervention.
4	Speech and language therapy, physical or occupational therapy, psychological services, home visits, medical, nursing or nutrition services, hearing (audiology) or vision services, social work services.
5	Guidelines for planning and implementation of intervention programmes for differently abled. Problems and strategies for planning and implementation of intervention programmes for differently abled
6	Process and steps of intervention. Screening, assessment and diagnosis of differently abled and at-risk children.
7	Curriculum planning for differently abled children.

Duration (weeks)	Topics
8	Understanding key elements for successful interventions- tailoring for individual needs, providing normality and integration, environmental compatibility and remedial services.
9	Developing need based intervention programmes and strategies for different categories of developmentally challenged children (continued)….
10	Developing need based intervention programmes and strategies for different categories of developmentally challenged children.
11	Implementation of need based intervention programmes for different categories of developmentally challenged children.
12	Provision of optimal environment for developmental progress. Environmental compatibility and remedial services.
13	Multi disciplinary approach-significance, strategies to include parents and community and overcoming barriers.
14	Need, significance and strategies to counsel parents of differently abled
15	Planning interventions for inclusive education.
16	Guidelines for involving parents and community in interventions and evaluating its effectiveness.

I. Course Title : Family Ecology

II. Course Code : HDFS 511

III. Credit Hours : 2 (2+0)

IV. Rationale

Family is a child's first context and as a social system plays a vital role in human development. From ecological perspective, children cannot be understood properly outside the context of their families, as interactions within the family and other social settings outside family play a vital role in individual's development. Families' roles, relationships and functioning have undergone dramatic transition. It is essential to the students to get exposed to different aspects of family ecology.

V. Aim of the course

- To orient the students regarding family as an institution.
- To impart knowledge about family transitions and impact of social change and development

VI. Theory

Unit I: Family relationships

Family as a social system. Socialization within the family. Models of parenting. Parent child relationships- functional and dysfunctional dyads. Family cohesion, conflict and family disorganization –impact on parenting. Children as family agents. Children and marital life. Child abuse. Bidirectionality in parent child relations. Family interactions and delinquency. Improving family communication and interpersonal relations.

Unit II: Family under transition

Family transitions. Change and continuity over life cycle. Needs and problems of families at different developmental stages. Impact of social change on family and changing family patterns in India. Religion and family. Family social class and ethnic variations in child rearing.

Unit III: Family stressors and resilience

Family as an institution under stress. Family crisis. Poverty and children. Stressors and family relations - with special reference to family disruption, sickness, divorce, substance abuse and disability. Stress Process Model. Family's adaptation to stress. Family resilience and protective factors for promotion of family resilience. Family environment and social support as a source of risk and resilience for vulnerable children/youth. Intergenerational family dynamics in management of family conflicts and negative patterns.

Unit IV: Impact of consumerism, emigration and multiculturalism on families

Impact of consumerism on rural and urban families. Impact of emigration and multiculturalism on families. Two culture children and their psycho-social dilemmas. Contemporary issues related to family.

VII. Teaching Methods/ Activities

- Lecture cum discussion.
- Observations and interviews with different types of families.
- Case study of families in crisis.
- Class reports- based on mass media narratives.
- Seminars- Review of research studies .

VIII. Learning Outcome

After successful completion of this course, students are able to

- Students develop deep insight into role of family in individuals' development and different issues of family systems.

IX. Suggested Reading

- Carson DK, Carson CK, Chowdhury A. 2007. *Indian Families at the Crossroads*. Gyan Publishing House, New Delhi.
- Daly KJ. 2007. *Qualitative Methods for Family Studies & Human Development*. Sage Publications, New Delhi.
- Falcov CJ. 1991. *Family Transitions*. Gulford Press, California.
- Garbarino J, Eckenrode J and Barry F D. 1997. *Understanding Abusive Families: An Ecological Approach to Theory and Practice*. Jossey-Bass, New York.
- Grigorenko EL and Stenberg RJ. 2001. *Family Environment and Intellectual Functioning: A Life-Span Perspective.* Lawrence Erlbaum Associates Publishers, London.
- Karim AB. 2014. *Family Interactions: Concepts, Mechanism & Methods to Improve the Family Communication & Interpersonal Relationships*. Successful Family Upbringing Series, Refman.
- Kuczynski L. 2003. *Handbook of Dynamics in Parent-Child Relations*. Sage Publications, New Delhi.
- McCubbin H and Figley CR. 1991. *Stress And The Family: Coping with Normative Transitions Routledge*. Taylor and Francis Group, New York.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Family as a social system, ecological perspective of family. Family as an agent of Socialization.
2	Models of parenting. Parent child relationships- functional and dysfunctional dyads.

Duration (weeks)	Topics
3	Family cohesion and adaptability. Family cohesion, conflict and family disorganization –impact on parenting.
4	Children as family agents. Children and marital relations.
5	Child abuse- understanding abusive families. Bi-directionality in parent child relations.
6	Family interactions and delinquency. Improving family communication and interpersonal relations.
7	Family transitions- continuity and change over life cycle. Needs and problems of families at different developmental stages.
8	Religion and family. Impact of social change on family and changing family patterns in India.
9	Family disorganization. Family Social class and ethnic variations in child rearing.
10	Family as an institution under stress. Family crisis. Stress Process Model.
11	Poverty and children. Stressors and family relations - with special reference to family disruption, sickness, divorce, substance abuse and disability. Stress Process Model.
12	Family resilience and protective factors for promotion of family resilience. Family and social support as a source of resilience for vulnerable children/youth.
13	Intergenerational family dynamics in management of family conflicts and negative patterns.
14	Impact of consumerism on rural and urban families.
15	Impact of emigration and multiculturalism on families. Two culture children and their psycho-social dilemmas.
16	Contemporary –researchable issues related to family.

I. Course Title : Family and Cultural Diversities

II. Course Code : HDFS 512

III. Credit Hours : 2(2+0)

IV. Rationale

Family values and functions are determined by its cultural milieu. Families must be studied in diverse cultures to understand variations in its members' status, development, interactions, relationships, concerns and their challenges in cross-cultural context. It helps to dispel negative stereotypes and personal biases about different groups. As this course deals with different elements of families in western and eastern cultures cutting across different communities, the students get an intellectual perspective of families with cultural diversities.

V. Aim of the course

- To sensitize the students, regarding the theories and issues pertaining to cultural difference in family studies.
- To orient students about families across India in diversified cultural context with special reference to the farming community and their quality of living and concerning issues

VI. Theory

Unit I: Culture and family

Culture- definition, components and characteristics of culture. Agents of cultural influences- school, family, community and other social groups. Cultural factors and impact on families. Western versus Eastern family culture. Cultural diversities in India. Elements of India's diverse culture – religion, philosophy, cuisine, language, fine arts, dance, music.

Unit II: Families in India and abroad

Families in India and abroad - communal, nuclear, joint, extended, polyamorous, polyandrous, polygynous, single parent families, unrelated families. Indian family culture-values and issues concerning families and its stability. Factors determining social status of families. Families in rural and tribal agrarian community – status of women, children, elderly and men in the families.

Unit III: Cross-cultural variations in family functioning

Cross-cultural variations in different aspects of family functioning across different West and East countries/ cultures *vis-à-vis* – marriage, parenthood, relationships, care of elderly and status of women. Cross cultural variations in family functioning, roles and responsibilities, cohesion, interpersonal communication patterns, conflict resolution. Parenting across cultures – child rearing, socialization and socialization practices. Family crisis and adaptations across cultures. Unique family experiences across cultures, some classic examples like Kibbutz in Israel.

Unit IV: Diversities in family life and challenges

Diversities in family life – ethnic, linguistic, regional, etc. Effect of urbanization, secularization, westernization, technological advancement, globalization and other such developments on families in general and agrarian in particular. Challenges before families across cultures. Legal provisions – emerging cultural trends. Research trends in cross-cultural family studies, methodological issues.

VII. Teaching Methods/ Activities

- Lectures.
- Viewing video films on national & international families.
- Case studies of families in diverse cultures.
- Book review
- Class reports & seminars.

VIII. Learning Outcome

After successful completion of this course, students are enable to

- Understand different elements of families in international perspective.
- Comprehend individual's development and issues differently in families of various cultural settings.
- Recognize and respect "Ways of being"that are not be our own.

IX. Suggested Reading

- Ballard SM and Taylor AC. 2012. *Family Life Education with Diverse Populations*. Sage Publications, Los Angeles.
- Brislin RW. 1990. *Applied Cross Cultural Psychology*. Sage Publications, New Delhi.
- Carson DK, Carson CK and Chowdhury A. 2007. *Indian Families at the Crossroads*. Gyan Publishing House, New Delhi.
- Ratra A, Kaur P, Chhikara S, Varma T and Chawla P. 2006. *Marriage and Family- In Diverse and Changing Scenario.* Deep & Deep Publications Pvt. Ltd, New Delhi.
- Saraswathi TS. 2003. *Cross Cultural Perspectives In Human Development*, Sage Publications, New Delhi.
- Selin H. 2014. *Parenting Across Cultures: Childrearing, Motherhood and Fatherhood in Non-Western Cultures*. Springer, Dordecht.

• Trask BS and Hamon RR. 2013. *Cultural Diversity and Families: Expanding Perspectives.* Sage Publications, New Delhi.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Culture- definition, components and characteristics of culture.
2	Agents of cultural influences- school, family, community and other social groups.
3	Cultural diversities in India and abroad. Elements of India's diverse culture – religion, philosophy, cuisine, language, fine arts, dance, music.
4	Cultural factors and impact on families. Western versus Eastern family culture.
5	Families in India and abroad - communal, nuclear, joint, extended, polyamorous, polyandrous, polygynous, single parent families, unrelated families.
6	Indian family culture-values and issues concerning families and its stability.
7	Factors determining social status of families. Families in rural and tribal agrarian community – status of Women, children, elderly and men in the families.
8	Male headed and female headed families in agrarian community – causes and concerns.
9	Cross cultural variations in different aspects of family across different West and East countries/ cultures viz marriage, parenthood, care of elderly and status of women and other functions of family, roles and responsibilities.
10	Parenting across cultures – child rearing, socialization and socialization practices. Some classic examples like Kibbutz in Israel.
11	Cross cultural variations in family cohesion, interpersonal communication patterns, conflict resolution. Family crisis and adaptations.
12	Diversities in family life – ethnic, linguistic, regional, etc. Unique family experiences across groups.
13	Effect of urbanization, secularization, westernization, technological advancement, globalization and other such developments on families in general and agrarian in particular.
14	Challenges before families across cultures.
15	Interventions on ideals and practice of families
16	Legal provisions – emerging cultural trends in different societies/ countries. Research trends in cross-cultural family studies, methodological issues.

I. Course Title : Family Therapy

II. Course Code : HDFS 513

III. Credit Hours : 3 (2+1)

IV. Rationale

The family as an institution is envisaging ever increasing stress, disruption and dysfunction. Family therapy is useful for resolving various vertical and horizontal issues of individuals. Family therapy helps in better functioning of individuals and creates happy home environments. In the current scenario of increasing number of nuclear type families, single parent families, atypical families, the course is very beneficial for social well being.

V. Aim of the course

- To orient the students regarding various methods and techniques of family therapy.
- To help students know their abilities as counselors and equip them with family therapies.
- To enable application of therapies in different case studies.

VI. Theory

Unit I: Family therapy - orientation and theoretical perspectives

Family Therapy – concept, need, significance, areas, scope, goals and application of marriage and family therapies. Evolution of family therapy. Early models and basic techniques of family therapy- group process and communications analysis. Theoretical developments in marital and family therapy. Approaches in family therapy - Social Learning approach, Psychoanalytic, Behavioural, Systems approach. Social Constructionism theory. Attachment theory.

Unit II: Types of family therapy

Classic schools of family therapy- Bowenian Family Systems therapy, Strategic, Structured, Communication and Experiential therapies, Psychodynamic Therapy, Cognitive- Behaviour family therapy and integrated family therapy. Contemporary marital therapies. Family therapy in the 21st century and its application to multicultural, single parent and disorganized families, solution focused therapy, narrative therapy and integrative models. Application of family therapy in depression, substance abuse, schizophrenia and eating disorders.

Unit III: Concerns for family therapy

Signs and symptoms of family in need of therapies- psychosomatic symptoms, psychiatric disorders, marital distress, alcoholism, drug dependence, juvenile offences, problems of adolescence, conduct problems, work and school phobias.

Unit IV: Prospects of family therapy

Qualities of marriage and family therapists. Techniques of marriage and family therapy. Advances in clinical assessment, preventive and enrichment programmes. Future direction for marriage and family therapy- bridging research, theory and practices.

VII. Practical

1. Observational visits and screening families in need of therapy (in various settings) andpreparation of format for it. Visiting and screening of urban families in need of therapy
2. Visiting and screening of slum families in need of therapy
3. Visiting and screening of rural families in need of therapy
4. Report presentation and discussion
5. Case studies of different areas of marriage and family therapy (alcoholism, drug, dependence, juvenile offences, problems of adolescence).
6. Preparation of format. Case study of alcoholic de-addiction.
7. Case study of drug dependence and de-addiction.
8. Case study of juvenile offences and rehabilitation.
9. Case study of socio-emotional problems of adolescents.
10. Report presentation and discussion.
11. Case studies of different methods and techniques of marriage and family Therapy (one from each).
12. Visit to marriage and family therapy centre
13. Observation of sessions for knowing the methods and techniques used in marriage and family therapy (actual).
14. Observation of sessions for knowing the methods and techniques used in marriage and family therapy (recorded ones).

15. Report presentation and discussion.
16. End term assessment.

VIII. Teaching Methods/ Activities

- Lectures.
- Survey of families with different issues.
- Viewing of related films/ video clips.
- Field visits to family therapy/ family counselling clinics.
- Technical interactions with family therapists
- Class reports on current issues of families therapy impact.
- Case studies of beneficiaries of family therapy.

IX. Learning Outcome

After successful completion of this course, students are enlightened to

- Deal with family issues more scientifically in light of acquired knowledge and skills.
- Develop confidence to deal with a range of family issues under the professional guidance experts.

X. Suggested Reading

- Carr A. 2008. *Family Therapy – Concepts, Process and Practice.* 2nd Ed., John Wiley & Sons Ltd, Chichester.
- Carson DK, Carson CK, Chowdhury A. 2007. *Indian Families at The Crossroads*. Gyan Publishing House, New Delhi.
- Doherty W, Boss P, Larossa R, Schumm W and Steinmets S. 1993. *Family Theories and Methods: A Contextual Approach.* Mac Millan & Company.
- Lowe R. 2004. *Family Therapy a Constructive Framework.* Sage Publications, New Delhi.
- Mark R. 2003. *Family Therapy in Focus.* Sage Publications, London.
- Roger L. 2004. *Family Therapy - A Constructive Framework*. Sage Publications London.

Weekly Lecture Schedule

Duration (weeks)	Topics
1	Concept. Need and significance of family therapy. Areas, scope and goals of family therapy.
2	Application of marriage and family therapy. Evolution of family therapy. Early models and basic techniques of family therapy- group process and communications analysis.
3	Theoretical developments in marital and family therapy. Approaches in family therapy - Social Learning approach and Psychoanalytic approach.
4	Behavioural approach, Systems approach. Social Constructionism and Attachment theory approach.
5	Classic schools of family therapy- Bowenian Family Systems therapy, Strategic therapy, Structured therapy.
6	Psychodynamic therapy, Communication therapy and Experiential therapy.
7	Cognitive- Behaviour family therapy and Integrated family therapy. Contemporary marital therapies.
8	Family therapy in the 21st century and its application to multicultural, single parent and disorganized families, solution focused therapy, narrative therapy and integrative models.
9	Application of family therapy in depression, substance abuse, schizophrenia and eating disorders.
10	Signs and symptoms of family in need of therapies- psychosomatic symptoms, psychiatric disorders, marital distress.

Duration (weeks)	Topics
11	Role of family therapy in alcoholism, drug dependence, juvenile offences, problems of adolescence,
12	Role of family therapy in conduct problems, work and school phobias.
13	Qualities of marriage and family therapists. Techniques of marriage and family therapy.
14	Advances in clinical assessment, preventive and enrichment programmes.
15	Future direction for marriage and family therapy- bridging research, theory and practices
16	Wrap up

Course Title with Credit Load
Ph.D. in Human Development and Family Studies

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
*HDFS 601	Advanced Human Development	3(3+0)
*HDFS 602	Ecology and Human Development	3(3+0)
*HDFS 603	Programme Development for Vulnerable Families	3(2+1)
HDFS 604	Strategic Developmental Intervention	3(2+1)
HDFS 605	Family Studies	3(3+0)
HDFS 606	Adulthood and ageing	3(3+0)
HDFS 607	Mental Health	3(3+0)
HDFS 608	Qualitative Research Methods	2(1+1)
	Minor Courses (06 Credits)	
CS/PGS 601	Research and Publication Ethics	2(1+1)
EECM 602	Impact Assessment of Development Programmes	3(1+2)
EECM 603	Scaling Techniques for Behavioural Research	3(1+2)
EECM 608	Advocacy and Behavior Change Management	3(1+2)
FN 606	Maternal and Child Nutrition	2(2+0)
FN 604	Global Nutritional Problems	2(2+0)
FN 605	Nutrition in Calamities	2(2+0)
	Supporting Courses (05 Credits) **	
HDFS 691	Doctoral Seminar I	1+0
HDFS 692	Doctoral Seminar II	1+0
HDFS 699	Research	75
	Total	**100 Credits**

*Core courses/ compulsory courses

Course Contents
Ph.D. in Human Development and Family Studies

I. Course Title : Advanced Human Development
II. Course Code : HDFS 601
III. Credit Hours : 3(3+0)

IV. Rationale

Development as a dynamic phenomenon in life course of all human beings is an integrated, multifaceted and interdependent process. Human development as a subject has also undergone a lot of revolution. There is a great need to understand the recent orientation and advances in nature, developmental perspective, processes and the latest trends in human development throughout the life span.

V. Aim of the course

- To create awareness among students regarding the model of human development as a science and as a process, its orientation and nature.
- To impart knowledge regarding theoretical foundations, issues and research trends in human development

VI. Theory

Unit I: Human development – a science and a process

Classical and contemporary theoretical orientation to human development. Relational developmental systems and developmental science. Developmental psychology to developmental science from deficit to diversity in development. Regulation of development and differentiation. Constructing general model for development – developmental behaviour genetics. Multilevel nature and analysis of developmental processes.

Unit II: Developmental diversity and regularity

Concept of Consistency vs. change in development. Developmental diversity and regularity. Developmental diversity and consequences for Human Development. Dynamics of stability and variability in development – role of experience in development, Optimal Experience theory. Human action perspective to developmental diversity and regularity. Abnormal behaviour vs. individual differences. Intentional personal development and personal control over development.

Unit III: Development through life span

Life span theory in development, five levels of analysis – Life cause theory, basic concepts, life transitions and historical change. Continuity vs. discontinuity in different developments across stages of life. Cognitive and emotional development-development of children's thinking and emotions. Dynamic development of thinking, feeling and acting- infancy through adulthood. Emotional development and consciousness. Dynamic structure in cognitive and emotional development - growth cycle and brain activity. Unravelling the processes underlying social, emotional and personality development.

Unit IV: Psycho-social perspective

Dialectical models of socialization. Development of self-regulation and morality. Pro-social behaviour development-development across lifespan and correlates. Religious and spiritual development through life span – positive and negative correlates. Issues concerning children in difficult circumstances. Multilevel perspective on child maltreatment. Resilience in the face of adversities. Socio-emotional development in diverse family contexts. Gendered development. Future directions for life course and behaviour genetics.

Weekly Teaching Schedule

Duration (weeks)	Topics
1	Classical and contemporary theoretical orientation to human development. Relational developmental systems and developmental science.
2	Developmental psychology to developmental science from deficit to diversity in development. Regulation of development and differentiation.
3	Constructing general model for development – developmental behaviour genetics. Capability_approach in studying human development.
4	Multilevel nature of developmental processes
5	Consistency vs. change in human development. Consistency of concepts and phenomenon.
6	Developmental diversity and regularity. Developmental diversity and Consequences for Human Development
7	Dynamics of stability and variability in development – role of experience in development, Optimal Experience theory.
8	Human action perspective to developmental diversity and regularity. Abnormal behaviour vs. individual differences Intentional personal development and personal control over development.
9	Life span theory in development, five levels of analysis – life cause theory, basic concepts, life transitions and historical change. Continuity vs. discontinuity in different developments across stages of life.
10	Cognitive development across life span. Development of children's thinking and emotions. Dynamic development of thinking, feeling and acting- infancy through adulthood.
11	Emotional development across life span. Emotional development and consciousness.
12	Dynamic structure, growth cycle and brain activity in cognitive and emotional development.
13	Dialectical Models of Socialization. Development of self-regulation and morality across life span. Pro-social behaviour development across lifespan and its correlates.
14	Unravelling the processes underlying social, emotional and personality development. Religious and spiritual development through life span – positive and negative correlates.
15	Issues concerning children in difficult circumstances. Socio-emotional development in changing family contexts. Multilevel perspective on child maltreatment.
16	Resilience in the face of adversities. Socio-emotional development in changing family contexts. Gendered development. Future directions for life course and behaviour genetics

VII. Teaching Methods/ Activities

- Lecture and classroom discussion
- Group discussion
- Case specific discussions

- Assignment (Reading/Writing), Book/Publication Review
- Student presentation
- Case studies and analysis
- Guest Lectures

VIII. Learning Outcome

After this course, the students will be able to

- Understand the concepts, complex system, process and sequence of human development.
- Comprehend the nature of development by getting oriented to phenomenon of diversity, regularity, continuity and stability in development.
- Recognize the current trends and issues of human development.

IX. Suggested Reading

- Ausubel D and Sullivan EV. 1980. *Theory and Problems of Child Development*. 3rd Ed., Grune & Stratton, New York.
- Berk LE. 2013. *Child Development*. Pearson, New Delhi.
- Damon W and Lerner R. 1998 & 2006. *Handbooks of Child Psychology*. Vol. I to Vol. IV. John Wiley & Sons.
- Lerner RM and Newell KM. 2014. *Handbook of Developmental Systems Theory and Methodology*. Pp. 19-65. The Guilford Press, New York.
- Rogoff B. 2005. *The Cultural Nature of Human Development*. Oxford University Press, New York.
- Saraswathi TS and Kaur B. 1993. *Human Development and Family Studies in India*. Sage Publications, New Delhi.
- Sharma N and Chaudhary N. 2009. Human development: Context and Processes. In G. Misra (Ed.), *Psychology in India* (*Vol.I*) *Basic Psychological Processes and Human Development*. Pp. 69-109. Pearson, New Delhi.
- https://en.wikipedia.org/wiki/Capability_approach
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5830131/

I. Course Title : Ecology and Human Development

II. Course Code : HDFS 602

III. Credit Hours : Credits: 3(3+0)

IV. Rationale

Each human being is like others in some ways and also remains unique in others. The uniqueness rests upon the ecological settings of the individual one experiences in varied forms in biological, psychological sociological and cultural contexts. The students getting expertise in Human Development need to understand the diverse array of ecological modelling and the environmental complexities that influence human developmental processes.

V. Aim of the course

- To help students understand the process of interaction between human development and ecological systems.
- To provide in-depth knowledge about physical, economic, socio-cultural and socio-political role of ecology in life course development.
- To make the students realise research and assessment of human development based on ecological perspective.

VI. Theory

Unit I: Ecological modelling in human development

Human ecology – concept and relevance in understanding human development. Ecological modelling, ecology of developmental processes, bio-ecological model of Bronfenbrenner. Developmental ecology through space and time. The Process–Person–Context–Time (PPCT) Model . An Integrated model of individual development based on PPCT Model. Life course development through ecological perspective.

Unit II: Physical ecology and human development

Developmental tasks through lifespan – role of ecology, social roles and structural role of ecology. Behavioural development – role of physical ecological factors, terrain, climatic changes, demographics and their effect on human development. Children's physical environment, housing, overcrowding, neighborhood and development. Economic factors and their impact on human development.

Unit III: Socio-cultural ecology and human development

Building blocks in the environment. Interpersonal structures as context of human development. Dyads- types, nature and function of joint and molar activities, affective relations, balance of power. Race, class, ethnicity and development. Socio-cultural and sub-cultural context of human ecology and development- differences in child's ecological systems and their impact on parenting and development. Socio-cultural imbalances and their impact on human development. Contemporary child rearing and implications for human development. Impact of time factor and cultural history on development.

Unit IV: Role of systems and policies

Children's institutions, day care and preschools as context of human development. Children in war and disaster. Socio-political, legal systems and policies and human development. Religion, caste, minority and deprived states and their effects. Community support and its value for human development. Impact of media, technology and social networking. Policies, programmes based on ecological factors impacting human development. Research and assessment of human development based on ecological perspective.

Weekly Teaching Schedule

Duration (weeks)	Topics
1	Human ecology – its concept and relevance in understanding human development. Life course development through the ecological perspective.
2	Ecology of developmental processes. Bio-ecological model of Bronfenbrenner
3	Developmental ecology through space and time: referred to as process–person–context–time (PPCT) model.
4	An Integrated model of Individual Development based on PPCT Model.
5	Developmental tasks through lifespan –role of ecology, social roles and structure role of ecology.
6	Physical ecological factors, Terrain, climatic changes, demographics and their effect on human development.
7	Behavioural development –role of ecology, physical, environmental impact on behaviour. Environmental aspects - Children's physical environment, housing, overcrowding, neighbourhood and development. Economic factors and their impact on human development.

Duration (weeks)	Topics
8	Interpersonal structures as context of human development. Building blocks in the environment. Dyads, nature and function of joint and molar activities Impact of affective relations, balance of power.
9	Race and ethnicity and human development. Socio-cultural and sub-cultural differences in child's environment and their impact on childrearing practices and development. Socio-cultural imbalances and their impact on development.
10	Impact of time factor and cultural history on development. Contemporary child rearing practices and their implications for human development.
11	Children's institutions, day care and preschools as context of human development.
12	Children in war and disaster. Socio-political, legal systems and policies impact on human development.
13	Religion and caste systems, minority and deprived states and their effects on human development.
14	Community support and its value for human development. Impact of media, technology and social networking.
15	Policies, programmes based on ecological factors impacting human development.
16	Research and assessment of human development based on ecological perspective.

VII. Teaching Methods/ Activities

- Lecture and class room discussions
- Group discussion
- Case specific discussions
- Assignment (Reading/Writing)
- Book/publication Review
- Student presentation
- Case studies and analysis
- Guest Lectures

VIII. Learning Outcome

After studying this course, the students would be able to

- Have gained the knowledge of both the various ecological structural factors that can impact upon developmental pattern and the processes that underlie it.
- Acquire information about how complex combinations of biological and socio-cultural events produce development.
- Appreciate the impact of context and culture on children's development.
- Describe, explain, and optimize the course of human life for diverse individuals living within diverse contexts.

IX. Suggested Reading

- Begon M, Harper JL and Townsend CR. 1990. *Ecology: Individuals, Populations and Communities*. Blackwell, Cambridge.
- Bronfenbrenner U. 1977. *Toward An Experimental Ecology of Human Development*. *American Psychologist*. 2, pp. 513-531.
- Bronfenbrenner U. 1979. *The Ecology of Human Development: Experiments by Nature and Design*. Harvard University Press, Cambridge.
- Hames R. 2001. *Human Behavioral Ecology*. *International Encyclopedia of the Social and Behavioral Sciences.* Elsevier Science Ltd.
- Ingold T. 1986. *Evolution and Social Life*. Cambridge University Press, Cambridge.
- Klein RG. 1989. *The Human Career: Human Biological and Cultural Origins*. University of Chicago Press, Chicago.

- Lerner RM. 2015. *Handbook of Child Psychology* (Ed.), Vol. 1 to 7. John Wiley & Sons, Harvard.
- Smith EA and Winterhalter B. 1992. *Evolutionary Ecology and Human Behavior*. Aldine, New York.
- https://en.wikipedia.org/wiki/Human_behavioral_ecology

I. Course Title : Programme Development for Vulnerable Families

II. Course Code : HDFS 603

III. Credit Hours : 3(2+1)

IV. Rationale

A family that is suffering from its own disadvantages, vulnerabilities and problems is likely to produce problem children. It is conceptualised that families have the ability to bounce back from difficult circumstances or stressful experiences to make a good adaptation to life if they participate in supportive programmes and thus diminish the chances of causing damage to its incumbents. The students seeking expertise in human development need to understand and gain skills in designing intervention programmes for vulnerable families, to step in when appropriate, to help people live happier and have more fulfilled lives.

V. Aim of the course

- To make the students learn to identify vulnerable population in rural and urban areas.
- To develop an understanding regarding techniques of planning, implementing and evaluating development and programmes and projects for vulnerable families.

VI. Theory

Unit I: Family Vulnerabilities

Vulnerable families- meaning, categories, forms of vulnerability, characteristics. Family vulnerability factors - poverty, alcohol and drug abuse, AIDS, prostitution, delinquency, social disadvantages, mental disorders, chronic serious health issues, destitute women and children, street children, abused children, women and senior citizens. Impact of family vulnerabilities on children and families.

Unit II: Programmes for vulnerable families

Developmental programmes for vulnerable families – concept, history and five year plans. Types of programmes and projects for vulnerable families. Different approaches to develop programmes for families. Inter disciplinary approach to research project management. National and international research projects for vulnerable families. National and International programmes and policies for vulnerable children and families. UNICEF framework for protection, care and support of orphans and vulnerable children. National Plan of Action for protection and care of children.

Unit III: Programme development – elements and process

Need assessment of vulnerable families. Developing need based multiple programmes for vulnerable families and children - project proposal, principles of project design, steps, guidelines, process involved, aspects of appraisal, basic considerations, risks and returns in project proposal development. Elements of effective programmes for families. Project sustainability- factors, components and action plan. Scientific values and professional ethics in development of programmes for vulnerable population. Donors and funding agencies- types, National and International donors funding projects. Role of public and private donors in funding projects.

Unit IV: Working with vulnerable families

Working with vulnerable families- need, goals and significance. Developing strategies to support vulnerable children and their families. Strategies for increasing participation and retention. Ethics in working with vulnerable families. Working with children in vulnerable families- need, goals, strategies. Family resilience in the face of adversities- concept, risk and protective factors. Strengthening family relations. Including fathers in work with vulnerable families. Implementing the stimulating management techniques- Programme Evaluation and Review Technique (PERT), Critical Path Method (CPM), Line of Balance (LOB), Gantt Chart and SWOT analysis.

VII. Practicals

1. Review of the national international projects and programmes for vulnerable families.
2. Discussion on programmes and research projects
3. Developing need assessment performa
4. Learning to use selected PRA techniques –
   – Focus group discussions/ interviews
   – Transit walk, social mapping and time line
5. Interviewing families with need assessment
6. Developing need based programme for vulnerable families
7. Class discussion on developed programme and enhancement
8. Programme implementation – Working with families and execution of developed programmes- home based approach
9. Working with families and execution of developed programmes- child centred approach
10. Programme Evaluation by using- Programme Evaluation and Review Technique (PERT), Critical Path Method (CPM)
11. SWOT analysis
12. Developing concept note for research project on vulnerable families
13. Developing Multiple Programs for promoting family health with vulnerable Children
14. Dissemination/ publishing of success stories, popular articles.
15. End term assessment

Weekly Teaching Schedule (Theory)

Duration (Weeks)	Topics
1	Vulnerable families- meaning, categories, forms of vulnerability and characteristics.
2	Family vulnerability factors and family vulnerability processes - poverty, alcohol and drug abuse, AIDS, prostitution, delinquency. Impact of family vulnerabilities on children and families.
3	Other vulnerability factors and their impact- social disadvantages, mental disorders, chronic serious health issues.
4	Vulnerable groups - destitute women and children, street children, abused children, women and senior citizens.
5	Developmental programmes for vulnerable families – concept, history and five year plans. Types of programmes and projects for vulnerable families.

Duration (Weeks)	Topics
6	Different approaches to develop programmes for families. Inter disciplinary approach to research project management.
7	National and international research projects for vulnerable families. National and international programmes and policies for vulnerable children and families.
8	UNICEF framework for the protection, care and support of orphans and vulnerable children. National Plan of Action for protection and care of children.
9	Need assessment of vulnerable families. Developing need based multiple programmes for vulnerable families and children - project proposal, principles of project design, steps, guidelines.
10	Process involved, aspects of appraisal, basic considerations, risks and returns in project proposal development. Elements of effective programmes for families.
11	Project sustainability, factors, components and action plan. Scientific values and professional ethics in development of programmes for vulnerable population.
12	Donors and funding agencies- types, National and International donors funding projects. Role of public and private donors in funding projects.
13	Working with vulnerable families- need, goals and significance. Developing strategies to support vulnerable children and their families.
14	Strategies for increasing participation and retention. Ethics in working with vulnerable families. Working with children in vulnerable families- need, goals, strategies. Social context of children in difficult circumstances and developmental vulnerabilities.
15	Family resilience in the face of adversities- concept, risk and protective factors. Strengthening family relations. Including fathers in work with vulnerable families.
16	Implementation/ stimulating management techniques- Programme Evaluation and Review Technique (PERT), Critical Path Method (CPM) Line of Balance (LOB) Gantt Chart and SWOT analysis

VIII. Teaching Methods/ Activities

- Lecture and class room discussions
- Group discussion
- Assignment (Reading/Writing)
- Surveys and community work
- Classroom and field practicals
- Case specific discussions
- Student presentation
- Case Analysis and case studies
- Guest Lectures

IX. Learning Outcome

After completion of this course, the students will be able to

- Develop a knowledge base into family vulnerabilities and will learn to identify vulnerable population in different settings. .
- Gain hands-on training in planning, designing, management and monitoring need based programmes and projects to make a positive impact on families in difficult circumstances

X. Suggested Reading

- Chandra P. 1995. *Project Planning, Analysis, Selection, Implementation and Review*. Tata McGraw, New Delhi.
- Chaudhary DP. 1992. *Women Welfare and Development*. NIPPCD, New Delhi.

- Dunst C, Trivette C and Angela D. 1998. *Enabling and Empowering Families: Principles and guidelines for families*. Brookline Books, Inc. Newton.
- Golden O, Lopres P and Mills G. 2012. *Economic Security for Extremely Vulnerable Families: Themes and Options for Work-force Development and Asset Strategies*. Urban Institute, University of New Hampshire, New Hampshire.
- Resource and Development Unit. 2012. *Supporting Vulnerable Families: Self-guided learning package*. Community Child Care Unit, Victoria.
- Mynarska M, Riederer B and Jaschinski I. 2015. *Vulnerability of families with children: Major risks, future challenges and policy recommendations*. Wittgenstein Centre for Demography and Global Human Capital, stockhom.
- https://www.dcya.gov.ie/documents/publications/A_Guide_to_what_Works_in_Family_Support_Serviecs_for_Vunerable_Families.pdf
- https://www.who.int/maternal_child_adolescent/documents/pdfs/lancet_child_dev_series_paper3.pdf
- https://www.unicef.org/aids/files/Framework_English.pdf
- https://www.cambridge.org/working-with-vulnerable-families/children-in-the-midst-of-family-and-domestic-violence

I. Course Title : Strategic Developmental Intervention

II. Course Code : HDFS 604

III. Credit Hours : 3(2+1)

IV. Rationale

The dysfunctional families and their children who have unmet needs deviate from the normal development pattern and are in need of intervention during different phases of life. Early intervention services can change their developmental path and improve outcomes for families and communities. The human development specialists need to be professionally equipped with competencies and hands-on skills to design and implement macro and micro level situation specific customized interventions. Further, their resourcefulness in utilizing available expertise in allied areas and networking with them needs to be strengthened.

V. Aim of the course

- To make the students aware about the significance, scope, issues and current trends in interventions.
- To develop insight into different strategies and approaches of developmental intervention.
- To provide hands-on learning in designing, implementing, and evaluating developmental intervention package in various settings.

VI. Theory

Unit I: Developmental intervention – concept and significance

Intervention – definition, need and importance. Early intervention for promoting children's development - principles, assumptions, eligibility and success criteria, theory and practice, biosocial developmental contextualism. Current orientation towards developmental intervention for children from birth to early school years. Children with developmental vulnerablilities and their characteristics. Sources of developmental vulnerabilities and resources. Risk - biological, other personal and contextual risks, impact of social inequality. Protective factors - influences on children's development. Neurological basis for developmental intervention needs- importance of early years, sensitive periods and factors influencing brain development.

Unit II: Intervention approaches and framework

Need assessment for intervention, Contemporary issues and current trends in intervention. Intervention principles strategies and process. Theoretical frameworks in early intervention. Intervention models. Multi-disciplinary approaches to early intervention and programmes for motor, cognitive, language and social development. Characteristics of effective Intervention strategies. Framework for developing and implementing programs for children with developmental delays.

Unit III: Intervention procedural guidelines

Early intervention therapy program- guidelines, purpose, program goals and objectives, program description, service delivery and role of other supportive team members. Types of early intervention therapies. Service delivery models in early intervention- child centred, parent centred, family centred, home based, center/ school based. Role of personnel in intervention – role of physiotherapist, speech pathologist, audiologist, occupational therapist, behaviour therapist and developmental therapist. Developing network with other agencies. Resource Generation. Role of family and community in implementation of intervention programmes. Family as developmental context.

Unit IV: Strategic planning and implementation

Planning and implementation of intervention programme. Utilisation of other local level services offered to children and families – screening, referral, assessment, family education and support. Arranging services and family support, collaboration and teamwork with families and professionals. Collaboration and interdisciplinary practices. Professional and ethical behavior. Early intervention - operational standards, accountability and quality assurance, accreditation, program resources and service delivery. Evaluation of developmental intervention programmes – basic concepts, effectiveness, efficiency and economics. Government policies and provisions. Early intervention policies – an international perspective.

VII. Practical

Week	Topics
1	Compilation of research reviews on various developmental Interventions for young children.
2	Observational visits to intervention unit to understand the organizational structure, objective, types of services provided, facilities available, frequency, duration & cost of the Intervention, etc.
3	Observational visit to Paediatric Intervention unit to understand the process/ steps followed in Intervention programme
4	Observational visits to any National Institute offering Intervention programmes for children with developmental delays
5	Observational visits to any NGO offering intervention programmes for children with developmental delays
6	Identification of groups for intervention and Developmental assessment
7	Conducting need based assessment to identify target groups in need of intervention using Developmental Screening test/ appropriate psychological tests
8	Preparing developmentally appropriate intervention package for the selected group
9	Involving parents in the intervention programme, offering home based parent education programmes for managing children with developmental delays.
10	Field testing the developed intervention package at– – Day care centers/ pediatric wards
11	– Clinics/ special schools

Week	Topics
12	Conducting home based intervention programme for children with developmental delays
13	Conducting center-based interventions at – Day care centers/ pediatric wards/ Clinics/ special schools
14	Developing a checklist for assessing the quality & effectiveness of the intervention packages.
15	Evaluation of developed intervention programmes
16	End term assessment

Weekly Teaching Schedule (Theory)

Duration (weeks)	Topics
1	Introduction to early childhood intervention – definition, need and importance. Early intervention for promoting children's development – aims, principles, assumptions, eligibility and success criteria, theory and practice, biosocial developmental contextualism.
2	Current orientation towards developmental intervention for children from birth to early school years. Children with developmental and their characteristics. Sources of developmental vulnerabilities and resources.
3	Risk factors for developmental vulnerabilities among children- biological, other personal and contextual risks, impact of social inequality. Protective factors - influences on children's development.
4	Neurological basis for developmental intervention needs- importance of early years, sensitive periods and factors influencing brain development.
5	Need assessment for intervention, Contemporary issues and current trends in intervention, cultural considerations in children's wellbeing and development. Intervention principles strategies and process.
6	Theoretical frameworks in early intervention. Types of early childhood interventions. Ecological framework, transactional theory, developmental systems model, psychoanalytic perspective, behavioural and educational approaches to early intervention; behavioural perspective.
7	Intervention models – Guralnick's early developmental and risk factors model, Dunst & Trivette's resource based approach**.** Early Intervention approaches and programmes- relationship based approach, early intervention therapy team approach, multidisciplinary, interdisciplinary and trans-disciplinary approaches for promoting development of children.
8	Characteristics of effective Intervention strategies. Framework for developing and implementing programs for children with developmental delays.
9	Early intervention therapy program- guidelines, purpose, program description, program goals and objectives, service delivery, other supportive team member roles. Types of early Intervention therapies **-** play therapy, behavior modification, speech & auditory therapy, hydro therapy, physio-therapy, cognitive therapy.
10	Service delivery models in early intervention- child centred, parent centred, family centred, home based, school/ center based, home-cum-centre based programmes. Developing network with agencies.
11	Role of personnel in intervention – role of physiotherapist, speech pathologist, audiologist, occupational therapist, behaviour therapist, developmental therapist.
12	Developing network with agencies and generating resources. Role of family and community in implementation of early intervention programme. Families as developmental contexts. Generating resources.
13	Planning and implementation of intervention programme. Utilisation of other local level services offered to children and families – screening, referral, assessment,

Duration (weeks)	Topics
	family education and support. Arranging services and family support, collaboration and teamwork with families and professionals.
14	Professional and ethical behavior. Early intervention - operational standards, accountability and quality assurance, accreditation, program resources, service delivery.
15	Evaluation of developmental intervention programmes – basic concepts. Economics of developmental intervention– cost - benefit analysis in early intervention, programme effectiveness.
16	Government policies and provisions.Early intervention policies – an international perspective.

VIII. Teaching Methods/ Activities

- Lecture and class room discussions
- Group discussion, Case specific discussions
- Assignment (Reading/Writing)
- Surveys
- Classroom and field practicals
- Community work
- Student presentation
- Case studies and analysis

IX. Learning Outcome

After studying this course, the students will

- Gain an understanding of the concept, significance, strategies and approaches of developmental intervention.
- Be able to design, implement, and evaluate need based developmental intervention package for assisting children and families in various settings.

X. Suggested Reading

- Berk LE. 1996. *Child Development*. Prentice Hall.
- Chandra P. 1995. *Project Planning, Analysis, Selection, Implementation and Review*. Tata McGraw, New Delhi.
- Choudhary DP. 1992. *Women Welfare and Development*. NIPCCD, New Delhi.
- Guralnick MJ. 2017. Early intervention for young children with developmental delays. In H Sukkar CJ, Dunst & J Kirkby (Eds.), *Early Childhood Intervention* (pp. 17-35). Oxon, UK: Routledge.
- Hetherington EM and Parke RD. 1993. *Child Psychology: A Contemporary View Point*. Mc Graw Hill.
- Saraswathi TS and Kaur P. 1999. *Human development and Family Studies in India*. Sage Publications, New Delhi.
- Sukkar H, Dunst CJ and Kirkby. 1999. *Early Childhood Intervention*. Routledge, Oxon.

I. Course Title : Family Studies

II. Course Code : HDFS 605

III. Credit Hours : 3 (3+0)

IV. Rationale

Numerous frame-works and perspectives about families have been developed by several theorists and researchers which have contributed towards the knowledge building of families. It is very pertinent to understand the family as a social system and its transformed patterns, structure, roles, and ecological phenomenon that lay foundation for human development.

V. Aim of the course

- To develop an in-depth understanding among students regarding various approaches and frameworks for understanding families.
- To give them exposure to the various family issues in the current scenario and to orient them to psycho-social analysis of the changing family roles, responsibilities and relations in the context of human development.

VI. Theory

Unit I: Theoretical frameworks and perspectives

Different frameworks to understand families-conceptual framework, institutional, developmemtal and interactional framework. Family theories- Family Systems theory, human ecology theory, life course perspectives, social-cognitive-behavioral theory, biosocial theory and family communication theories. Family perspectives- Parson's sociological perspective, Marxist perspective, feminist perspectives, modern perspective.

Unit II: Family assessment

Different approaches to Family research- demographic, psychological, psychiatric, ethnographic and inter disciplinary approach. Measurement of family roles and relationships. Ethics in family research. Current issues for research in Indian families in different communities- rural and urban.

Unit III: Family under transition

Indian family system and changing patterns. Fatherhood- changing role of parents. Global migration- demographics, nature, contemporary migration patterns and effects. Cultural identity, family change and transnational mothering. Influence of globalization on children, youth, aged and families. Work and family interface - changing nature of work, feminization of the labour force and changing nature of family life and family roles. Diverse families -single parent families, female headed households, dual career families, one child family, adoptive families. Marital distress, family disorganisation.

Unit IV: Family therapy

Evolution of family therapy. Early models and basic techniques of family therapy- group process and communications analysis. Classic schools of family therapy- Bowenian family systems therapy, strategic, structured and experiential therapies, solution focused therapy, narrative therapy, psychodynamic therapy and integrative models. Cognitive behaviour family therapy. Application of family therapy in mental disorders. Family resilience- concept, developmental systems perspective, advances and challenges in family resilience research.

Weekly Teaching Schedule

Duration (weeks)	Topics
1	Different frameworks to understand families-conceptual framework, institutional, developmemtal and interactional.
2	Family theories- Family Systems theory, human ecology theory, life course perspectives, social-cognitive-behavioral theory.

Duration (weeks)	Topics
3	Biosocial theory and family communication theories.
4	Family perspectives- Parson's sociological perspective, Marxist perspective, feminist perspectives, modern perspective.
5	Different approaches to Family research- demographic approach, psychological approach and psychiatric approach.
6	Ethnographic and inter disciplinary approach. Measurement of family roles and relationships.
7	Ethics in family research. Current issues for research in Indian families in different communities- rural and urban.
8	Indian family system and changing patterns. Fatherhood and changing role of parents. Global migration- demographics, nature, contemporary migration patterns and effects- cultural identity, family change and transnational mothering.
9	Influences of globalization on children, youth, aged and families. Vulnerability of young people in a globalizing environment. Work and family interface - changing nature of work, feminization of the labour force and changing nature of family life and family roles.
10	Diverse families -single parent families, female headed households, dual career families, one child family, adoptive families. Marital distress, family disorganisation.
11	Evolution of family therapy-Palo Alto, Murray Bowen, Carl Whittaker and Minuchin
12	Early models and basic techniques of family therapy- group process and communications analysis, fundamental concepts such as systems theory, social constructionism and attachment theory.
13	Classic schools of family therapy- Bowenian family systems therapy, strategic, structured and experiential therapies. Psychodynamic therapy and cognitive behaviour family therapy.
14	Solution focused therapy, narrative therapy and integrative models
15	Family therapy in the 21st century and its application. Application of family therapy in mental disorders like depression, substance abuse, schizophrenia and eating disorders.
16	Family resilience- concept, developmental systems perspective, advances and challenges in family resilience research. Ecology of the family and healthy functioning.

VII. Teaching Methods/ Activities

- Lecture and class room discussions
- Group discussion
- Assignment (Reading/Writing)
- Case specific discussions
- Student presentation
- Case Analysis
- Guest Lectures

VIII. Learning Outcome

After successful completion of this course students will gain

- Comprehensive knowledge of different approaches to study families including explanations of major family theories, and their applications.
- Ability to reflect significant advances in the field of family studies and researchable issues including reconceptions of theories and cultural concerns.

- Reflects the paradigm shift that involves families, process of family transition and impact of its changing patterns on human development.

IX. Suggested Reading

- Bernardes J. 1997. *Family Studies: An Introduction*. Routledge, New York.
- Bharat S. 1996. *Family Measurement in India.* Sage Publlications, New Delhi.
- Boss P, Doherty WJ, LaRossa R, Schumm WR and Steinmetz SK. 1993. *Sourcebook of Family Theories and Methods: A Contextual Approach*. Plenum Press, New York.
- Le Poire and Beth A. 2005. *Family Communication: Nurturing and Control in a Changing World*. Sage Publications, New Delhi.
- Nichols P and Schwartz R. 2006. *Family Therapy - Concepts and Methods* (7th Ed.). Pearson Education, Inc. USA.
- Roger L. 2004. *Family Therapy - A Constructive Framework.* Sage Publications, New Delhi.
- Trask B. 2010. Globalization and Families: Accelerated Systemic Social Change.
- White JM and Klein DM. 2007. *Family Theories.* Sage Publications, New Delhi.
- http://www.Springer.com.

I. Course Title : Adulthood and Aging

II. Course Code : HDFS 606

III. Credit Hours : 3 (3+0)

IV. Rationale

Population ageing phenomenon is widely observed across the world. The scholars need to have a wide understanding of the implications of this for the society at large and families in particular. Resonant, theoretical and empirical, understanding of adulthood and ageing from various biological, social and psychological perspectives with a specific focus on development in family context can empower students to develop a vision and contribute to the society in creating an environment for optimizing the quality of life of seniors in the prevailing socio-cultural circumstances.

V. Aim of the course

- To orient the students about the theoretical perspectives and current issues of aging.
- To inculcate knowledge regarding the methods and techniques in conducting researches in gerontology among students.

VI. Theory

Unit I: Ageing perspectives and developmental changes

Socio demographic profile of the aged in Indian context. Biological theories of aging, programmed ageing theories, random damage theories. Stochastic theories, evolutionary theories . The Ageing body - physical, sensory, cardiovascular, brain and central nervous system changes. Changes in bodily systems - muscular and skeletal system, respiratory system, immune system. Cognition during adulthood-fluid and crystallized intelligence, decline/ stability in intelligence, dialectic operations, memory, multidimensional changes. Cognitive neuroscience and aging. Healthy aging.

Unit II: Ageing personality

Personality changes during late adulthood. Personality types among the elderly. The Five-factor Model of dispositional traits by Tupes and Christal. Neugarten's Personality Styles. Levinson's theory of Social development, Carl Jung's theories-personality, psyche & dreams. Peck's theory of personality adjustment in late adulthood. Erikson's theory. Disengagement theory. Information-processing in old age- attention, memory, pathological changes in memory. Cognitive disorders-dementia, Parkinson's disease and Alzheimer's disease. Ageing and sexuality, illness and sexuality.

Unit III: Ageing in the family context

Aged in the family milieu- family relationships, problems, prospects and support systems. Attachment and relationships in late adulthood. Ageing and mental health, Mental health risks and disorders. Loneliness, depression and sociability in old age. Indicators of successful and positive aging. Ageing and financial status. Elderly abuse. Stress among the aged and coping strategies. Grief and bereavement- patterns of bereavement and stages of grief. Dying with dignity.

Unit IV: Ageing in the current scenario

Contemporary socio-cultural changes and aging. Ageing in the current scenario-impact of urbanisation, globalisation and migration. Dual career families and aging, stress among caretakers and sandwich generation. International scenario of the aged. Critical issues around global aging. Reconceptualising aging. Researchable issues related on aging. Welfare of the aged- policies and programmes. Research trends in gerontology and methodological issues.

Weekly Teaching Schedule

Duration (weeks)	Topics
1	Socio demographic profile of the aged in Indian context. Theories of aging-Stochastic theories, programmed theories, evolutionary theories and random damage theories.
2	Biological theories of ageing - programmed ageing theories, random damage theories. Stochastic theories, evolutionary theories . Changes in bodily systems - muscular and skeletal system, respiratory system, immune system.
3	The Ageing body - physical, sensory, cardiovascular, brain and central nervous system changes. Changes in bodily systems - muscular and skeletal system, respiratory system, immune system. Cognition during adulthood- fluid and crystallized intelligence, decline/ stability in intelligence, dialectic operations, multidimensionality and multi-directionality. Cognitive neuroscience and aging.
4	Cognitive changes - the selection, optimization, and compensation theory (SOC theory), wisdom. Information-processing - attention, memory, pathological changes in memory.
5	Personality changes during late adulthood. Personality types among the elderly. The Five-factor Model of dispositional traits by Tupes and Christal.
6	Neugarten's Personality Styles. Levinson's stages of adult development theory. Disengagement theory.
7	Carl Jung's theories- personality, psyche and dreams, Peck's Views of Personality Adjustments. Erikson's theory.
8	Neuro -Cognitive disorders-dementia, Parkinson's disease and Alzheimer's disease.
9	The aged in the family context- family relationships, problems, prospects and support systems. Loneliness, depression and sociability in old age. Attachment & relationships in late adulthood.
10	Ageing and mental health, Mental health risks, indicators of successful and positive aging. Ageing and financial status. Elderly abuse.
11	Stress among the aged and coping strategies. Grief and bereavement- patterns of bereavement and stages of grief. Dying with dignity.

Duration (weeks)	Topics
12	Contemporary socio-cultural changes and aging. Ageing in the current scenario-impact of urbanisation, globalisation and migration.
13	Dual career families and aging, stress among sandwich generation and caretakers. International scenario of the aged.
14	Critical issues around global aging- reconceptualising aging. Researchable issues related on aging.
15	Welfare of the aged- policies and programmes.
16	Class discussions on Research trends in gerontology and methodological issues.

VII. Teaching Methods/ Activities

- Lecture and class room discussions
- Group discussion, - Case specific discussions
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Case studies and analysis
- Guest Lectures

VIII. Learning Outcome

After this course, the students will be able to

- Develop an insight into the individual, interpersonal and broader social contexts that influence adult development and changes from young adulthood through mid life and old age impacting quality of life.
- Gain understanding of the social and psychological issues and challenges of ageing for individuals and families and further for society in a broader context.

IX. Suggested Reading

- Baron RA. 2008. *Psychology. Pearson*, Prentice Hall, New Delhi.
- Bigner JJ. 1994. *Individual and Family Development. A Life-Span Interdisciplinary Approach*. Prentice Hall, Englewood Cliffs, New Jersey.
- Brophy JE and Willis SL. 1981. *Human Development and Behaviour*. St. Martin's Press, New York.
- Dandekar K. 1996. *The Elderly in India*. Sage Publications, New Delhi.
- Hayslip B and Panek P. 1989. *Adult Development and Aging*. Harper & Row.
- Leme BH. 1995. *Development in Adulthood*. Pearson, Chicago.
- Richardson B and Barusch A. 2005. *Gerontological Practice for the 21st Century*. Columbia University Press.
- Sheets D, Bradley DB and Hendricks J. 2005. *Enduring Questions in Gerontology*. Springer Publishing Co., New York.

I. Course Title : Mental Health

II. Course Code : HDFS 607

III. Credit Hours : 3(3+0)

IV. Rationale

Although the general perception of mental illness has improved over the past decades, studies show that stigma against mental illness is still persistent, due to stereotypes and unawareness. Untreated, mental illness can contribute to higher medical issues, expenses, under-performance at school, college and at work, fewer employment opportunities and also to increased risk of suicide. Hence, the professionals dealing with human beings need to have basic understanding about the types, symptoms and diagnostic measures of various mental health issues and the therapies for behavior modification.

V. Aim of the course

- To develop an insight into the issues related to mental health in varied contexts, theoretical perspectives and its relevance to individual functioning.
- To make them aware about various mental health disorders, their etiology, contemporary intervention techniques, therapies and programmes and policies for promotion of mental health.

VI. Theory

Unit I: Mental health - Issues and theories

Mental health – concept, biological and psychological basis, historical perspectives. Concept, criteria and measurement of normality and abnormality. Cognitive functions - normal and pathological. Theories of mental health - behavioural, biological, humanistic, existential, psychoanalytical and related theories. Family and mental health. Gender and mental health. Sociology of mental health. Culture and mental health.

Unit II: Mental health disorders

Types, etiology and behavioural symptoms of various mental health disorders and maladjustments- psychosomatic problems, anxiety disorders, mood disorders, schizophrenia and multiple-personality disorders. Clinical manifestation and effects/ consequences of mental disorders- cognitive disturbances, affective disturbances, functional impairments, addictions, alcoholism, substance abuse, gambling, other addictions and social networking.

Unit III: Behaviour assessment and modification

Identification and assessment of mental disorders – approaches to diagnosis of mental disorders, techniques, steps in mental health assessment. Diagnostic and Statistical Manual of Mental Disorders (DSM) IV and DSM V. Psychological assessment - Role of mental health professionals. Strategies for behaviour modification - behaviour therapy, cognitive therapy, psycho therapy and family therapy.

Unit IV: Mental health programme and policy

Status of mental health in vulnerable population – children, adolescents, women and senior citizens in India and abroad. Contemporary intervention techniques. Mental Health Policy – legislations, programmes and policies for the promotion of mental health in India.

Weekly Teaching Schedule

Duration (weeks)	Topic
1	Mental Health – Concept, definitions, Biological basis, Psychological basis. Historical perspectives of mental health.
2	Definition of normality and abnormality- criteria and measurement. Cognitive functions-normal and pathological
3	Theories of Mental Health- Behavioural theories, Biological theories, Humanistic and existential theories, Psychoanalytical and related theories

Duration (weeks)	Topic
4	Family and mental health, Gender and Mental Health, Sociology of mental health, Culture and mental health.
5-6	Types, etiology and behavioural symptoms of various behavioural disorders and maladjustments- psychosomatic problems, anxiety disorders, mood disorders, schizophrenia and multiple-personality disorders.
7-9	Clinical Manifestations, effects/consequences of mental disorders- cognitive disturbances, affective disturbances, functional impairments, addictions-alcoholism, substance abuse, tobacco addiction, Gambling, other addictions and social networking.
10	Identification and assessment of mental disorders – Approaches to diagnosis of mental disorders. Techniques, steps in mental health assessment - psychological assessment
11	Diagnostic and Statistical Manual of Mental Disorders (DSM) IV and DSM V
12	Role of mental health professionals. Strategies of behaviour modification
13	Psycho therapy, behaviour therapy, cognitive behaviour therapy and family therapy.
14	Status of Mental Health in vulnerable population – Children, adolescents, women and senior citizens in India and abroad. Contemporary intervention techniques.
15	Mental Health Policy- legislations on Mental Health. Programmes and policies for the promotion of mental health in India.
16	Wrap up

VII. Teaching Methods/ Activities

- Lecture and class room discussions
- Group discussion
- Case specific discussions
- Assignment (reading/writing)
- Book/publication Review
- Student presentation
- Case studies and analysis
- Guest Lectures

VIII. Learning Outcome

After successful completion of this course, the students will

- Be aware of the issues related to mental health, theoretical perspectives on mental health its significance in life and trends of mental health in varied contexts.
- Develop an insight into various mental health disorders, their etiology, symptoms, assessment and diagnostics, contemporary intervention techniques and therapies and the ongoing mental Health programmes and policies.

IX. Suggested Reading

- Herrman H, Saxena S and Moodie R (Eds). 2005. *Promoting Mental Health*. World Health Organization.
- Kapur M. 1995. *Mental Health of Indian children*. Sage Publications, New Delhi.
- Paul S A. 2011. *Reference guide on Mental Health Evidence*. The National Academic Press, New York.
- Sreevani R. 2016. *A Guide to Mental Health and Psychiatric Nursing*. 4th Ed., Jaypee Publishers, New Delhi.
- Witte R and Howard GS. 2016. *Mental Health Practices in Today's Schools- Issues and Interventions*. Springer Publishing Company.
- https://www.who.int/mental_health/media/investing_mnh.pdf

I. Course Title : Qualitative Research Methods

II. Course Code : HDFS 608

III. Credit Hours : 2 (1+1)

IV. Rationale

Qualitative research opens avenues for giving in-depth understanding of impact of socio-historical factors and life course variables on human beings. It also helps in developing competency for utilizing multiple research methods, simultaneously. This can guide in generating intensive data and critical analysis of human development and behaviour and action to be taken in various natural settings. Such research can provide a base for developing new theoretical inputs and for developing interactions for fruitful outcomes.

V. Aim of the course

- To orient the students regarding the need and scope of qualitative research.
- To impart knowledge and training in methods and techniques of qualitative research.

VI. Theory

Unit I: Introduction to qualitative research

Qualitative research design- concept, need and scope of qualitative research methods. Types, contribution, overview and practical applications of qualitative research methods.

Unit II: Qualitative research methods

Case studies, naturalistic design, historical methods, content analysis, ethnography, single cases experimental design, grounded theory, phenomenology.

Unit III: Qualitative data analysis and interpretation

Coding procedures, analysis and interpretation of qualitative data. Report writing. Evaluation of qualitative research.

Unit IV: Issues in qualitative research

Trends, challenges, limitations and constraints of various qualitative research methods. Ethical issues in conduct of research.

VII. Practical

Week	Topics
1	Critical review of research papers using qualitative methods
2	Critical analysis of research papers using qualitative methods
3	Extensive review of the empirical research works using qualitative method
4	Preparing any one review paper using qualitative methods
5	Identifying researchable issues that can be researched for qualitative methods
6	Designing qualitative research, site selection, sampling. Data collection by using qualitative methods- i) Conducting in-depth interviews ii) Focused group interviews iii) Naturalistic design iv) Historical method v) Ethnography vi) Single cases experimental design vii) Grounded theory
13	Coding procedures, data analysis

Week	Topics
14	Report writing and presentation
15	Ethical issues in qualitative methods
16	End term assessment

Weekly Teaching Schedule (Theory)

Duration (weeks)	Topics
1	Qualitative research design- concept, need and significance of qualitative research methods.
2	Scope of qualitative research.
3	Types of qualitative research and its contribution.
4	Overview and practical applications of qualitative research methods.
5	Case studies.
6	Naturalistic design, Historical methods, content analysis
7	Ethnography, single cases experimental design
8	Grounded theory, Phenomenology.
9	Coding procedures and analysis of data.
10	Interpretation of qualitative data
11	Report writing
12	Evaluation of qualitative research
13-14	Trends, challenges, limitations and constraints of various qualitative research methods
15	Ethical issues in conduct of research
16	Wrap up

VIII. Learning Outcome

After studying this course, the students will

- Gain deep understanding of the qualitative *research, various methods* and its practical applications.
- Will develop competency for utilizing *Qualitative* research methods by designing, . data generation, interpretion and writing report using qualitative analysis.

IX. Suggested Reading

- Barbour R. 2008. *Introducing Qualitative Research*. Sage Publications, New Delhi.
- Corbin J and Strauss A. 2008. *Basics of Qualitative Research*. Sage Publications, New Delhi.
- Denzin N and Lincon Y. 2008. *Collecting and Interpreting Qualitative Materials*. Sage Publications, New Delhi.
- Hennink M, Hatter I and Bailay A. 2003. *Qualitative Research Methods*. Sage Publications, New Delhi.
- Ritchie J and Lewis J. 2003. *Qualitative Research Practices*. Sage Publications, New Delhi.
- Sharan BM. 2002. *Qualitative Research in Practice for Discussion and Analysis*. Jossey-Bass, Georgia.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 6

Community Science
– Resource Management and Consumer Science

Preamble
(Resource Management and Consumer Science)

Professionals in the field of Resource Management and Consumer Sciences are required to understand the interactions among humans and other elements of a system and allocate resources to maximize efficiency. The courses in the discipline should promote proficiency among students to apply theory, principles, and methods to optimize human well-being and overall system performance. Resource management is the efficient and effective development of consumer resources when they are needed.Thus the discipline of resource management and consumer science is linked with ergonomics, a major component of the human resources management and space planning which is an important factor in determining the productivity and safety in workplace. Management education provides knowledge on features and methods of contemporary management practices

The new education policy of India envisages systemic and structural changes in higher education system to enhance essential learning and critical thinking among students with a focus on experiential learning. By engaging students in hands-on experiences they are better able to connect theories and knowledge learned in the classroom to real-world situations.

Therefore, the courses are designed to give intense training to students in the field of ergonomics, space planning and management. Some of the exiting courses were modified to suit to the needs of present society. In the area of ergonomics focus was laid on understanding interactions among humans and other elements of system Upgraded the content integrating the human factor into workplace design. A new course on product design was introduced with a focus on generating and developing new product ideas. The concept of outsourced product development was introduced to establish linkages with industry. In the area of space planning and interior enrichment, upgraded the content of some of the existing courses as per the requirements of contemporary interior design profession and added new courses to enhance the architectural drawing skills of students.

The courses are upgraded to provide on hand skill training to student. Innovative methodologies were suggested to improve the understanding and vision of the students. Orientation towards research was given to enhance the aptitude for research among students. New initiatives like professional practice and industrial attachment give scope for developing professionalism among students.

Modifications Suggested in Courses in the Revised Curricula

M.Sc. (Community Science) in Resource Management and Consumer Science

Course Code	Course Title	Credit Hours	Remarks
	Major Courses		
RMCS 501*	Resource Management: Principles and Practices	3 (3+0)	Changed the title and modified the content to provide knowledge on features and methods of contemporary management practices.
RMCS 502*	Human Factors and Ergonomics	3 (2+1)	Changed the title and included content on human physiology and interactions among humans and other elements of system.
RMCS 503*	Interior Space Planning	3(1+2)	Changed the title and upgraded the content as per the requirements of contemporary interior design profession.
RMCS 504*	Consumer Economics	3 (2+1)	Upgraded the content in light of changing consumer behaviours.
RMCS 505	Work and Work Station Design	3(1+2)	Upgraded the content integrating the human factor into workplace design.

Course Code	Course Title	Credit Hours	Remarks
RMCS 506	Colour and Lighting in Interiors	3 (2+1)	Modified the content taking onto consideration the changing trends in interior colour and lighting developments.
RMCS 507	Consumer Issues and Legislations	2 (2+0)	Three existing consumer courses are merged and modified the content in light of modifications in consumer legislations.
RMCS 508	Product Design	3(1+2)	New course is added with a focus on generating and developing new product ideas. The concept of outsourced product development was introduced.
RMCS 509	Ergonomic Research Techniques	3(1+2)	New course is added to expose students to the developments in ergonomic research methodologies.
RMCS 510	Housing and Energy Efficient Building Design	3 (2+1)	Two courses are merged and modified the content.
RMCS 511	Technical Drawings	3(1+2)	New course is added to enhance the architectural drawing skills of students.
RMCS 512	Interior Design Business Management	3(1+2)	Increased the practical credits and decreased the theory credits.

Course Code	Course Title	Credit Hours	Remarks
RMCS 513	Environmental Resource Management	2(1+1)	New course is added to expose students to emerging scientific and policy issues.
RMCS 514	Special Project	2(0+2)	
	Minor Courses		
FN 505	Nutrition and Physical fitness	3(2+1)	Proposed minor courses from subjects closely related to a student's major subject. Apart from these courses a student can register any other course offered by any other departments.
FN 509	Food Safety and Standards	3(2+1)	
FN 513	Human Physiology	3(3+0)	
EECM 502	Development communication	3(2+1)	
EECM 505	Dynamic communication skills	2(0+2)	
EECM 507	Organisational development and HRD	2(1+1)	
EECM511	Climate Change Management	2(1+1)	
HDFS 503	Methods and Techniques of Assessment in Human Development	3(2+1)	
HDFS 506	Management of differently abled	3(2+1)	
ATS 512	Apparel and Textile Product Development	2(1+1)	
ATS 513	Laboratory Techniques in Textiles Research	2(0+2)	
	Supporting Courses		
	Research methodology	3(2+1)	Course numbers will be assigned by the departments that offer these courses.
	Statistics	3(2+1)	
	Common Courses		
	Library and Information Services	1(0+1)	Common to all disciplines. The course numbers will be assigned by the departments that offer these courses.
	Technical Writing and Communication Skills	1(0+1)	
	Intellectual Property and its management in Agriculture	1(0+1)	
	Basic Concepts in Laboratory Techniques	1(0+1)	
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)	
	Total	**5(0+5)**	
RMCS 591	Seminar	1(0+1)	
RMCS 599	Thesis/ Reseach	30	
	Total	**70 credits**	

*Core curses/ compulsory courses

Ph.D. (Community Science) in Resource Management and Consumer Science

Course Code	Course Title	Credit Hours	Remarks
	Major Courses		
RMCS 601*	Trends in Resource Management	3 (3+0)	Changed the title and added content on skills and tools for better resource management.
RMCS 602*	Occupational Biomechanics	3 (2+1)	Modified the content focusing on biomechanical analysis for designing work environment that minimizes load on worker's body
RMCS 603	Globalization and Consumer Economics	3 (2+1)	Content modified to focus on changes in consumer pattern.
RMCS 604	Space Designing and Managerial Dimensions for Special needs	3(1+2)	Changed the title and included recent developments and transitions in space designing for special needs.
RMCS 605	Physical Ergonomics	3(1+2)	New course is added to make the students understand the potential effects of physical load on human body.
RMCS 606	Environmental Issues and Challenges	2 (2+0)	Added challenges due to recent environmental issues.
RMCS 607	Family Dynamics and Women Power	3 (2+1)	No major changes made.
RMCS 608	Special Project	2(0+2)	

Course Code	Course Title	Credit Hours	Remarks
	Minor Courses		
FN 604	Global Nutrition Problems	2(2+0)	Proposed minor courses from subjects closely related to a student's major subject. Apart from these courses a student can register any other course offered by any other departments.
FN 608	Energy Metabolism	2(2+0)	
EECM 602	Impact Assessment of Development Programmes	3(1+2)	
EECM 603	Scaling Techniques for Behavioural Research	3(1+2)	
EECM 607	Media application and product promotion	4(2+2)	
HDFS 608	Qualitative research methods	3(2+1)	
ATS 602	Technical Textiles	3(2+1)	
ATS 605	Functional Clothing	3(2+1)	
ATS 607	Operational Management in Textiles and Apparel	2(2+0)	

Supporting Courses

A student can opt any course related to the topic of research offered by other faculties of agriculture university or SWAYAM/ MOOCS or other online courses up to a maximum of 5 credits.

RMCS 691	Doctoral Seminar I (Core Field)	1 (1+0)	
RMCS 692	Doctoral Seminar II (Optional Field)	1 (1+0)	
RMCS 699	Research	75	
	Total	**100 Credits**	

*Compulsory core curses

Course Title with Credit Load M.Sc. in Resource Management and Consumer Science

Course No	Course Title	Credit Hours
	Major Courses	
RMCS 501*	Resource Management: Principles and Practices	3 (3+0)
RMCS 502*	Human Factors and Ergonomics	3 (2+1)
RMCS 503*	Interior Space Planning	3 (1+2)
RMCS 504*	Consumer Economics	3 (2+1)
RMCS 505	Work and Work Station Design	3 (1+2)
RMCS 506	Colour and Lighting in Interiors	3 (2+1)
RMCS 507	Consumer Issues and Legislations	2 (2+0)
RMCS 508	Product Design	3 (1+2)
RMCS 509	Ergonomic Research Techniques	3 (1+2)
RMCS 510	Housing and Energy Efficient Building Design	3 (2+1)
RMCS 511	Technical Drawings	3 (1+2)
RMCS 512	Interior Design Business Management	3 (1+2)
RMCS 513	Environmental Resource Management	2 (1+1)
RMCS 514	Special Project	2 (0+2)
	Minor Courses**	
FN 505	Nutrition and Physical fitness	3 (2+1)
FN 509	Food Safety and Standards	3 (2+1)
FN 513	Human Physiology	3 (3+0)
EECM 502	Development communication	3 (2+1)
EECM 505	Dynamic communication skills	2 (0+2)
EECM 507	Organisational development and HRD	2 (1+1)
EECM511	Climate Change Management	2 (1+1)
HDFS 503	Methods and Techniques of Assessment in Human Development	3 (2+1)
HDFS 506	Management of differently abled	3 (2+1)
ATS 512	Apparel and Textile Product Development	2 (1+1)
ATS 513	Laboratory Techniques in Textiles Research	2 (0+2)
	Supporting Courses	
	Research methodology	3 (2+1)
	Statistics	3 (2+1)

Course No	Course Title	Credit Hours
	Common Courses	
	Library and Information Services	1(0+1)
	Technical Writing and Communication Skills	1(0+1)
	Intellectual Property and its management in Agriculture	1(0+1)
	Basic Concepts in Laboratory Techniques	1(0+1)
	Agricultural Research, Research Ethics and Rural Development Programmes	1(0+1)
RMCS 591	Seminar	1(0+1)
RMCS 599	Thesis/ Reseach	30
	Total	70 credits

*Core curses/ compulsory courses. **A student can also choose a course from other fields related to the student's research

Course Contents
M.Sc. in Resource Management and Consumer Science

I. Course Title : Resource Management: Principles and Practices

II. Course Code : RMCS 501

III. Credit Hours : 3(3+0)

IV. Rationale

Global scenario presents tremendous challenges at the forefront of upcoming managers. Management education provides a potential productive ground to develop entrepreneurial skills and abilities. There is a need to facilitate students in developing competencies related to the role of managers as required in today's competitive environment. This course will nurture the students in a way that their abilities can be sharpened to take up managerial responsibilities in future.

V. Aim of the course

- To impart knowledge on the multifarious concepts, principles and processes of management
- To enable students to develop skills in the application of managerial skills in an organizational setup.

VI. Theory

Unit I: Nature and functions of management

Importance of management; Management functions; Management principles; Management levels; Functional areas of management; Managerial skills; Managerial roles.

Unit II: Evolution of management thought

Early classic approaches- Scientific management, administrative management and bureaucracy; Neo-classic approaches- human relation approach and behavioral approach; Modern approach; Quantitative approach; Systems approach; Contingency approach.

Unit III: Managerial competencies

Planning and administrative competencies; Decision making- Introduction, nature of managerial decision making, approaches to decision making; Types of decisions; Process of decision making; Tools and techniques of decision making; Creativity and rationality in decision making; Models of decision making behaviour; Risk and certainty in decision making; Authority and responsibility in decision making; Communication- Functions, factors and features, process, barriers and principles, types and channels; Leadership-Meaning, importance, characteristics and styles.

Unit IV: Management process

Steps in management process; Planning- types and dimensions, planning in systems perspective, factors affecting planning; Organizing- Departmentalization, line and staff relationship; Coordinating – need, types, principles, techniques and problems of coordination; Directing; Controlling.

Unit V: Human behaviour and organization

Introduction to organizational behaviour; Values; Attitudes and performance; Motivation-Importance, contemporary theories of motivation, approaches, elements of sound motivation; Stress management- concepts, causes, consequences, stress managing techniques.

VII. Teaching Methods/ Activities

- Lectures
- Assignments
- Publication review
- Students' presentations
- Case studies
- Guest lectures
- Online learning

VIII. Learning Outcome

After successful completion of the course, the students will be able to:

- Identify managerial activities that contribute to managerial effectiveness
- Observe and evaluate the influence of historical forces on the current practice of management
- Explain how organizations adapt to an uncertain environment and identify techniques that managers apply to influence and control the internal environment

IX. Suggested Reading

- Gaurav A. 2010. *Management Functions and Process, Management Thought* https://kalyan-city.blogspot.com/2010/06/management-functions-process-management.html
- Hellregel. 2002. *Management*. Thomason Learning, Bombay.
- Henry John. 2019. Functions of Management Process: Planning, Organizing, Leading, Controlling https://iedunote.com/function-of-management-process
- Koontz H and Wechrich H. 2008. *Management*. Tata McGraw Hill Inc., N.Y.
- Draft Richard L. 2015. *Management*. Thomson South-Western.
- Robbins SP and Decenzo DA. 2010. *Fundamentals of Management*. Pearson Education Asia, New Delhi.
- SatyaRaju R and Parthasarthi A. 2009. *Management- Text &Cases*. PHI, New Delhi.
- Stephen PR and Mary AC. 2015. *Management*. 13th Edition. Prentice Hall of India. New Delhi.
- Subba Rao P. 2017. *Management and Organizational Behaviour* (*Text and Cases*). Himalaya Publishing House, New Delhi.
- Tripathi PC and Reddy PN. 2013. *Principles of Management*. Tata McGraw Hill Education Pvt Ltd, ND.

Weekly Lecture Schedule

Duration (week)	Topic
1	Nature and functions of management-definition and importance of management, management and administration; Management functions- Planning, organizing, staffing, directing, motivating, controlling and coordinating; Management principles- Importance, Fayol's principles of management.
2	Management levels-administrative level, executor level, supervisory level; Functional areas of management; Human resource management; Production management; Office management; Financial management and marketing management; Managerial skill- Roles and effectiveness.

Duration (week)	Topics
3	Evolution of management thought- Early classic approaches, scientific management, and Taylor's contribution, contributions of Gantt and Gilbreth, criticism of scientific management; Administrative management- Fayol's contribution, Principles of administration.
4	Limitations of administrative management; Bureaucracy- Important features, limitations; Classic approaches- Human relation approach, Hawthorne study.
5	Contributions and limitations of human relations approach; Behavioral approach- Emergence, key ideas, contributions and weaknesses; Modern approach- Contributions and limitations.
6	Quantitative approach-Contributions and limitations; Systems approach – Introduction, system's vocabulary, features of system, system's framework; Contingency approach-contributions and limitations.
7	Managerial competencies; Planning and administrative competencies; Decision making-Introduction, nature of managerial decision making; Approaches to decision making; Types of decisions; Process of decision making.
8	Tools and techniques of decision making; Creativity and rationality in decision making; Models of decision making behaviour; Risk and certainty in decision making; Authority and responsibility in decision making.
9	Communication-Functions, factors and features; Communication Process; Barriers of communication; Principles of communication; Types and channels.
10	Leadership- Meaning and importance, characteristics and styles of leadership; Management process; Steps in management process; Planning- Nature, types, importance and dimensions.
11	Strategic planning process; Planning in systems perspective; Factors affecting planning, limitations of planning.
12	Organizing-Process, departmentalization, organization structure, line and staff relationship; Coordinating-Need, types, principles.
13	Techniques and problems of coordination; Difference between coordination and cooperation; Directing- Elements of directing; Controlling- Need, steps, benefits and problems of controlling, controlling techniques.
14	Human behaviour and organization; Introduction to organizational behaviour; Values; Attitudes and performance; Motivation- definition, process, nature and importance of motivation.
15	Contemporary theories of motivation; Approaches and elements of sound motivation; Stress management- concepts and causes.
16	Signs and symptoms of stress; Sources and consequences of stress; Stress managing techniques.

I. Course Title : Human Factors and Ergonomics

II. Course Code : RMCS 502

III. Credit Hours : 3(2+1)

IV. Rationale

Ergonomics is an applied science that coordinates the design of devices and physical working conditions with the capacities and requirements of the worker. Human factors and ergonomics is the application of physiological and psychological principles to design of products, processes, and systems. The course is intended to train the students to reduce human error, increase productivity, and enhance safety and comfort with a specific focus on the interaction between the human and the thing of interest.

V. Aim of the course

- To acquaint students with basic principles of human anatomy, physiology, human anthropometry and its relation to ergonomics
- To enable the students, understand the human factors and its relation to ergonomic design.

VI. Theory

Unit I: Introduction to ergonomics

Definition, aim, objectives and scope of ergonomics; Domains of ergonomics; Historical development of ergonomics and human factor; Interface between man machine and environment; Ergonomics in design.

Unit II: Human body systems

Structure and functions of major body systems- parts and basic functions of skeletal system; Properties and functions of muscular system; Components of circulatory system; Parts and functions of respiratory system; Structure and functions of digestive system and nervous system.

Unit III: Human anthropometry

Human anthropometry; Static and dynamic anthropometry; Anthropometric measurements; Normal distribution and percentiles; Anthropometry in ergonomics and design.

Unit IV: Body movement and postures

The functions and movements of skeletal system - functional classification of bones, joints, ligaments and tendons; Neuromuscular aspects of movement; Joints and movements; Classification of joints on the basis of function; Movement at synovial joints; Skeletal muscle as levers; Posture- Work posture, postural discomfort and its impact on work and human health, posture analysis tools.

Unit V: Work physiology

Fundamentals of work physiology; Muscular efforts; Energy consumption; Physical fitness-Measuring physical fitness using different techniques; Physical work capacity and its measurement; Determination of cardiac cost of work; Factors influencing energy requirements and energy costs for various activities.

VII. Practical

1. Collection of anthropometric measurements of school children
2. Analysis of data on school children anthropometry
3. Presentation of report on school children anthropometry
4. Designing study table based on the anthropometric data
5. Measuring the work posture of a worker involved in manual work using RULA/ REBA/OWASA
6. Analysis of work posture data
7. Presentation of report on work posture of person involved in manual work
8. Determination of physical fitness using any one of the technique
9. Analysis of data and presentation of report on physical fitness
10. Measurement of cardiac cost of selected activity
11. Analysis of data on cardiac cost of selected activity
12. Presentation of report on cardiac cost of selected activity
13. Assessment of ergonomic cost of work in terms of physiological indices

14. Analysis of data on ergonomic cost of work
15. Presentation of report on ergonomic cost of work
16. End of Term Assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Student presentations
- Group and individual research work
- Field visits
- Guest lectures

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Appreciate the role of ergonomics in reducing human error in designing and increase productivity
- Understand the importance of people in work systems, their abilities and limitations for designing tasks and work for effectiveness, efficiency, health and safety
- Contribute to new thinking and innovation processes within human factors and ergonomics

X. Suggested Reading

- Benchmark Research and Safety Inc. 2008. *A Brief History of Human Factors and Ergonomics* http://www.benchmarkrs.com/main/human-factors/what.aspx
- Dalela S and Saurabh. 1999. *Text book of Work Study and Ergonomic*s. Standard Publishers and Distributors, Delhi.
- Galer IAR. 1982. *Applied Ergonomics Handbook*. Butterworth-Heinemann.
- Grandgean E. 1978. *Ergonomics of the Home*. Taylor & Francis, London.
- Grandjean E. 1980. *Fitting the Task to the Man*. Taylor & Francis, London.
- Jain AK. 2017. *Human Anatomy and Physiology*. Arya Publications, Udaipur.
- Panero J and Zelnik M. 1979. *Human Dimension and Interior Space*. Whitney Library of Design.
- Roebuck John A. 2016. *Anthropometric Methods: Designing to Fit the Human Body*. http://www.hfes.org/Publications.
- Rodahl AK, Hans A Dahl and Sigmund B Stromme. 2005. *Text Book of Work Physiology*. CRC Press, London.
- Salvendy (Ed). 2006. *Handbook of Human Factors and Ergonomics*. Third edition, John Wiley and Sons, Hoboken, NJ.

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction to ergonomics- Definition, aim, objectives and scope of ergonomics; Physical, cognitive and organizational domains of ergonomics; History and status of ergonomics; Developments in the field of ergonomics; Approaches, characteristics, classification and interface between man, machine and environment system.
2	Ergonomics in designing for human comfort and safety; Human body systems; Components of human skeleton -bones, cartilage, joints.
3	Parts of human skeleton-Skull, vertebral column, rib cage, shoulder girdle, skeleton of upper limb, pelvic girdle, skeleton of lower limb; Functions of human skeletal system- Strength, support and shape, protection of delicate organs, leverage for movements, production of red blood cells.

Duration (week)	Topics
4	Introduction to muscular system; Properties of muscles- irritable, contractible, extensible, elastic and adaptability; Types of muscles-Skeletal muscles, cardiac muscles, smooth muscles.
5	Functions of the muscular system- Mobility, stability, posture, circulation, respiration, digestion, urination, childbirth, vision, organ protection, temperature regulation; Components of the human circulatory system- Heart, blood, red and white blood cells, platelets, and the lymphatic system.
6	Respiratory system-Upper respiratory tract, nose, mouth, and the beginning of the trachea; Lower respiratory tract-The trachea, the bronchi, bronchiole and the lungs.
7	The act of breathing– inhalation and exhalation and involvement of muscles; Measurements of lung function.
8	Structure and functions of digestive system and nervous system; Human anthropometry- Static and dynamic anthropometry.
9	Anthropometric measuring techniques; Normal distribution and percentiles; Anthropometry in ergonomics and design-designing for extremes, designing for adjustability, designing work heights.
10	The skeletal system- Functions and movements; Functional classification of bones, joints, ligaments, tendons.
11	Neuromuscular aspects of movement; Joints and skeletal movement; Classification of joints on the basis of structure-Fibrous joints, cartilaginous joints, synovial joints.
12	Classification of joints on the basis of function- synarthrosis, amphiarthroses, diarthroses; Movement at synovial joints- Gliding movement, angular movement, rotational movement, special movements.
13	Skeletal muscles as levers and their role in body movement; Posture- Workplace posture, posture and muscle activity, postural discomfort and its impact on work and human health.
14	Posture analysis tools- Rapid Upper Limb Analysis (RULA); Rapid Entire Body Analysis (REBA); Ovako Working Posture Analysis (OWASA); Fundamentals of work physiology- Muscular efforts, energy consumption, body size and movements.
15	Physical fitness- Techniques to measure physical fitness; Physical work capacity and its measurement.
16	Determination of cardiac cost of work; Factors influencing energy requirements and energy costs for various activities.

I. Course Title : Interior Space Planning

II. Course Code : RMCS 503

III. Credit Hours : 3(1+2)

IV. Rationale

Space planning either in residential or commercial buildings is the most imperative aspect of interior design profession. The interior designer is expected to develop a space plan for either residential or commercial buildings with its space allocations and divisions, arrangements and organizations to accommodate the functional, special and occupancy requirements in the form of space layout and final planning. The course is designed to expose students to advances in interior space designing process.

V. Aim of the course

- To gain insight into the process of interior design and the various aspects and considerations involved in practice of both residential and commercial design
- To exposes the students to advanced space planning techniques of residential and commercial buildings.

VI. Theory

Unit I: Interior design and user comfort

Residential buildings- Types and its characteristics; Commercial buildings- Types and its characteristics; Effect of interior design on user comfort- residential, commercial, special needs.

Unit II: Building planning principle

Functional and aesthetic considerations in the use of elements of design; Functional and aesthetic considerations in the use of principles of design; Housing principles for designing public private and circulation spaces; Advances in design process of residential interiors-Personal space, public space, utility space; Advances in design process of commercial interiors- Service institutions, marketing institutions; Recent trends in interior space management.

Unit III: Space standards

Space standards for various rooms in residential and commercial buildings; Building materials and their standards; Space saving furniture.

Unit IV: Building services

Electrical and safety fittings; House wiring; Plumbing systems for residential and commercial buildings; Sanitary fittings and fixtures for residential and commercial buildings.

VII. Practical

1. Preparation of a schedule to collect information regarding the characteristics of residential and commercial buildings
2. Visits to identify the characteristics of residential buildings
3. Visits to identify the characteristics of commercial buildings
4. Presentation of report on characteristics of residential and commercial buildings
5. Designing a residential house as per space standards –development of conceptual drawings
6. Designing a residential house as per space standards –development of design details and working drawings
7. Designing a residential house as per space standards –portfolio preparation
8. Designing a residential house as per space standards –presentation and group discussion
9. Designing any commercial building as per space standards- development of conceptual drawings
10. Designing any commercial building as per space standards- development of design details and working drawings
11. Designing any commercial building as per space standards- portfolio preparation
12. Designing any commercial building as per space standards- presentation and group discussion
13. Market survey on electrical and sanitary fittings and fixtures

14. Market survey on space saving furniture suitable
15. Presentation of report on sanitary fittings, fixtures and space saving furniture for residential and commercial buildings available in market
16. Cost estimation of residential building (apartment/condominium/row house)
17. Cost estimation of commercial building (Ice cream parlor/Tiffin centre/beauty salon/ restaurant, etc.)
18. Designing space saving furniture for residential buildings
19. Portfolio preparation on space saving furniture for residential buildings
20. Presentation of report on space saving furniture for residential buildings
21. Design and development of space saving furniture for commercial buildings
22. Portfolio preparation on space saving furniture for commercial buildings
23. Presentation of report on space saving furniture for commercial buildings
24. Project on renovation of a residential building with cost estimation
25. Portfolio preparation on renovation of a residential building with cost estimation
26. Presentation of report and group discussion on renovation of a residential building with cost estimation
27. Project on renovation of a commercial building with cost estimation
28. Portfolio preparation on renovation of a commercial building with cost estimation
29. Presentation of report and group discussion on renovation of a commercial building with cost estimation
30. Preparation of material board and presentation for a residential project
31. Preparation of material board and presentation for a commercial project
32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Field visits
- Assignments
- Preparation of manuals
- Market survey
- Students' presentation
- Group and individual research work
- Guest lectures

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Understand the effect of interior design on user comfort and plan interiors for residential, commercial and special needs
- Get acquainted with recent trends in interior space management
- Develop plans as per space and building materials standards
- Update knowledge on building services

X. Suggested Reading

- Allen PS, Stimpson MF and Jones LM. 2000. *Beginnings of Interior Environments*. Prentice Hall.
- Choudhari SN. 2006. *Interior Design*. Avishkar Publ.
- Gilliatt M. 1981. *The Decorating Book*. Pantheon Books.
- Hamstech Interior Design. 2017. *Importance of Space Planning in Interior Designing* http://www.hamstech.com/blog/importance-of-space-planning-in-interior-designing/
- Panero J and Zelnik M. 1979. *Human Dimension and Interior Space*. Whitney Library of Design.

- Parikh A, Robertson D, Lane T, Hilliard E and Paine M. 2000. *The Ultimate Home Design Source Book*. Conran Octopus.
- Pears A, Lawrence M, Hymers P and Howell J. 2000. *Working with the Professionals*. Marshall Publ.
- Philip S. 2017. *Concept Design and Space Planning*.https://www.designblendz.com/solutions/concept-design-space-planning
- Seetharaman P and Pannu P. 2005. *Interior Design and Decoration*. CBS.
- Zimmerman N. 2003. *Home Workspace Idea Book*. The Taunton Press.

Weekly Lecture Schedule

Duration (week)	Topic
1	Types and characteristics of residential buildings; Types and characteristics of commercial buildings-Public and private educational institutions, health related buildings, recreational buildings, market buildings, etc.
2	Effect of interior design on user comfort in residential, commercial and buildings for people with special needs in terms of colour, space, texture, and light.
3	Functional and aesthetic considerations in the use of elements of design- Line, form, texture, colour, pattern and space.
4	Functional and aesthetic considerations in the use of principles of design – Proportion, balance, emphasis, harmony and rhythm.
5	Housing principles for designing public spaces and private spaces like living room, dining room, porticos, drawing room, media room, bedrooms, pooja room, bathrooms, bar area, etc.
6	Housing principles for designing circulation and utility spaces – kitchen, laundry, stair cases, path ways and corridors.
7	Advances in design process of residential interiors- Personal space, public space, utility space.
8	Advances in design process of commercial interiors- Service institutions, marketing institutions.
9	Recent trends in interior space management with reference to colour, architectural features, building materials, etc.
10	Space standards for public, private, utility and circulation spaces in residential and commercial buildings.
11	Building materials and their standards.
12	Space saving and multipurpose furniture suitable for residential and commercial interiors and their standards.
13	Electrical and safety fittings; Wiring system in residential and commercial buildings.
14	Plumbing systems for residential buildings in terms of fittings and fixtures.
15	Plumbing systems for commercial buildings in terms of fittings and fixtures.
16	Sanitary fittings and fixtures for residential and commercial buildings.

I. Course Title : Consumer Economics

II. Course Code : RMCS 504

III. Credit Hours : 3(2+1)

IV. Rationale

Consumer economics is a broad field, principally concerned with microeconomic analysis behaviour in units of consumers, families, or individuals. Students need to develop in-depth understanding of the functioning of domestic and global economies and to develop the necessary and portable skills to perform economic analysis. The course will provide an insight to understand the role of consumption in shaping India's economy

V. Aim of the course

- To provide a comprehensive study of the basic institutions, concepts, principles, and practices of economics
- To impart knowledge about consumer behaviour with reference to micro and macroeconomic systems and its impact on consumption behavior.

VI. Theory

Unit I: Consumer behaviour

Consumer behavior; Environmental influences on consumer behaviour; Individual determinants of consumer behavior; Models of consumer behavior - Micro economic model, Nicosia model, Howard-Sheth model, Engel- Block well-Miniard model; Application of consumer behaviour knowledge in marketing; Consumer decision process- Problem recognition, search and evaluation, purchasing process, post purchasing behavior; Researching consumer behaviour.

Unit II: National income

Definition and significance; Concepts of national income; Methods of measurements of national income - value added method, income method, expenditure method, reconciliation of the three measures of national income; Difficulties in measurement of national income- Conceptual difficulties and practical difficulties; National income and Economic welfare.

Unit III: Consumption economics

Concept of consumption economics; Theories of consumption- Engels law of consumption, relative income theory of consumption, life cycle theory of consumption, permanent income theory of consumption; Budget and economy; Fiscal policy; Annual financial statement of the government and budget; Revenue receipts and revenue expenditure; Capital receipts and capital expenditure; Overall budget; Concepts of deficits in government budget; Revenue deficits and fiscal deficit; Taxation- India's tax structure; Tax as a source of public revenue; Direct and indirect taxes; Merits and demerits of taxes; Role of indirect tax in a developing economy; Incidence and effects of taxes; Inflation- Meaning of inflation, types of inflation, causes, effects, measures to check inflation; Deflation- Meaning, deflation and disinflation, causes, effects, measures to control deflation.

Unit IV: Financial systems of India

Introduction to financial system of India; Financial institutions; Financial services; Financial markets; Structure of Indian financial system; Importance of financial system for the economic development; Banking-Types of banking institutes; Functions; Types of loans and advances; Indian money market; Indian capital market; Financial intermediaries and services; Insurance and its regulations.

VII. Practical

1. Project work: Study of consumer buying behaviour while buying a selected commodity –Collection of review
2. Formulation of objectives of the study
3. Selection of sample, and study location
4. Designing the data collection tool

5. Pre testing and finalization of data collection tool
6. Collection of data
7. Data analysis
8. Report writing
9. Finalization of report
10. Presentation of the report on "Consumer buying behaviour while buying a selected commodity"
11. Discussion on the findings of the research
12. Visit to any one financial institute
13. Preparation of documents required for applying for a loan
14. Study the trends of stock market index given in magazines or news papers
15. Critical analysis of National Budgets through panel discussion.
16. End of Term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Students' presentation
- Group work
- Student's interview of key policy makers
- Case analysis and case studies
- Guest lecture
- Review of policy documents

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Understand how markets organize core economic activities, such as production, distribution, consumption, and the growth of productive resources
- Appreciate the role of factors that influence consumer decisions in consumer buying behaviour
- Gain knowledge on the determinants of macroeconomic conditions , causes of business cycles, and interactions of monetary and fiscal policy

X. Suggested Reading

- Ahuja HL. 2012. *Modern Micro Economics: Theory & applications*. Chand Company Ltd., New Delhi.
- Chadha R. 1995. *The Emerging Concepts and Strategies*. New Age International & Wiley Eastern.
- Deepashree. 2016. *Introductory Macroeconomics*. Saraswati House Pvt Ltd.
- Dewett KK and Varma JD. 2017. *Elementary Economic Theory*. S. Chand & Company Ltd., New Delhi.
- Dhingra IC and Garg VK. 2002. *Basic Economics & Business Environment*. Sultan Chand & Sons, New Delhi.
- Dhingra IC and Garg VK. 2004. *Economics Fundamentals*. Sultan Chand & Sons, New Delhi.
- Kaur S, Lekhi RK and Joginder S. 1997. *Consumer Economics*. Kalyani Publishers.
- Loudon David L and Albert JDB. 1993. *Consumer Behaviour*. 4th edition. Tata McGrawHill Publishing company Limited, New Delhi.
- Marguerite B. 2000. *Consumer Economics: A Multidisciplinary Approach*. John Wiley &Sons.
- Schiffman LG and Kaunuk LL. 2004. *Consumer Behaviour*. Prentice Hall of India.

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction to consumer behaviour, consumer and customer, buyers and users, organization of buyers, development of marketing concept. Environmental influences on consumer behaviour- Culture, social class, family, personal influences; Diffusion of innovations.
2	Individual determinants of consumer behaviour- personality and social concept, motivation and involvement, information processing, learning and memory, attitudes; Models of consumer behaviour-Micro economic model, Nicosia model.
3	Models of consumer behaviour- Howard-Sheth model, Engel- Block well-Miniard model; Application of consumer behaviour knowledge in marketing; Consumer behaviour and marketing management; Consumer behaviour and non-profit and social marketing; Consumer behaviour and government decision making; Consumer behaviour and consumer research process.
4	Consumer decision process-Problem recognition, search and evaluation, purchasing process, post purchasing behaviour; Researching consumer behaviour-Consumer research strategies, methods of gathering information, measuring consumer characteristic.
5	National income-definition and significance; Concepts of national income- Gross Domestic Product (GDP), Gross National Product (GNP), Net Domestic Product (NDP), Net National Product (NNP).
6	Concepts of national income- Net national product at market price, net domestic product at factor cost, income from domestic product occurring to private sector, private income, personal income, personal disposable income, inter-relationship between different concepts of national income; Methods of measurements of national income-value added method, income method.
7	Methods of measurements of national income- Expenditure method, reconciliation of the three measures of national income; Difficulties in measurement of national income-Conceptual difficulties and practical difficulties.
8	National income and economic welfare- Changes in the composition of national income and economic welfare, changes in the distribution of national income and economic welfare; Consumption economics-Definition, terms and concepts.
9	Theories of consumption- Engels law of consumption, relative income theory of consumption,life cycle theory of consumption, permanent income theory of consumption.
10	Budget and economy- Fiscal policy, objectives, annual financial statement of the government and budget; The Budget-revenue receipts and revenue expenditure, capital receipts and capital expenditure, overall budget, concepts of deficits in government budget, revenue deficits and fiscal deficit.
11	Taxation; India's tax structure; Tax as a source of public revenue, direct and indirect taxes, merits and demerits of taxes, role of indirect tax in a developing economy, incidence and effects of taxes; Inflation- Introduction, meaning of inflation, types of inflation, causes, effects, measures to check inflation.
12	Deflation- Meaning, deflation and disinflation, causes, effects, measures to control deflation; Introduction to financial system of India- Financial institutions, financial services, financial markets.
13	Meaning of financial services, structure of Indian financial system, importance of financial system for the economic development; Definition of Bank, Functions of Reserve Bank of India, Commercial Banks, Regional Rural Banks, Cooperative Banks, Micro Finance, Priority Sector Lending, NABARD, Development Financial Institutions SFC, SIDBI.
14	Types of loans and advances, principles of sound lending policies, credit appraisals of various forms of loans and advances; Modes of creating charges-lien, pledge,

Duration (week)	Topics
	mortgage and hypothecation; Indian money market- Characteristics, structure, composition; Problems and reforms in Indian money markets.
15	Indian capital market- Composition and growth of primary and secondary markets, difference between primary and secondary markets, capital market reforms and NBFC in capital markets, stock exchange, NSE, OTCEL, Online trading and role of SEBI; Financial intermediaries and services- Merchant banker, mutual funds, leasing companies, venture capital funds, forfeiting, loan syndication, factoring, custodial services, depository services and depository by participants.
16.	Meaning of insurance and reinsurance; Principles and advantages of insurance; Globalization of insurance and insurance sector reforms in India; Types of insurances; Regulations of insurance in India; Insurance act 1938.

I. Course Title : Work and Workstation Design

II. Course Code : RMCS 505

III. Credit Hours : 3(1+2)

IV. Rationale

Workplace design has a profound impact on the productivity of workers. Making the best use of space through optimum placement of equipment, integrating the human factor into workplace design, and effectively aligning the workplace into the surrounding environment are important aspects of ergonomics. This course prepares students to develop work stations as per the requirements of the organizations and its technologies that satisfy the workers individual requirements.

V. Aim of the course

- To acquaint students with the interrelatedness of work, worker and workstation environments
- To infuse an interdisciplinary approach to workstation engineering and techniques to reduce human cost of work.

VI. Theory

Unit I: Work, worker and workplace

Work, worker and workplace-definition, types and interrelationship**;** Classification of work based on energy consumption and nature of work; Time and energy requirements of work; Introduction to components of worker input- affective, cognitive, temporal and physical.

Unit II: Work measurement techniques

Work measurement techniques- Subjective judgment, Record of past performance, Scientific methods; Tools for work analysis-charts, diagrams, models and photographic aids.

Unit III: Workplace layout and equipment design

Principles of workstation and system design; Design and arrangement of different work centers; Work reaches; Working heights; Visual design parameters- Work surface, space allowance and storage; Design considerations for different workstation designs-Seated work, Standing work, Sit stand work; Controls, displays and information; Visual, auditory and other displays; Quantitative and qualitative information; Methodologies for studying workplace design; Hazards of ill designed workstation.

Unit IV: Physical factors of the work environment

Environmental factors in workplace and their measurement-Heat, light, sound and noise, vibration, radiation, humidity; Effect of environmental parameters on worker and work performance.

VII. Practical

1. Selection of workplace unit for taking the anthropometric measurements of worker and dimensions of equipment and furniture used in a selected workplace units
2. Measuring and recording the anthropometric measurements of worker in the selected workplace unit
3. Measuring and recording the dimensions of equipment and furniture used in the selected workplace unit
4. Working on developing design for a workplace unit as per data collected in previous exercise
5. Determining the space relationships as per workers anthropometry
6. Determining the space relationships as per workers posture and movement at selected workstations
7. Developing the 2D design of selected workplace unit
8. Developing the 3D design of selected workplace unit
9. Work measurement in the selected workstation using two hand process charts
10. Analysis of data collected
11. Presentation of report on work done in the selected workstation using two hand process charts
12. Work measurement in the selected workstation using photographic aid
13. Analysis of data on work measurement collected in the selected workstation using photographic aid
14. Presentation of report on work done in the selected workstation using photographic aid
15. Measuring environmental factors in the workplace: Heat
16. Measuring environmental factors in the workplace: Light
17. Measuring environmental factors in the workplace: Noise
18. Measuring environmental factors in the workplace: Vibration
19. Measuring environmental factors in the workplace: Radiation
20. Measuring environmental factors in the workplace: Humidity
21. Analysis of data collected on environmental parameters
22. Presentation of report on environmental parameters
23. Developing a design layout of a selected commercial workplace: Preparation of check list
24. Collection of data on design features, space relationships, dimensions of equipment and furniture, and environment control parameters in the workplace
25. Analyzing the data
26. Finalizing the dimensions of selected commercial workplace
27. Developing a design layout of the selected commercial workplace based on the DATA.
28. Presentation and group discussion on the design layout of the selected commercial workplace
29. Finalization of design layout of the selected commercial workplace

30. Developing 2D plan of the selected commercial workplace
31. Developing 3D workplace design of the selected commercial workplace
32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Reading assignment
- Photographic technique for recording posture at workplace
- Hands on experience on measuring ergonomic parameters
- Students' presentation
- Group discussions
- Guest lectures
- Visits to industries

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Asses the workers requirements in a workplace
- Determine the space relationships as per workers anthropometry, posture and movement at any workstations
- Develop workplace design for various occupations

X. Suggested Reading

- Barnes RM. 1980. *Motion and Time Study*. John Wiley & Sons.
- Bridger JD. 1995. *Introduction to Ergonomics*. McGraw-Hill Book Co., Singapore.
- Dalela S and Saurabh. 1999. *Textbook of Work Study and Ergonomics*. Standard Publishers Distributors, Delhi.
- GalerIAR. 1982. *Applied Ergonomics Handbook*. Butterworth-Heinemann.
- Grandgean E. 1978. *Ergonomics of the Home*. London: Taylor & Francis.
- Grandjean E. 1980. *Fitting the Task to the Man*. Taylor & Francis, London. https://workdesign.com/2012/08/ergonomics-and-workplace-design/
- Mundel M. 1978. *Motion and Time Study*. Prentice Hall.
- Panero J and Zelnik M. 1979. *Human Dimension and Interior Space*. Whitney Library of Design.
- Singh S. 2007. *Ergonomics Interventions for Health and Productivity*. Himanshu Publications.
- Thomas Jiji. 2012. *Ergonomics and Workplace Design*

Weekly Lecture Schedule

Duration (week)	Topic

1. Definition, types and interrelationship of work, worker and workplace.
2. Classification of work-Based on the amount of physical exertion that the work requires as sedentary, light, medium, heavy, and very heavy; Based on the nature of work as manual repetitive, cognitive repetitive, manual non repetitive and cognitive non repetitive work; Time and energy requirements of work.
3. Introduction to components of worker input- affective, cognitive, temporal and physical.
4. Affective component- job satisfaction, task performance and goal of work; Cognitive component- Knowledge, thinking and mental skill.
5. Temporal component- Techniques of organizing work; Physical Component-Productivity.
6. Work measurement techniques- Subjective judgment, record of past performance, scientific methods.

7. Tools for work analysis (i) Charts indicating sequence of events, flow process chart, two hand process chart; (ii) Charts indicating sequence of events happening in the order in which they occur on a time scale-Multiple activity chart, man-machine chart, simo chart; (iii) Diagrams indicating movements along the events happening in the order in which they occur- Flow diagram, string diagram, cycle graph, chrono-cycle graph, travel chart.
8. Tools for work analysis- (i) Models indicating the actual layout on a dimensional scale, two dimensional models, three dimensional model; (ii) Photographic aids.
9. Principles of workstation and system design.
10. Design and arrangement of different work centres, work reaches, working heights.
11. Design considerations for different workstation designs- Seated work, standing work, sit stand work.
12. Controls and displays- Visual, auditory and other displays, quantitative and qualitative information.
13. Methodologies for studying workplace design- Formal and informal techniques.
14. Hazards of ill designed workstation.
15. Environmental factors in workplace and their measurement- Heat, light, sound and noise, vibration, radiation, humidity.
16. Effect of environmental parameters on worker and work performance.

I. Course Title : Colour and Lighting in Interiors

II. Course Code : RMCS 506

III. Credit Hours : 3(2+1)

IV. Rationale

Colour and lighting influence and manipulate space through strategic lighting designs. The study of the relationship between light, colour and spaces is an essential element of the whole interior design process. The course provides an opportunity for students to learn principles of lighting and investigate lighting for contemporary lifestyle and luxury interiors and correctly interpret the 'light' atmosphere of a space and translate this into creative and technical lighting solutions.

V. Aim of the course

- To gain insight into the use of colour and lighting in various buildings and its significance
- To assess the technical aspects and interrelationship of colour and light and their effect on interior spaces.

VI. Theory

Unit I: Colour as an interior design element

Historical perspective of colour as an interior design element; Properties of colour - Hue, value and intensity; Approaches and theories of colour.

Unit II: Applications of colour in various elements of interiors

Cultural and psychological effects of colour; Types of colour schemes-Related colour schemes, contrast colour schemes; Factors to consider while choosing colour schemes for buildings; Suitable colour schemes for residential, commercial, public, educational and religious building interiors.

Unit III: Introduction to lighting in interior

Importance and sources of lighting; Cultural and social aspects of lighting; Physiology of vision; Properties of lighting - Reflection, absorption, transmission and diffusion; Types of lighting; Safety and emergency lighting; Lighting requirements for household activities; Lighting requirements in commercial buildings.

Unit IV: Quantity and quality of lighting

Measurement of light and its units; Types of lamps from animal fat lamps to LEDs, their characteristics and suitability to various rooms; Types of lighting based on direction of use, place of use, purpose and portability; Lighting controls- Type, selection, care, maintenance and economic use; Lamp holders; Lighting switches; Motion sensors; Factors affecting the quantity of illumination in a room- Room proportion, colour, texture and cleanliness of room surface, lamp lumen, lamp lumen depreciation; Method of calculating lighting requirements for various rooms; Lighting for outdoor living and gardens.

Unit V: Effect of colour on lighting

Colour rendition; Use of colour and lighting in architecture, materials and finishes from 16th century to the date; Use of colour and lighting in problematic areas to disguise and camouflage.

VII. Practical

1. Study of types of colour schemes in residential interiors
2. Study of types of lamps and lighting used in residential interiors
3. Group discussion on use of colour and lighting in interiors
4. Study of types of colour schemes in commercial interiors
5. Study of types of lamps and lighting used in commercial interiors
6. Presentation on use of colour and lighting in commercial interiors
7. Suggesting suitable colour schemes for residential buildings and its cost estimation
8. Suggesting suitable colour schemes for commercial buildings and its cost estimation
9. Group discussion on suitable colour schemes for residential and commercial buildings
10. Suggesting suitable lighting fixtures for residential buildings and its cost estimation
11. Suggesting suitable lighting fixtures for commercial buildings and its cost estimation
12. Group discussion on suitable lighting fixtures for residential and commercial buildings
13. Prepare a colour and lighting plan for problematic areas like space below stair case and estimate the cost
14. Prepare a colour and lighting plan for problematic areas like, irregular shape rooms or narrow areas and estimate the cost
15. Market survey to understand the available safety and emergency lighting systems and presentation of report
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Preparation of manuals

- Students' presentation
- Visits to institutes
- Group research work
- Guest lectures

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Develop a detailed lighting plan for different context
- Successfully create a project outline on lighting installation for residential and commercial interiors, events and exhibition
- Design suitable colour scheme for residential and commercial building interiors

X. Suggested Reading

- Cullision PW. 1981. *New Decorating Boo*k. Meredith Corporation, Iowa.
- James D. 1997. *Lighting*. Cassell Publ, U.K.
- Mark K and James Benya. 2004. *Lighting Design Basics*. John Wiley &Sons, Inc, U.S.A.
- Michael W. 2002. *Advances in Colour Harmony & Contrast for the Home Decorator*. School of Colour Publ.
- Parikh A *et al*. 2000. *The Ultimate Home Design Source Book*. Conran Octopus, London.
- Sarao M and Laurie Z. 1995. *The Power of Colour*. John Wiley & Son.
- Stepat Dorothy. 1971. *Introduction to Home Furnishings*. MacMilan.
- Tim Anderson. 2018. *Importance of Lighting in Interior Design* https://homeguides.sfgate.com/importance-lighting-interior-design-56751.html

Weekly Lecture Schedule

Duration (Week)	Topic
1	Historical perspective of colour as an interior design element- Definition, origin, old theories of colour; Properties of colour -Hue, value and intensity and their effect on space and texture in different rooms.
2	Approaches to the concept of colour- Physicist, physiologist, chemist, artist, and psychologist; Theories of colour –Prang and Munsell colour theories.
3	Theories of colour – Ostwald colour theory; Cultural and psychological effects of primary, secondary and tertiary colours.
4	Related colour schemes- Monochromatic, analogous, neutral colour schemes; Characteristics and applicability of related colour schemes in interiors; Contrast colour schemes- Single, double and split complementary, triad and tetrad colour schemes; Characteristics and applicability of contrast colour schemes in interiors.
5	Factors to consider while choosing colour schemes for buildings -Age, gender, orientation of the room, climate, personal preferences, mood, occasion, etc.; Suitable colour schemes for residential, commercial, public, educational and religious building interiors.
6	Importance and sources of lighting - Natural and manmade; Cultural and social aspects of lighting -Usage for different occasions.
7	Physiology of vision with reference to the perception of colour; Properties of lighting- Reflection, absorption, transmission and diffusion.
8	Types of lamps for household and commercial interiors- Low intensity and high intensity discharge lamps; Safety and emergency lighting needs in residential and commercial buildings.
9	Lighting requirements in residential buildings for cooking, reading, washing, sewing, cleaning, watching, grooming, etc.; Lighting requirements in commercial buildings like banks, bus stations, air ports, stadiums, theatres, restaurants, etc.
10	Measurement of light and its units- Lumen, candle power, lux, foot candle; Types of lamps from past to present, their characteristics and suitability to various rooms.

Duration(Week)	Topic
11	Types of lighting based on direction of use, place of use, purpose and portability; Types of architectural lighting -. Luminous, recessed, valance, cove, cornice, etc.
12	Lighting Controls- Type, selection, care, maintenance and economic use- lamp holders, lighting switches, motion sensors; Factors affecting the quantity of illumination in a room-Room proportion, colour, texture and cleanliness of room surface, lamp lumen, lamp lumen depreciation.
13	Method of calculating lighting requirements for various rooms by lamp lumen method; Lighting for outdoor living like terraces, balconies, patios, decks, etc. and gardens in residential and commercial buildings.
14	Meaning of colour rendering, types of glare and visual illusions; Use of colour and lighting in Roman, English, French and Indian architecture from 16^{th} century to the date.
15	Use of colour and lighting in materials (wall, floor, ceiling, furnishings) and in finishes (wall, floor, ceiling) from 16^{th} century to the date.
16	Use of colour and lighting in problematic areas to disguise - Low height rooms, high ceiling rooms, narrow rooms, tiny rooms, projections and recesses, spaces below stair cases, awkward shape windows, irregular shaped rooms.

I. Course Title : Consumer Issues and Legislations

II. Course Code : RMCS 507

III. Credit Hours : 2(2+0)

IV. Rationale

Globalization of trade, market-dominated economy, information revolution and emergence of e-commerce has contributed towards development of consumer protection measures. The subject has received tremendous importance among the contemporary legal fraternity in India. The legal experts are emphasizing on the need for teaching consumer law to present generation for making them equipped to handle issues relating to this branch of law. In this background the present course will introduce the students to the existing law and practice relating to consumer protection.

V. Aim of the course

- To acquaint the students with various consumer issues and legislative framework available for consumer protection
- To make students approach the subject from a multifaceted erspectives such as changing trends in consumerism, legal and non-legal consumer protection measures, consumer and communication tools.

VI. Theory

Unit I: Consumer issues

Changing trends in consumerism; Profile of consumers in India and abroad; Consumer issues and challenges; Social media management; Consumer finance; Multiple tax structure: Gender issues in consumerism; Gender division of labour; Access to decision making; Marketing and gender consumerism; Wealth and gender consumerism; Green consumerism- Definition, objectives and necessity of green consumerism; Agriculture credit in India; Agriculture marketing in India.

Unit II: Consumer legislations

Significance of consumer guidance and counseling; Consumer protection measures- Legal and non-legal consumer legislations; The Contract Act 1982; The Sale of Goods Act 1930; The Essential Commodities Act 1955; The Agricultural Produce (Grading and Marking) Act 1937; The Standard of Weights and Measures Act 1976; The Trade Mark Act 1999; The Competition Act 2002; The Bureau of Indian Standard Act 1986; Consumer Protection Act1986; Consumer protection Bill 2018; Right to Information Act 2005; Information Technology Act 2000; Food Safety and Standards Act,2016.

Unit III: Consumer and communication tools

Consumer communication- Significance, history and types; Communication media and social change; Trends in consumer communication; Media and consumer demand; Advertising as a mode of communication; Trends and impact of advertising on consumers; Social media- chats, Blogs, Face book, LinkedIn, Twitter, Instagram, Pinterest, YouTube.

Unit III: On line marketing

E-marketing in India- Evolution; Growth and challenges; Legislative frame work.

VII. Teaching Methods/ Activities

- Lectures
- Assignments
- Book/Publication Review
- Students' presentation
- Group work
- Guest lectures
- Review of policy documents

VIII. Learning Outcome

After successful completion of the course, the students will be able to

- Understand challenges faced by consumers in the economy because of changing trends in consumerism
- Conversant with major national and international instruments on consumer protection.
- Recognize common problems involving consumer transactions; identify relevant statutes and regulations; and apply them to specific problems

IX. Suggested Reading

- Bhatt R. 2010. *Consumer Behaviour*. Common Wealth Publishers Pvt. Ltd.
- Clarke J, Janet N, Smith EV and Westmarland L. 2007. *Creating Citizen Consumers*. Sage Publ.
- Jones RN. 2007. *Basic Counseling Skills*. Sage Publ.
- *Nations Guidelines on Consumer Protection*. 2008. https://unctad.org/en/Pages/DITC/CompetitionLaw/UN-Guidelines-on-Consumer- Protection.aspx
- Pant H. 2007. *Advertising & Media*. ABD Publishing.
- Potter WJ. 2008. *Media Literacy*. Sage Publ.
- Seetharaman P and Sethi M. 2001. *Consumerism: Strategies and Tactics*. CBS.
- Sharma S and Kumar D. 2001. A*dvertising, Planning, Implementation and Control*. Mangal Deep Publ.
- Shukul M and Gandotra V. 2006. *Home Management & Family Finance*, Dominant Publishers & Distributors New Delhi.
- Sparks C. 2008. *Globalization, Development and Mass Media*. Sage Publ.

Weekly Lecture Schedule

Duration (week)	Topic
1	Changing trends in Consumerism; Changing economy, rapid urbanization, increasing income levels, digital marketing, shift in approach towards family systems; Profile of consumers in India and abroad- socially connected, environmentally aware, style –conscious, low brand loyalty, informed purchases, spends on leisure, health conscious; Consumer issues and challenges- on line marketing, social media management, consumer finance, multiple tax structure.
2	Gender issues in consumerism- gender division of labour, access to decision making, marketing and gender consumerism, wealth and gender consumerism; Green consumerism-definition, objectives and necessity of green consumerism.
3	Consumer guidance and counseling: Significance, aims and objectives, major areas of guidance and counseling; Agriculture credit in India ,Agriculture marketing in India.
4	Unfair trade practices in India- Introduction, types of unfair trade practices, false representation, false offer of bargain price, free gifts offers and prize scheme, non-compliance of prescribed standards, hoarding, destruction, etc.; Provisions and remedies for unfair trade practices in legal system- Removal of defects, replacement of goods, refund of price, removal of deficiency in service, discontinuance of unfair trade practice, stopping of sale and withdrawal of hazardous goods, payment of adequate cost.
5	Consumer protection against unfair trade practices- The monopolistic and restrictive trade practices Act, 1969 and The Competition Act, 2002; Authorities and agencies for settling unfair trade practices in India- District Forum, State Commission, National Commission, Supreme Court, Competition Commission of India
6	Non-legal Consumer Protection Measures; Types of alternate dispute resolution techniques- mediation, arbitration, ombudsman, peer review, early neutral evaluation, settlement conference, facilitation, adjudication; Provisions for consumer protection and welfare under The Contract Act 1982 and The Sale of Goods Act 1930.
7	Provisions for consumer protection and welfare under The Essential Commodities Act 1955; The Agricultural Produce (Grading and Marking) Act 1937; The Standard of Weights and Measures Act 1976 and The Trademark Act 1999.
8	Provisions for consumer protection and welfare under The Competition Act 2002 The Bureau of Indian Standard Act 1986; and Consumer Protection Act 1986 and Consumer protection Bill 2018.
9	Provisions for consumer protection and welfare under Right to Information Act 2005; Information technology Act 2000 and Food Safety and Standards Act, 2016.
10	Consumer communication media- significance, history and types; Communication media and social change.
11	Trends in consumer communication and their role in creating consumer demand; Advertising as an effective mode of consumer communication- History, target audience, impact of advertising on consumers.
12	Legal and ethical aspects of advertising in India; Social media and new trends in consumer communication.
13	Types of social media; Chats, Blogs, Face book, Link din, Twitter, Instagram, Pinterest, Youtube; Communication through blog- Origin, types, communication through personal blogs, collaborative blogs, corporate and organizational blogs.
14	Effective methods of communication through face book and link din; Communication through Twitter, Instagram, Pinterest, YouTube.
15	Online marketing- Definition, evolution and benefits; Online marketing tools- Types, merits and demerits.
16	Challenges of On line marketing; On line marketing and legislative frame work.

I. Course Title : Product Design

II. Course Code : RMCS 508

III. Credit Hours : 3(1+2)

IV. Rationale

Product design is highly customized and user centered. The purpose of every product is to increase safety, comfort and performance. An integrated approach to management of product design and development is required to create better quality products with enhanced capabilities. This course is designed with focus on theory and practical applications in the product design and development for all purposes not undermining the environment in which it will be used.

V. Aim of the course

- To present an overview of the product designing and development process.
- To facilitate for gaining hands on experience in design and development of consumer product.

VI. Theory

Unit I: Introduction to product design

Product Design- Definition, significance and essentials of product design and consumer demand; Product attributes-usability, contextual needs, compatibility, product aesthetics.

Unit II: Approaches to product designing

Concepts in product designing; User-centered design; Universal design; Accessible design; Usable design; Anthropometry in product design; Design consideration in product for geriatrics; Design consideration in product for people with special needs.

Unit III: Outsourced product development (OPD)

Introduction; Importance; Concept and need; Major differentiating factors- technology related, people related, process related; Emerging models of product development.

Unit IV: Product development process

Stages of product development process; Market analysis; Product analysis; Identification and innovation; User-Product relationship and ergonomics; Cognitive and social engineering issues; User interface designing.

Unit V: Product testing

Product testing- definition, purpose, role of government, Industry and consumer organizations; Product testing techniques and devices-product evaluation, quality control and standardization.

VII. Practical

1. Checklist for evaluation of a selected consumer product against the manufacturer's guidelines-Literature survey
2. Designing a checklist for evaluation of a selected consumer product against the manufacturer's guidelines
3. Evaluation of the selected consumer product against the manufacturer's guidelines
4. Presentation and group discussion

5-9. Exposure to Outsourced product development (OPD)

10. Conceptualization and development of consumer products with functional alternatives

11. Product Idea generation through brainstorming
12. Evaluation of the product idea generated; Group participation
13. Finalization of product
14-18. Working on design criteria
19. Collection of feedback from market
20. Analyzing the user's option on the design of the consumer product
21-26 Developing the prototype of the product
27. Evaluation of the product developed for identifying the problems through brain storming
28. Proposing design solutions to rectify identified lacunas in the product design
29-31. Finalization of product design
32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Students' presentation
- Exposure to outsourced product development
- Guest lectures
- Visits to industries

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Understand the technical and business aspects of the product development
- Analyze and apply methodologies for product design and development
- Undertake a meticulous approach to the management of product development to satisfy consumer needs

X. Suggested Reading

- Boothroyd G, Dewhurst P and Knight W. 2002. *Product Design for Manufacture and Assembly*. CRC Press.
- Cross N. 2000. *Engineering Design Methods: Strategies for Product Design*. Reiters Publications.
- Dumas JF and Redish JC. 1993. *A Practical Guide to Usability Testing*. Greenwood Publications.
- Meilgaard M, Civille GV and Carr BT. 2006. *Sensory Evaluation Techniques*. CRC Press.
- Otto KN and Wood KL. 2001. *Product Design: Techniques in Reverse Engineering*. New Age International.
- Parker G and Alstyne MV. 2005. *Management Science: The Theory of Information Product Design*. INFORMS Publications.
- Roozenburg NFM and Eekels J. 1995. *Product Design: Fundamentals and Methods*. Wiley.
- Sharma DD. 2000. *Total Quality Management*. Sultan Chand and Sons.
- Stone H and Sidel JL. 2004. *Sensory Evaluation Practices*. Academic Press.
- Ulrich KT and Eppinger SD. 1995. *Product Design and Development*. Irwin McGraw Hill.

Weekly Lecture Schedule

Duration (week)	Topic
1	Product Design- definition, significance and essentials of product design.
2	Consumer behaviour considerations in product design.
3	Product attributes- Usability, contextual needs, compatibility, product aesthetics.
4	Design considerations and product design process.
5	User-centered design- need, models, elements and process.

Duration (week)	Topic
6	Universal design, Accessible design, Usable design- concept, design for improving product accessibility, need identification and process.
7	Definition and application of anthropometry in product design- design diversity, Design for extreme individuals, design for adjustable range, design for average.
8	Functional limitations and design consideration in designing product for geriatrics.
9	Disabilities, specific barriers and design consideration in designing products for people with special need.
10	Outsourced product development (OPD) - introduction, importance, concept and need. Major differentiating factors-Technology related, people related, process related; Emerging models of product development.
11	Stages of product development process- market analysis, product analysis, identification and innovation.
12	User-Product relationship and ergonomics; Cognitive and social engineering issues in product development.
13	User Interface designing- definition, requirements and process.
14	Product testing- definition, purpose, role of government, industry and consumer organizations.
15	Product testing techniques and devices.
16	Product evaluation, quality control and standardization.

I. Course Title : Ergonomic Research Techniques

II. Course Code : RMCS 509

III. Credit Hours : 3(1+2)

IV. Rationale

The use of established, documented research tools, techniques and methods is important when conducting any research as it ensures that investigations are conducted in a standardized, repeatable way. This course will introduce a number of constructive tools, techniques and methods to conduct research in the area of ergonomics which enable the student to analyze and evaluate humans while they are carrying out work tasks.

V. Aim of the course

- To equip students with the ergonomic research methods
- To provide hands on experience in the application of ergonomic research methods.

VI. Theory

Unit I: Approaches to research methods in ergonomics

Measurement and information gathering; Ergonomic standards; Observational techniques; Rating scales; Questionnaires and checklist; Digital models and simulation.

Unit II: Subjective assessment tools

NIOSH discomfort survey; The Dutch Musculoskeletal Nordic Questionnaire (DMQ); Nordic Musculoskeletal Questionnaire (NMQ); Cornell Musculoskeletal Discomfort Questionnaire; University of Michigan Upper Extremity Questionnaire (UMUEQ); Job stress Questionnaire; Work Style Questionnaire; NIOSH Generic Job Stress Questionnaire.

Unit III: Postural evaluation tools

Ovako Working Posture Analyzing System(OWAS); Quick Exposure Checklist(QEC); Concise Back Screening Instrument(CBSI); Rapid Upper Limb Assessment (RULA); Plan for Identifying av Belastnings faktorer (PLIBEL); Rapid Entire Body Assessment (REBA); Model for Comprehensive Evaluation of Risks of Musculoskeletal Disorders (MODSI).

Unit IV: Measurement of work effort and fatigue

Borg Rating of Perceived Exertion Scale; Muscle Fatigue Assessment Method; Hand Activity Level (HAL); The Occupational Repetitive Action (OCRA); NIOSH Lifting Equation); The Strain Index.

VII. Practical

1. Collection of literature on occupational disorders in any one occupation such as Construction Industry/ Manufacturing industry
2. Review of collected literature to understand the type of disorders prevailing in the selected industry
3. Elicit information on musculoskeletal disorders experienced by workers from a selected field using Nordic Musculoskeletal Questionnaire -Data collection
4. Discuss the merits and demerits of the tool
5. Propose modifications in light of demerits of the tool
6. Gain hands on experience on the use of a selected postural evaluation tool
7. Evaluation of posture adopted by sweepers using a selected postural evaluation tool
8. Identify the level of risk
9. Group discussion on the use of postural evaluation tool
10. Gain hands on experience on the use of a selected muscle fatigue assessment tool
11. Measure the muscle fatigue experienced by workers involved in manual work using the selected muscle fatigue assessment tool
12. Group discussion on the use of muscle fatigue assessment tool
13. Gaining hands on experience on the use of OCRA checklist
14. Identify the risk of upper extremity work related musculoskeletal disorders among workers involved in repetitive work using OCRA checklist
15. Develop a measuring scale to measure work stress: Collection of literature
16. Identifying the parameters to be included in the scale
17. Item collection
18. Identifying the items to be included in the scale
19. Validation of the tool
20. Collection of expert remarks on the items included in the scale
21. Modifying the scale as per the remarks of experts
22. Testing reliability of the tool- test retest method
23. First phase data collection.
24. Second phase data collection
25. Testing the reliability
26. Finalization of scale
27. Pre testing of scale
28. Modifications as per the identified lacunas
29. Data collection in the field
30. Data analysis

31. Critical evaluation and finalization of the scale
32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Hands on experience on different assessment tools
- Preparation of manuals
- Students' presentations
- Group research work
- Guest lectures

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Get acquaint with the subjective assessment tools
- Gain confidence in conducting ergonomic research and identifying risk factors
- Develop measuring instruments for conducting research

X. Suggested Reading

- *Ergonomic Workplace Analysis Course Manual* compiled by RECOUP Neuromuscloskeletal Rehabilitation Centre, Bangalore.
- Helmut Strasser. 2009. *Principles, Methods and Examples of Ergonomics Research and Work Design* https://link.springer.com/chapter/10.1007/978-3-642-01293-8_28
- Hendrick, HW and Kleiner BM. 2001. *Macroergonomics. An Introduction to Work System Design*. Human Factors and Ergonomics Society, Santa Monica, CA.
- McCabe Paul T. 2003. *Contemporary Ergonomics*. Taylors And Francis.
- Neville AS and Alan Hedge. 2004. *Hand Book of Human Factors and Ergonomics Methods*. CRC Press.
- Soares Mand Rebalo F (Ed.). 2016. *Ergonomics in Design Methods &Techniques*. Balkema: CRC Press.
- Suzanne H Rodgers. 1986. *Ergonomic Design for People at Work*. John Wiley & Sons, New York.
- Taylor JC and Felton DF. 1993. *Performance by Design*. Prentice-Hall, Englewood Cliffs, NJ.

Weekly Lecture Schedule

Duration (week)	Topic
1	Measurement and information gathering; Literature search, strategies for gathering data on physical work-related strain, qualitative and quantitative data, methods of quantification of data.
2	Ergonomic standards, OSHA's ergonomic standards, legal provisions and guidelines.
3	Observational techniques-Rating scales, questionnaires and checklist.
4	Digital human models and simulation in ergonomic research.
5	Subjective assessment tools- NIOSH discomfort survey, The Dutch Musculoskeletal Questionnaire (DMQ), Nordic Musculoskeletal Questionnaire (NMQ).
6	Subjective assessment tools- Cornell Musculoskeletal Discomfort Questionnaire, University of Michigan Upper Extremity Questionnaire (UMUEQ).
7	Subjective assessment tools- Job stress Questionnaire, Work Style Questionnaire, NIOSH Generic Job Stress Questionnaire.
8	Postural evaluation tools- Ovako Working Posture Analysing System (OWAS),Quick Exposure Checklist (QEC).

Duration (week)	Topic
9	Postural evaluation tools- concise Back Screening Instrument (CBSI), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment(REBA).
10	Postural evaluation tools- Plan for Identifying av. Belastnings faktorer (PLIBEL).
11	Postural evaluation tools- Model for Comprehensive Evaluation of Risks of Musculoskeletal Disorders (MODSI).
12	Measurement of work effort and fatigue-Borg Rating of Perceived Exertion Scale.
13	Muscle Fatigue Assessment Method.
14	Measurement of work effort and fatigue, Hand Activity Level (HAL), The Occupational Repetitive Action (OCRA).
15	Measurement of work effort and fatigue, NIOSH Lifting Equation.
16	Measurement of work effort and fatigue, The Strain Index.

I. Course Title : Housing and Energy Efficient Building Design

II. Course Code : RMCS 510

III. Credit Hours : 3(2+1)

IV. Rationale

There is an immense need in the field of interior design to be aware of the environmental impacts of the built environment on the natural environment and to reduce the negative environmental impacts by designing buildings based on the concept of energy efficiency and sustainability. As interior design professionals, students need to develop skills to plan energy efficient buildings. This course train students to develop skills in planning eco friendly buildings

V. Aim of the course

- To provide an understanding of the concept of reduction in energy consumption through low energy building design
- To impart knowledge on strategies to integrate day lighting and low energy heating/ cooling in building.

VI. Theory

Unit I: Socio cultural and economic issues in housing

Historical perspective of the architectural features of buildings; Ancient science of house design; Role of housing in developing economies; Economic impact of housing; Housing markets and housing policies in India; Housing finance; Role of Government and non-government organizations in providing and regulating housing needs.

Unit II: Recent trends in building design

Emerging techniques in the house construction; Building design- need and scope for energy use and conservation; Design parameters for visual comfort; Day lighting and artificial lighting; Recent developments in building bye-laws; Low-cost building materials and fabrication technologies; Estimation of construction cost and housing finance; Housing research in energy efficient building design.

Unit III: Energy and climate

Structural features of residential buildings in different geo-climatic conditions; Environmental and architectural characteristics and energy consumption; Design parameters for climate and energy control; Eco and Ergo friendly house design; Low and zero carbon buildings and energy infrastructure.

Unit IV: Energy efficient building design

Green building design- Concept; Need and scope for energy use and conservation in building design; Energy efficient design principles and guidelines; Techniques for improving energy efficiency in residential and commercial buildings; Energy efficient building materials and construction technology; Energy flow audit and economy; Energy economy in residential and commercial buildings; Energy efficiency building regulations; Housing and energy models-Residential and commercial.

VII. Practical

1. Collection of information on building forms in different geo-climatic regions
2. Presentation and group discussion on building forms in different geo-climatic regions
3. Visits to organizations promoting green building technology
4. Collection of information on green building technology through literature search
5. Presentation and group discussion on green building technology
6. Analysis of research trends in energy efficient building design
7. Panel discussion on energy efficient building design
8. Assessment of existing house plan in terms of energy efficiency
9. Suggesting suitable renovations to improve energy efficiency
10. Evolving Eco friendly housing plan for selected geo-climatic region - development of conceptual drawings
11. Evolving Eco friendly housing plan for selected geo-climatic region- development of design details
12. Presentation and group discussion
13. Housing research in energy efficient building design-review of literature
14. Estimation of cost of construction
15. Energy audit of a residential building
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Institutional visits
- Students' presentation
- Group research work
- Guest lectures

IX. Learning Outcome

After successful completion of the course the student will be able to:

- Apply design parameters for climate and energy control in buildings
- Develop eco and ergo friendly building designs
- Plan energy efficient buildings

X. Suggested Reading

- Ambadker SN. 2000. *Rural Housing: Agro-socio-economic Impact*. Special Indian Ed. Agrobios.
- Hawkes D and Forster W. 2002. *Energy Efficient Buildings: Architecture, Engineering and Environment*. WW Norton & Co.
- Jefferis A and Madsen DA. 2004. *Architectural Drafting and Design*. Thomas Delmar Co.
- Lal AK. 1999. *Handbook of Low Cost Housing*. New Age International.
- Mahadeva M. 2002. *Housing in India: The Situation, Development and Challenges*. Orient Longman Publ.

- Morris EW. 1979. *Housing Family and Society*. John Wiley & Sons.
- RajaRao YN and Subrahmanyam Y. 2002. *Planning and Designing of Residential Buildings*. Standard Publ.
- Steffy GR. 2002. *Architectural Lighting Design*. John Wiley & Sons.
- Stitt FA. 1999. *Ecological Design handbook: Sustainable Strategies for Architecture*. McGraw Hill.
- University of Calgary. 2007. *Energy Efficient Building Design* https://energyeducation.ca/encyclopedia/Energy_efficient_building_design

Weekly Lecture Schedule

Duration (week)	Topics
1	Historical perspective of the architectural features of buildings; Ancient science of house design.
2	Role of housing in developing economies; Economic impact of housing.
3	Housing markets and housing policies in India; Housing finance- Sources, types and financial institutions.
4	Role of Government and non-government organizations in providing and regulating housing needs; Emerging techniques in the house construction.
5	Building design- need and scope for energy use and conservation; Design parameters for visual comfort- day lighting.
6	Design parameters for visual comfort-artificial lighting; Recent developments in building bye-laws.
7	Low-cost building materials; Low-cost building fabrication technologies.
8	Estimation of construction cost and housing finance; Housing research in energy efficient building design.
9	Structural features of residential buildings in different geo-climatic conditions in India; Structural features of residential buildings in different geo-climatic conditions in western countries.
10	Environmental and architectural characteristics and energy consumption; Design parameters for climate and energy control.
11	Eco friendly house design; Low carbon buildings and energy infrastructure.
12	Zero carbon buildings and energy infrastructure; Green building design- concept, need and scope for energy use and conservation in building design.
13	Energy efficient design principles and guidelines- Site analysis, building orientation and layout, fenestration and shading, insulation, thermal mass and building material, ventilation, landscape; Techniques for improving energy efficiency in residential and commercial buildings.
14	Energy efficient building materials and construction technology; Energy flow audit and economy.
15	Energy economy in residential and commercial buildings; Energy efficient building regulations.
16	Housing and energy models – residential and commercial.

I. Course Title : Technical Drawings

II. Course Code : RMCS 511

III. Credit Hours : 3(1+2)

IV. Rationale

Technical drawings are tools for communication in the interior design field. There is a great demand from the client for clarity on the output of the interior design project. The designers need to provide with virtual interiors before the actual project is executed. The course will enable students mastering in interior design to equip with design skills and presentation techniques to communicate effectively with clients.

V. Aim of the course

- To acquaint students with architectural drafting and their application in developing interior design plans
- To gain hands on experience in using computer programmes for drawing architectural plans and 3D representation of spaces for interior design.

VI. Theory

Unit I: Drafting fundamentals

Measurement and scaling; Lines-Types, quality and weights; Lettering styles; Sheet format and layout; Blocks and layout; Legend and dimension; Conventions and preliminary drawings.

Unit II: Presentation techniques

Orthographic plans- Plan, elevations and sections; Design drawings; Projection drawings; Isometric drawings; Perspective drawings; Rendering and hatching techniques; Presentation boards.

Unit III: Introduction to AutoCAD

Introduction to AutoCAD as 2D drafting tool; Digital drawings tools; Drawing lines and shapes; Modifying lines and shapes; Drawing with accuracy and speed; Organizing plans; Sections and elevations; Drawing and printing to scale; Text styles and sizes; Hatches and dashed lines; Stencils and blocks; Advanced editing tools and Dimensioning drawings.

Unit IV: 3D Modelling using AutoCAD

Introduction to 3D-modelling technique using AutoCAD; 3D basics– axes, Planes and Faces; 3D Object Modification– Rotate, Mirror, Array and Scale; 3D Boolean operations–Union, Subtract, Intersect; 3D Primitive objects– Box, Wedge, Cone, Sphere, Cylinder, Torus and Pyramids; Solid modeling – Revolve, Shell, Taper, Loft, Path extrusion and Sweep.

Unit V: Introduction to 3D Modelling and Rendering

Introduction to 3D Modelling and Rendering; Building Modelling and basic rendering techniques; Using 3DSMax or equivalent; Advanced 3D Modelling-Advanced modeling; Ray rendering engine.

Unit VI: Auto CAD and its application in interior design

Orientation to AutoCAD Main screen and menus; Coordinate systems; Use of Draw and edit menus; Hatching inquiry tools; Layers; 3D Modelling; Co-ordinate system; Primitive tools: Boolean operation; Editing 3D objects; Rendering; Printing; Introduction to ADT- creation of plans, sections, elevations, title marks and dimensioning, schedule table of doors and windows; Create still camera views; Creating a movie file; Walk through; Introduction to 3D Max -standard tool bar command panel; Concept of import and export of objects from ADT and Auto CAD to 3D Studio MAX; Creating objects in 3D Max using standard primitives; Using transforms; Introduction of material; Light; Colour; Render the images and save; Camera animation of walk through.

VII. Practical

1. Drawing a detailed floor plan showing the use of different lines, lettering styles, sheet format and layout, blocks and layout, legend and dimension, section drawing
2. Drawing a detailed floor plan showing the use of blocks and layout, legend and dimension, section drawing
3. Scale drawing of building components in plan and elevation
4. Preparation of electrical layout for a small building
5. Preparation of plumbing layouts for a small building
6. Working on presentation details for the above plans
7. Evolving floor plans for an existing residential building
8. Drawing views of brick arrangement to scale in two dimensions (Plan, elevation) and three dimension (isometric, oblique and axonometric)
9. Study of buildings and interiors in two and three dimensions
10. Drawing one/single perspectives of interiors
11. Drawing two point perspectives of interiors
12. Creation of texture effects in interior objects
13. Pencil rendering of interiors
14. Colour rendering of interiors
15. Developing a private project and presenting with views
16. Use of Presentation techniques

17-31 Project work: Application of CAD in developing plans and presentation details of any one residential and commercial building

32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Site visits
- Hands on experience
- Students' presentation
- Guest lectures

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Create orthographic plans and projection drawings
- Apply AUTOCAD in developing interior design plan
- Solve design problems using sketching and remodeling software
- Read and understand/pictorial drawings and advanced orthographic projections

X. Suggested Reading

- Chiavaroli J. 1999. *AEC Drafting Fundamentals*. Delmar Publishers, London.
- Frey D. 2000. *AutoCAD 2000*. BPB Publications, New Delhi.
- Gill RW. 1975. *The Thames and Hudson Manual of Rendering with Pen and Ink*. Thames and Hudson, London.
- George O. 2007. *Just Enough Auto CAD*. Wiley Publishing Inc.
- Hepler DE and Wallach PI. 1965. *Architecture – Drafting and Design*. McGraw-Hill Book Company, New York.
- Kalee S, Zaidi A and Siddique S. 2004. *Designing and Design of Residential and Commercial Buildings*. Standard Publ.
- Kasu AA. 1995. *An Introduction to Art, Craft, Technique, Science of Profession of Interior Design*. Iqura Publishing Pvt. Ltd., Bombay.

- Kilmer WO and Kilmer R. 2004. *Construction Drawings and Details for Interiors*. Wiley.
- Mitton M. 1999. *Interior Design Visual Presentation*. John Wiley & Sons, New York.
- Shah MG, Kale CM and Patkki SY. 1995. *Building Drawing*. 3rd Edition, Tata McGraw Hill.

Weekly Lecture Schedule

Duration (week)	Topic
1	Drafting fundamentals-Measurement and scaling; Lines; types, quality and weights; Lettering styles; Sheet format and layout; Blocks and Layout- Legend and Dimension; Conventions and Preliminary Drawings.
2	Orthographic plans- plan, elevations and sections; Design drawings.
3	Projection drawings- Isometric drawings; Perspective drawings; Rendering and Hatching techniques; Presentation boards.
4	Introduction to AutoCAD as 2D drafting tool; Digital drawings tools; Drawing lines and shapes; Modifying lines and shapes; Drawing with accuracy and speed.
5	Organizing plans; Sections and elevations; Drawing and printing to scale; Text styles and sizes; Hatches and dashed lines; Stencils and blocks.
6	Advanced editing tools and dimensioning drawings.
7	Introduction to 3D-modelling technique using AutoCAD; 3D basics- Axes, Planes and Faces.
8	3D Object Modification-Rotate, Mirror, Array and Scale; 3D Boolean operations-Union, subtract, intersect.
9	3D primitive objects- Box, Wedge, Cone, Sphere, Cylinder, Torus and Pyramids.
10	Solid modelling- Revolve, Shell, Taper, Loft, Path extrusion and Sweep.
11	Introduction to 3D Modelling and Rendering; Building modelling and basic rendering techniques, using 3DSMax.
12	Advanced 3D Modelling- Advanced modelling, V-Ray rendering engine, or equivalent.
13	Orientation to AutoCAD main screen and menus; Coordinate systems; Use of Draw and edit menus; Hatching inquiry tools; Layers; 3D Modelling; Co-ordinate system; Primitive tools; Boolean operation; Editing 3D objects; Rendering; Printing.
14	Introduction to ADT- Creation of plans, sections, elevations, title marks and dimensioning, schedule table of doors and windows; Create still camera views.
15	Creating a movie file; Walk through-Introduction to 3D Max -standard tool bar command panel, Concept of import and export of objects from ADT and Auto CAD to 3D Studio MAX, Creating objects in 3D Max using standard primitives, Using transforms.
16	Introduction of material, light, colour; Render the images and save; Camera animation of walk through.

I. Course Title : Interior Design Business Management

II. Course Code : RMCS 512

III. Credit Hours : 3(1+2)

IV. Rationale

Interior designing business is one of the upcoming professions and has lot of potential for business opportunities. This course justifies the natural affinity to style, fashion, glamour, painting, creativity, etc. and will enhance great imagination skills for interior designer. This is also a flourishing industry wherein a career and start-up in India and abroad can be taken up

V. Aim of the course

- To impart knowledge about profession and principles of interior design business management
- To build confidence among students for establishing a interior design firm.

VI. Theory

Unit I: Introduction to professional management

Definition of a profession; Principles of interior design business management; Ethics and professional conduct; Establishing interior design practice.

Unit II: Professional components of managing interior work

Legal issues of business; Business management applications; Marketing; Scale of professional fee and charges; Duties of employer under labour welfare provisions; Structure of interior designers office; Conditions of engagement; Risk management.

Unit III: Estimating and costing for interior work

Definition; Importance and types of estimation; Units and mode of measurement; Rate analysis; Bills of quantities; Contract design.

Unit IV: Professional practice

Professional portfolios; Resumes and business cards; Web page and e-service; Professional associations and support systems.

VII. Practical

1. Case study of an established interior design firm
2. Cost estimation for projects
3. Contracting and sub-contracting procedure for the estimated projects
4. Strategic plan for presentation of project for a tender call
5. Working on modalities for establishing an interior design firm
6. Preparation of financial plan for a design firm
7. Working on portfolio and resume design for job in professional firm

8-31. Working with an interior designer for work experience

32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Students' presentation
- Work experience
- Group work
- Guest lectures

IX. Learning Outcome

After successful completion of the course, the students will be able to:
- Take up interior designing as a profession
- Launch an Interior Design firm and run successfully

XI. Suggested Reading

- Christine MP. 2001. *Interior Design Management: A Handbook for Owners and Managers*. ASID, IIDA.
- Christine MP. 2002. *Professional Practice for Interior Designer*. John Wiley & Sons.
- Cindy C. 2002. *Interior Design Handbook of Professional Practice*. McGraw Hill.

- Kailee Helget May. 2019. *How to start an Interior Business* https://www.2020spaces.com/blog-start-an-interior-design-business/
- Terry LP (2002) *Architects Studio Handbook*. McGraw Hill.

Weekly Lecture Schedule

Duration (week)	Topic
1	Definition and meaning of a profession; History of interior design as a profession.
2	Principles, ethics and professional conduct of interior design business management.
3	Establishing interior design practice.
4	Legal issues of business.
5	Business management applications- People management, business information systems, financial management and control, management and economics.
6	Marketing, conditions, strategies, selling techniques, scale of professional fee and charges.
7	Duties of employer under labour welfare provisions.
8	Structure of interior designer's office, conditions of engagement.
9	Risk management plan for interior business.
10	Estimating and costing for interior work- Definition, importance and types of estimation.
11	Units, mode of measurement and standard methods of measurement for building elements.
12	Methods of rate analysis and bills of quantities.
13	Principles, practices and stages of contract design.
14	Need, importance and components professional portfolios, resumes, business cards.
15	Professional web page and e-service.
16	Professional associations and support systems.

I. Course Title : Environmental Resource Management

II. Course Code : RMCS 513

III. Credit Hours : 2(1+1)

IV. Rationale

Environmental resource management is an issue of increasing concern and can be viewed from a variety of perspectives. It involves the management of all components of the biophysical environment, and the relationships among all living species and their habitats. The essential aspects of environmental resource management are ethical, economical, social, and technological. It emphasizes on the sustainability development in future. These underling principles help students to make appropriate decisions.

V. Aim of the course

- To get an insight about the present scenario of global environment, environmental problems and management for sustainable development in future
- To provide an overview of management techniques for waste management and environment protection.

VI. Theory

Unit I: General perspectives

Man, environment and economic growth; Industrialization; Urbanization; Consumerism and environment; Environmental informatics; Environment and bio-technology; Environmental ethics.

Unit II: Ecology, environment and sustainability

Ecological environment and sustainability; Environmental dimensions of sustainable development; Equitable use of resources for sustainable development; Economical, political and cultural influences in the use of environmental resources; Role of government and non-government organizations and communities in sustainable development.

Unit III: Environmental waste management

Waste management; Waste management systems in India; Technologies for waste management; Hazardous waste management and treatment; Physical and chemical treatment; Thermal treatment and biological treatment; Hazardous waste treatment; E-Waste; Management of E-waste; Inventory management; Production process modification; Volume reduction; Recovery and reuse; Laws and regulations concerning waste management in India.

Unit IV: Energy and environment

Energy and environment; Economic growth and energy consumption; Increased energy consumption and climate change; Energy policy of India; Energy and sustainability; Sustainable energy resources.

Unit V: Environmental protection and management

Environmental economics- Concepts, evolution and its development; Important processes and technologies; Environmental protection and management; Environmental quality objectives and standards; Approaches with regard to environmental protection; Institutional and policy framework; Ministry of environment and forest, Pollution control boards.

VII. Practicals

1. Understanding the impact of urbanization and consumerism on resource utilization- Literature search
2. Report preparation on impact of urbanization and consumerism on resource utilization
3. Presentation and discussion on impact of urbanization and consumerism on resource utilization
4. Visit to any one industry to understand the types of wastes generated and their waste management practices
5. Presentation and group discussion
6. Plan awareness programme to educate college students on their role in environmental protection
7. Organizing awareness camp
8. Project work: Household waste management practices among families- Collection of review
9. Planning the research methodology
10. Designing data collection tool for collecting information on household waste management practices among families
11. Finalization of tool
12. Data collection
13. Data analysis
14. Report preparation on household waste management practices among families on household waste management practices among families

15. Presentation and Group discussion
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Book/Publication Review
- Students' presentation
- Group work
- Case studies
- Guest lectures
- Review of policy documents

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Gain knowledge about the present scenario of global environment and develop skills in the management of environmental resources for sustainable development in future
- Understand the essential aspects of environmental resource management and work on innovative solution for conservation of environmental resources
- Gain insight into management of all components of the biophysical environment

X. Suggested Reading

- Bhatnagar A. 2010. *Ecology and Environment*. Oxford Book Company, Jaipur.
- Bharucha E. 2017. *Text Book of Environmental Studies*. UGC University Press India Pvt. Ltd.
- Chary SN and Vyasula V. 2001. *Environmental Management-An Indian Perspective*. Macmillan India Ltd.
- Joseph K and Nagendran R. 2004. *Essentials of Environmental Studies*. Pearson Education Pvt. Ltd.
- International Hydropower Association. 2017. *Environmental Resources Management* (*ERM*)https://www.hydropower.org/companies/environmental-resources- management-erm
- Kuar A and Roy PK. 2008. *Environmental Resource Management*. Daya publishing House, Delhi.
- Pandey SN and Misra SP. 2011. *Environment and Ecology*. AneBools Pvt. Ltd., New Delhi.
- Singh K and Sisodia A. 2007. *Environmental Economics: Theory and Applications*. Sage Publ.
- Singh S. 2010. *Disaster Management*. Rajdhani printers, Delhi.
- Thakur V. 2012. *A Text Book of Environmental Science*. Scientific Publishers, Jodhpur.

Weekly Lecture Schedule

Duration (week)	Topic
1	Interrelation between man, economic growth and environment; Individual rights and responsibilities towards a clean environment; Environmental ethics- meaning, libertarian view, ecological view and conservation view.
2	Impact of industrialization, urbanization and consumerism on environment- Particulate matter concentration, modification of habitat, waste generation, degraded water quality, land contamination, biodiversity loss, etc. Environmental Informatics- concept, application and benefits.
3	Environment and bio-technology, objectives of environmental biotechnology, application of environmental biotechnology for sustainable development; Role of environmental biotechnology in protection and restoration of quality of environment.

Duration (week)	Topics
4	Ecology, Environment and sustainability- meaning, resource conservation, resource preservation, ecological footprints.
5	Environmental dimensions of sustainable development- Linkages and holistic approach in conservation and equitable use of specific indicators of sustainable development such as atmosphere, water and land.
6	Economical, political and cultural influences in the use of environmental resources, Role of government and non-government organizations and communities in sustainable development.
7	Waste management- introduction, classification of wastes, principles of waste management, waste management systems in India.
8	Technologies for waste management- physic, chemical, biological processes for waste treatment; Sanitary landfill Incineration; Gasification; Biodegradation processes; Composting, and anaerobic digestion; Conventional digestion; Dry anaerobic digestion process; Two phase digestion; Water and waste water treatment.
9	Hazardous waste management and treatment, identification and classification, collection, storage, transfer, processing, and disposal; Hazardous waste treatment; Physical and chemical treatment; Thermal treatment; Biological treatment; Hazardous waste treatment in India.
10	E-Waste-Introduction, effects on environment and human health, management of e-waste, inventory management, production process modification, volume reduction, recovery and reuse, management options.
11	Laws and regulations concerning waste management in India-The Water (Prevention and Control of Pollution) Act, 1974, The Air (Prevention and Control of Pollution) Act, 1981, The Environment (Protection) Act ,1986, The Public Liability Insurance Act, 1991, Municipal Solid Wastes (Management and Handling) Rules in 2000, Hazardous Wastes (Management and Handling) Rules in 1989 (amended in 2000 and 2003), The Biomedical Waste (Management and Handling) Rules 1998 (amended in 2000 and 2003), The E-waste (Management & Handling) 2012, "Plastics (Manufacture, Usage and Waste Management) Rules, 2009" (amended in 2003).
12	Energy and environment; Economic growth and energy consumption; Increased energy consumption and climate change; Energy policy of India.
13	Sustainable energy- history and need for sustainable energy, sustainable energy resources, solar energy, wind energy, geothermal energy, ocean energy, biomass energy, hydroelectric power, green energy and green power.
14	Environmental economics- concepts, evolution and its development, important processes and technologies.
15	Environmental protection and management, Environmental quality objectives and standards; Approaches with regard to environmental protection- Voluntary environmental agreement, ecosystem approach, international environmental agreements.
16	Institutional and policy framework- Ministry of Environment and Forest, Pollution control boards.

Course Title with Credit Load Ph.D. in Resource Management and Consumer Science

Course Code	Course Title	Credit Hours
	Major Courses	
RMCS 601*	Trends in Resource Management	3 (3+0)
RMCS 602*	Occupational Biomechanics	3 (2+1)
RMCS 603	Globalization and Consumer Economics	3 (2+1)
RMCS 604	Space Designing and Managerial Dimensions for Special needs	3 (1+2)
RMCS 605	Physical Ergonomics	3 (1+2)
RMCS 606	Environmental Issues and Challenges	2 (2+0)
RMCS 607	Family Dynamics and Women Power	3 (2+1)
RMCS 608	Special Project	2 (0+2)
	Total	22 (13+9)
	Minor Courses	
FN604	Global Nutrition Problems	2 (2+0)
FN 608	Energy Metabolism	2 (2+0)
EECM 602	Impact Assessment of Development Programmes	3 (1+2)
EECM 603	Scaling Techniques for Behavioural Research	3 (1+2)
EECM 607	Media application and product promotion	4 (2+2)
HDFS 608	Qualitative research methods	3 (2+1)
ATS 602	Technical Textiles	3 (2+1)
ATS605	Functional Clothing	3 (2+1)
ATS 607	Operational Management in Textiles and Apparel	2 (2+0)
	Supporting Courses	
A student can opt any course related to the topic of research offered by other faculties of agriculture university or SWAYAM/ MOOCS or other online courses up to a maximum of 5 credits.		
RMCS 691	Doctoral Seminar I (Core Field)	1 (1+0)
RMCS 692	Doctoral Seminar II (Optional Field)	1 (1+0)
RMCS 699	Research	75
	Total	**100 Credits**

*Compulsory core curses

Course Contents
Ph.D. in Resource Management and Consumer Science

I. Course Title : Trends in Resource Management

II. Course Code : RMCS 601

III. Credit Hours : 3(3+0)

IV. Rationale

Continuous changes in technology, economic, social and psychological understandings and structures have influence on resources and their management. In highly competitive and demanding times it is essential to train students in a manner that they are able to display good interpersonal skills by making decisions, allocate resources, and lead and direct others' activities to achieve and attain their goals. The course exposes the student to different functional areas of management to enhance the effectiveness.

V. Aim of the course

- To expose students to the emerging managerial ides, techniques, procedures and practices and their application in the field of resource management
- To impart knowledge, skill and concepts needed to resolve resource management problems or issues.

VI. Theory

Unit I: Significance and scope of family resource management

Introduction and history of family resource management and household trends; Resource management as a process; Influences on management styles; Life management for singles, families, households and non family households; Advances in the discipline of resource management.

Unit II: History and theories of resource management

Managerial practices and concepts from ancient civilization; Early years of family resource management; Household production and consumption systems during pre modern, modern and post modern periods; Theories in resource management; Pre scientific and post scientific approach; Human and non human resource management; Systems theory; Application of systems theory to households; Economic theory; Human ecology and ecosystems; Contemporary management practices.

Unit III: Managerial competencies

Conflict Management- Concepts, types, sources and levels of conflict; Conflict resolution strategies; Conflict management; Behavioural interventions for handling conflicts; Leadership; Theories of leadership; Types of leadership; Likert's four systems of leadership and managerial grid.

Unit IV: Management of resources

Managing time as a resource; Modern tools and techniques of time management; Qualitative and quantitative time measures; Legislations, policies and research in family management.

Unit V: Organizational behaviour

Organizational culture- Concepts, process and implications of organizational culture; Organizational performance-Concept and process, measures for organizational performance, controlling for organizational performance; Overview of control techniques (Scheduling, CPM, PERT, SWOT analysis, etc.); Effective control systems; Performance appraisal-purpose, methods, essentials of good appraisal system; Organizational change- concepts and nature; Kurt Lewin theory of change; Implementing change; Managing resistance to change.

Unit VI: Managerial ethics and social responsibilities

Managerial ethics- Factors affecting ethical choices; Ethical dilemma; Social responsibility- Concept and approaches; Evaluating institutional social performance; Managing institutional ethics and social responsibility.

VII. Teaching Methods/ Activities

- Lectures
- Assignments
- Book/Publication Review
- Students presentations
- Group work
- Case studies
- Guest lectures
- Online learning

VIII. Learning Outcome

After successful completion of the course, the students will be able to:

- Appreciate the importance of resource management as a field of study and as a central management function
- Understand the essentials for effective resource management
- Apply the principles and techniques of resource management to solve major issues and get solutions for typical case problems

IX. Suggested Reading

- Elezabeth BG. 2013. *Resource Management for Individuals and Families*. Thomson Learning Inc.
- Hellregel. 2002. *Management*. Thomason Learning, Bombay.
- Koontz H and Wechrich H. 2008. *Management*. Tata McGraw Hill Inc. N.Y.
- Richar LD. 2015. *Management*. Thomson South-Western.
- Robbins SP and Decenzo DA. 2010. *Fundamentals of Management*. Pearson Education Asia, New Delhi.
- Satya Raj R and Parthasarthi A. 2009. *Management- Text & Cases*. PHI, New Delhi.
- Stephen PR and Mary AC. 2015. *Management*. 13th Edition, Prentice Hall of India. New Delhi.
- Subba Rao P. 2017. *Management and Organizational Behaviour* (*Text and Cases*). Himalaya Publishing House, New Delhi.
- Trends in Management- https://www.toppr.com/guides/business-management-and-entrepreneurship/recent-trends-in-management/
- Tripathi PC and Reddy PN. 2013. *Principles of Management*. Tata McGRaw Hill Education Pvt Ltd, ND.

Weekly Lecture Schedule

Duration (week)	Topic
1.	Introduction and history of family resource management and household trends; Resource management as a process, influences on management styles; Life management for singles, families, households and non family households.
2.	Advances in the discipline of resource management; Managerial practices and concepts from ancient civilization; Early years of family resource management-Household production and consumption systems during pre modern periods.
3.	Household production and consumption systems during modern and post modern periods; Pre scientific theories in resource management-Contributions made by Robert Owen, Charles Babbage, Henery Venure Poor , Hanery Robinson.
4.	Pre scientific theories in resource management- contributions made by James Watt, Captain Henry Metcalf; Post scientific theories in resource management.
5.	Human and non human resource management- meaning, definition, scope and process; Systems theory; Application of systems theory to households; Family as a system; Family-environment interrelationship.
6.	Economic theory; Human ecology and ecosystems; Contemporary management practices; Conflict- Concept, types and sources; Levels of conflict.
7.	Conflict resolution strategies- Avoidance, De-fusion, containment, confrontation; Conflict management; Behavioural interventions for handling conflicts.
8.	Conflict stimulation techniques; Leadership- definition, meaning and characteristics; Leadership-traits and styles.
9.	Functional leadership characteristics; Theories of Leadership- Trait theory of leadership, behavioural theories of leadership; Theories of Leadership- Contingency theories, transformational leadership theory.
10.	Likert's four systems of leadership and managerial grid; Managing time as a resource; Unit of time and measurement of time.
11.	Modern tools and techniques of time management; Qualitative and quantitative time measures; Legislations, Policies and research in family management.
12.	Organizational culture- Concepts, difference between culture and climate; Process and implications of organizational culture; Components, determinants and types of organizational climate.
13.	Organizational performance-concept and process, measures for organizational performance; Controlling organizational performance; Overview of control techniques, scheduling, CPM; Overview of control techniques PERT.
14.	Controlling organizational performance- Overview of control techniques SWOT analysis; Effective control systems; Performance appraisal- Purpose, methods, essentials of good appraisal system.
15.	Organizational change- concept and nature, need ,process and resistance to organizational change; Kurt Lewin theory of change, implementing change, managing resistance to change; Managerial ethics- factors affecting ethical choices.
16.	Ethical dilemma- Social responsibility; Evaluating institutional social performance; Managing institutional ethics and social responsibility.

I. Course Title : Occupational Biomechanics

II. Course Code : RMCS 602

III. Credit Hours : 3(2+1)

IV. Rationale

Occupational biomechanics is the growing discipline necessary to improve workplace design. It focuses on the rapidly expanding body of biomechanics knowledge on workplace situations that cause musculoskeletal injuries and disabilities. The students in this course will study the physical interaction of workers with their tools, machines and materials as well as several new methods for evaluating the bio-mechanical consequences of workplace designs.

V. Aim of the course

- To acquaint students with occupational hazards and advances in ergonomics for enhancing job fitness compatibility
- To impart knowledge and skills to device injury prevention strategies at work and develop solutions.

VI. Theory

Unit I: Biomechanical concepts

Biomechanics as an area of study; The biomechanics of the human skeletal articulations; The biomechanics of human skeletal muscle; Application of biomechanics to movement-Qualitative and quantitative approach.

Unit II: Biomechanics of the human body

The biomechanics of the human upper extremity- shoulder, elbow wrist and hand; The biomechanics of the human lower extremity- Hip, knee, ankle and foot; The biomechanics of the human spine.

Unit III: Occupational biomechanics

Biomechanical oriented ergonomics in workplace; Activity-related soft tissue disorders (ASTDs); Work-related risk factors; Definition and ergonomic guidelines for controlling risk factors; Risk for back injuries in the workplace; Analysis and ergonomic guidelines for controlling.

Unit IV: Ergonomic task analysis and risk assessment

Ergonomic task analysis- Definition, importance and process; Occupational risk factors; Tools and techniques for identifying posture related risk factors; Tools and techniques for identifying risk factors related to forceful exertion; Tools and techniques for identifying risk factors related repetitive motion; Tools and techniques for identifying risk factors related workstation design; Tools and techniques for identifying risk factors related workplace environment; Ergonomic check points; Development of ergonomic checkpoints for various occupations.

Unit V: Application of biomechanics

Application of biomechanics for occupational safety; Use of SAMMIE (System for Aiding Man Machine Interaction Evaluation) and CAD system in occupational designs.

VII. Practicals

1. Assessing postural risks in a computer workstation
2. Designing ergonomic guidelines to overcome postural risks
3. Designing a tool to identify hazards in construction work
4. Collection of data on hazards in construction work
5. Preparation of report on hazards in construction work
6. Presentation of report and group discussion
7. Identification of hazards in agricultural operations-field level observation
8. Preparation of schedule for identification of hazards in agricultural operations
9. Data collection on hazards in agricultural operations

10. Preparation of report on hazards in agricultural operations
11. Presentation of report and group discussion
12. Designing ergonomic guidelines for risk elimination
13. Measuring occupational stress using a standardized tool
14. Collection of data on occupational stress
15. Preparation and presentation of report on occupational stress
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Publication review
- Students' presentations
- Group work
- Case studies
- On line learning

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Understand concepts of rapidly expanding body of biomechanics and their impact on workplace situations that cause musculoskeletal injuries and disabilities.
- Gain knowledge on physical interaction of workers with their tools, machines and materials as well as several new methods for evaluating the bio-mechanical consequences of workplace designs.

X. Suggested Reading

- Allan Toomingas, Svend Erik Mathiassen, Ewa WT. 2011. *Occupational Physiology*. 1st Edition, CRC Press, Taylor and Francis Group, London.
- Ayub MM and Mittal A. 1998. *Manual Material Handling*. Taylor and Francis, London.
- Chapanis A. 1996. *Human Factors in Systems Engineering*. John Wiley and Sons, New York\.
- Dalela S and Saurabh. 1999. *Text Bbook of Work Study and Ergonomics*. Standard Publishers Distributors, Delhi.
- John R Wilson and Nigel Corlett. 2005. *Evaluation of Human Work*. Third Edition Taylor and Francis Group, London.
- Kumar Shrawan. 2007. *Biomechanics in Ergonomics*. Second Edition, www.crcpress.com/product/isbn/
- Meister D. 1989. *Conceptual Aspects of Human Factors*. Johns Hopkins University Press, Baltimore, MD.
- Panero J and Zelnik M. 1979. *Human Dimension and Interior Space*. Whitney Library of Design.
- Tayyari F and Smith JL. 1997. *Occupational Ergonomics Principles and Applications*. Chapman and Hall, London.
- Wilson JR and Haines HM. 1997. Participatory Ergonomics.In: *SalvendyG* (*Ed.*) *Handbook of Human Factors and Ergonomics*. 2nd Edition, Taylor & Francis, Bristol, PA.

Weekly Lecture Schedule

Duration (week)	Topic
1	Biomechanics as an area of study and its application in occupational health; The biomechanics of the human skeletal articulations- Joint architecture, joint stability, joint flexibility.
2	Joint architecture- immovable joints, slightly movable joints, freely movable joints, articular cartilage, articular fibro cartilage, articular connective tissue; Joint

Duration (week)	Topic
	stability-Shape of the articulating bone surfaces, arrangement of the ligaments and muscles, other connective tissues.
3.	Joint flexibility-Measuring joint range of motion, factors influencing joint flexibility, flexibility and injury; The biomechanics of human skeletal muscle, behavioral properties of the musculotendinous unit, structural organization of skeletal muscle, skeletal muscle function, muscular strength, power, and endurance.
4.	Application of biomechanics to movement- Qualitative and quantitative approach; The biomechanics of the human upper extremity- structure of the shoulder, movements of the shoulder complex, loads on the shoulder.
5.	Structure of the elbow, Movements at the elbow, Loads on the elbow; Structure of the wrist, movements of the wrist, loads on wrist.
6.	Structure of the joints of the hand, movements of the hand; Thebiomechanics of human lower extremity- Structure of the hip, movements at the hip, loads on the hip.
7.	Structure of the knee, movements at the knee, loads on the knee; Structure of the ankle, Movements at the ankle.
8.	Structure of the foot, movements of the foot, loads on the foot; The biomechanics of the human spine- Structure of the spine, movements of the spine, muscles of the spine, loads on the spine.
9.	Biomechanical oriented ergonomics in workplace- Objectives and need; Introduction to Activity-related Soft Tissue Disorders (ASTDs)- Tendinopathies , Bursitis, Carpal Tunnel Syndrome , Carpel Tunnel Syndrome, Plantar Fasciitis and Radial Tunnel Syndrome.
10.	Definition and nature of work-related risk factors- Repetition, awkward posture, forceful exertions, Hand-arm vibration. Ergonomic guidelines for controlling risk factors related to soft tissue disorders.
11.	Analysis of risk for back injuries in the workplace; Back and shoulder over exertion injuries and risk factors such as manual materials handling, awkward postures, prolonged standing and sitting, whole body vibration.
12.	Ergonomic guidelines for controlling risk factors related to back and shoulder; Ergonomic task analysis- Definition and importance, steps in task analysis process, information collection, data recording, data analysis.
13.	Tools and techniques for identifying risk factors related to posture; (i) Rapid Upper Limb Assessment (RULA)(ii) Rapid Entire Body Assessment (REBA), (ii)Ovako Working Posture Analysis System (OWASA) 4. Biomechanical analysis.
14.	Tools and techniques for identifying risk factors related to Forceful Exertion – (i) Manual Handling Assessment Chart (MAC) (ii) Borg Scale (iii).Liberty Manual Material Handling Tables (Snook Table)(iv). NIOSH Lifting Equation.Tools and techniques for identifying risk factors related Repetitive Motion –(i). Assessment of Repetitive Tasks (ART) (ii).Occupational Repetitive Action (OCRA) Checklist (iii).OCRA Index.
15.	Tools and techniques for identifying risk factors related to workstation design – (i).Rapid Office Strain Assessment (ROSA) (ii). Anthropometry Analysis.Tools and techniques for identifying risk factors related workplace environmental –(i) Standards and guidelines as per regulations and industrial code of practice standard, (ii) Designated specific measurement instruments.
16.	Tools and techniques for identifying sources of work stress in an organizational set up; Application of biomechanics for occupational safety and accident protection and release of stress.

I. Course Title : Globalization and Consumer Economics

II. Course Code : RMCS 603

III. Credit Hours : 3(2+1)

IV. Rationale

Globalization may be described as the combined influences of trade liberalization, market integration, international finance and investment, technological change, the increasing distribution of production across national boundaries, and the emergence of new structures of global governance. The global marketplace has totally changed the consumer behaviour. As change agents, young professionals need to equip themselves with knowledge and skill sets required to understand the consumer behaviour in the era of globalization.

V. Aim of the course

- To impart knowledge on consumer concepts in combination with the development of financial literacy and consumer responsibility
- To develop insight into major global economic issues having local impact on market forces and consumers.

VI. Theory

Unit I: The ontology of consumer economics

Consumer motivation- Concept, components of motivation; Maslow's motivational theory and consumer behaviour; Consumer decision process- Problem or need recognition, information search, evaluation of alternatives, purchase decision, post-purchase decision; Models of buyer decision making -Economic model, psychological models, consumer behaviour models; Influence of purchase decision- external and internal; Consumer decision styles; Risk in consumer behavior -functional risk, physical risk, financial risk, social risk, psychological risk, time risk; Adoption and diffusion of innovations; Impulse buying- definition and types; Factors influencing impulse buying behavior -consumer related factors, Situational characteristics, product characteristics, store related factors, consumer behaviour.

Unit II: Global markets

Definition and importance; Features of global marketing; Forces affecting global marketing; Objectives of global marketing; Global marketing environment; Global marketing strategies; Difference between global and international market; Advantages and disadvantages of global marketing.

Unit III: New economic policies

Introduction to new economic policies- Liberalization, privatization, globalization; Privatization-introduction, objectives; Types of privatization; Problems of privatization; Privatization in India; Privatization and global impact; Globalization-meaning, trends, factors influencing globalization; Impact of globalization on Indian economy; Positive and negative impact of globalization in India; World Trade Organization(WTO) –objectives and functions; WTO agreement; Benefits of WTO; WTO and developing countries; WTO agreement on agriculture and subsidies; General Agreement on Tariff and Trade (GATT)-Purpose, implications of GATT agreement in various areas.

Unit IV: The services

Consumer services; Service providers and their obligations towards consumers;

Citizen Charter- Vision, mission objectives, importance in public administration; Goods and Service Tax (GST)- Components of GST, benefits of GST, impact of GST on consumers.

Unit V: Agriculture and Indian economy

Indian agriculture policy; Agriculture credit in India; National agricultural insurance schemes; Agriculture marketing in India; Sustainable agriculture and food security in India; Government programmes for increasing family food security and financial security of consumers.

VII. Practicals

1. Project work: Study on impulse buying behaviour among teenage consumers-collection of review
2. Formulation of objectives for the study
3. Finalization of method of research
4. Designing a data collection tool
5. Data collection on impulse buying behaviour among teenage consumers
6. Data analysis and report writing
7. Presentation of report on impulse buying behaviour among teenage consumers
8. Presentation of the report on impulse buying behaviour among teenage consumers
9. Critical analysis of citizen charter of electricity department
10. Study the crop insurance scheme
11. Conduct farmer awareness camp on crop insurance scheme
12. Study the implementation of any one government programme for increasing family food security and financial security
13. Identify structural and functional aspects of any one agriculture market
14. Observe the functioning of selected agriculture market
15. Group discussion on functional aspects of agriculture market
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Book/Publication Review
- Students' presentation
- Group work
- Field study
- On line learning

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Develop insight into major global economic issues having local impact on market forces and consumers
- Equip them to identify, evaluate and evolve ways to address changing economic scenario due to globalization.

X. Suggested Reading

- Dasgupta Biplab. 2005. *Globalization*. Sage Publications, New Delhi.
- Kotabe Masaki and Helsen Kristiaan. 2004. *Global Marketing Management*. 3rd Edition, John Wiley & Sons.
- Loudon DL. 1988. *Consumer Behavior: Concepts and Applications*. McGraw Hill, London.

- Nayar BR. 2007. *India's Globalization*. Vistaar Publication.
- Rajagopal. 2007. *Globalization and Consumer Behavior*. https://link.springer.com/chapter/10.1057%2F9781137281920_11
- Schiffman LG. 2004. *Consumer Behaviour*. Prentice Hall.
- Schiffman LG and Wisenblit JL. 2015. *Consumer Behaviour*. 11th Edition.
- Sharma AK. 2006. *Consumer Behaviour*. Global Vision Publcation.
- Sherlekar SA. 2012. *Marketing Management*. Himalaya Publishing House, Delhi.
- Srivastava R. 2011. *Marketing Skills in Globalisation*. Subline Publications, Jaipur.

Weekly Lecture Schedule

Duration (week)	Topic
1	Consumer motivation- concept of motivation, components of motivation; Maslow's motivational theory and consumer behaviour; Stages in consumer decision process- Problem or need recognition, information search, evaluation of alternatives, purchase decision, post-purchase decision.
2	Models of buyer decision making- Economic model, psychological models, consumer behaviour models; External and Internal influence on purchase decision.
3	Consumer decision styles; Risk in consumer behaviour- functional risk, physical risk, financial risk.
4	Risk in consumer behavior - social risk, psychological risk and time risk; Impulse buying- Definition and types; Factors influencing impulse buying behaviour- Consumer related factors, situational characteristics, product characteristics, store related factors, consumer behavior.
5	Global markets- Definition, importance and features; Forces affecting global marketing.
6	Forces affecting global marketing; Global marketing strategies.
7	Difference between global and international market; Advantages and disadvantages of global marketing.
8	Introduction to new economic policies; Liberalization-meaning, objectives of liberalization policy; Economic reforms during liberalization, industrial sector reforms, financial sector reforms, tax reforms, foreign exchange reforms, potential benefits, potential risks; Privatization- Introduction, objectives, types of privatization, problems of privatization, privatization in India, privatization and global impact.
9	Globalization- Meaning, trends, factors influencing globalization, impact of globalization on Indian economy; Positive and negative impact of globalization in India.
10	Positive and negative impact of globalization in India; General Agreement on Tariff and Trade (GATT)- Purpose, implications of GATT agreement in various areas.
11	Consumer services- Definition and types of consumer services; Service providers and their obligations towards consumers.
12	Citizen charter- Vision, mission objectives, importance in public administration; Goods and Service Tax (GST)- meaning, need, applicability and mechanism of GST.
13.	Goods and Service Tax (GST) –components of GST, benefits of GST, impact of GST on consumers; Indian Agricultural Policy- Objectives and features.
14.	Agriculture credit in India-Types, sources and credit institutions. National Agricultural Insurance Schemes (NAIS).
15	Crop insurance and livestock insurance; Agriculture marketing in India.
16	Sustainable agriculture and food security in India; Government programmes for increasing family food security and financial security.

I. Course Title : Space Designing and Managerial Dimensions for Special Needs

II. Course Code : RMCS 604

III. Credit Hours : 3(1+2)

IV. Rationale

People with special needs should enjoy the freedom and ease of living in their houses. Accommodating the needs and wishes of every one is a challenge the designers' face. The designer should create living environment for users to experience it and overcome functional limitations. This course gives an opportunity for students to learn designing an environment that supports independent functioning of individuals with special needs.

V. Aim of the course

- To impart theoretical understanding and legislative requirements for universal design
- To expose students to the application of principles of universal design and develop residential and commercial interiors for people with special needs.

VI. Theory

Unit I: Introduction to interiors for special needs

Types of disabilities and their needs; Barriers in residential and commercial buildings; Theoretical perspectives on efficiency; Comfort and safety; Physical environment; Architectural dimensions- Flooring, stairs, storage, workstations, furniture, fixtures, fitments and equipment.

Unit II: Universal design

Adapted; Adaptable; Barrier free; Accessible and Universal design-Meaning, differences and features; Principles to be followed in residential and commercial buildings; Suitability of elements and principles of design- lighting, colours, textures, arrangement of furnishings, floor coverings, window placement, etc. for people with special needs.

Unit III: Managerial dimensions

Managerial dimensions with special reference to time, money and energy for people with special needs; Managerial dimensions with special reference to food and health for people with special needs; External environment support systems for people with special needs; Guidelines for support systems.

Unit IV: Policies and institutional support

Policies and institutional support for people with special needs; Legal provisions; Access standards and regulations; Physical amenities to be provided for people with special needs; Qualities; Roles and responsibilities of special care managers.

VII. Practicals

1. Identifying the existing barriers and accessibility features provided in residential buildings for people with special needs – preparation of check list
2. Data collection
3. Presentation and group discussion
4. Identifying the existing barriers and accessibility features provided in commercial buildings for people with special needs -preparation of check list

5. Data collection
6. Presentation and group discussion
7. Design and development of scale model for residential and commercials buildings for visually impaired people – preparation of conceptual drawings
8. Design and development of scale model for residential and commercials buildings for visually impaired people – preparation floor plan, elevation
9. Design and development of scale model for residential and commercials buildings for visually impaired people – preparation of landscape plans,
10. Design and development of scale model for residential and commercials buildings for visually impaired people – Preparation of scale model
11. Presentation and discussion
12. Design and development of scale model for residential and commercials buildings for hearing impaired people - Preparation of conceptual drawings
13. Design and development of scale model for residential and commercials buildings for hearing impaired people - Preparation of floor plan, elevation
14. Design and development of a scale model for residential and commercials buildings for hearing impaired people - Preparation of landscape plans,
15. Design and development of a scale model for residential and commercials buildings for hearing impaired people - Preparation of scale model
16. Presentation and discussion
17. Design and development of a scale model for residential and commercials buildings for physically challenged people - Preparation of conceptual drawings
18. Design and development of a scale model for residential and commercials buildings for physically challenged people - Preparation of floor plan, elevation
19. Design and development of a scale model for residential and commercials buildings for physically challenged people - Preparation of d landscape plans,
20. Design and development of a scale model for residential and commercials buildings for physically challenged people - Preparation of scale model
21. Presentation and discussion
22. Visit to old age homes– Preparation of observation tool
23. Collection of data on living conditions in old age homes
24. Presentation of information and group discussion
25. Visit to schools for children with special needs
26. Collecting and presenting the information on living conditions in the school
27. Design and development of a scale model of an old age home with universal design features - Preparation of conceptual drawings
28. Design and development of a scale model of an old age home with universal design features - Preparation of floor plan, elevation
29. Design and development of a scale model of an old age home with universal design features - Preparation of landscape plans,
30. Design and development of a scale model of an old age home with universal design features - Preparation of scale model
31. Presentation and group discussion
32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Students' presentation
- Field visits

- Group work and case studies
- Guest lectures
- Online learning

IX. Learning Outcome

After successful completion of the course, the students will be able to:

- Understand the diverse needs of people with special needs
- Enforce a conscious application of universal design concepts and principles in designing for special needs
- Create an enabling environment for social inclusion of people with special needs in all fields of life

X. Suggested Reading

- Bridger RS. 1994. *Introduction to Ergonomics*. McGraw Hill.
- Dalela S and Saurabh. 1999. *Textbook of Work Study and Ergonomics*. Standard Publ.
- Designing for disabled children and children with special educational needs- https://www.unicef.org/devpro/files/CFSManual_Ch03_052009.pdf
- Grandjean E. 1978. *Ergonomics of the Home*. Taylor & Francis.
- Ian G. 2006. *Applied Ergonomics Handbook*. Butterworths.
- Panero JZ. 1979. *Human Dimensions and Interior Space*. The Architectural Press.
- Singh S. 2007. *Ergonomics Interventions for Health and Productivity*. Himanshu Publ.

Weekly Lecture Schedule

Duration (week)	Topic
1	Types of disabilities and their needs – Intellectual, learning, mental and physical disability, vision and hearing loss, speech and language disorders, autism, chronic illness, old people, pregnant women, children, etc.
2	Barriers in residential and commercial buildings for visually impaired, physically challenged, hearing impaired and elderly.
3	Theoretical perspectives on efficiency, comfort and safety in physical environment for children, elderly and pregnant women.
4	Architectural dimensions- flooring, stairs, storage, workstations, furniture, fixtures, fitments and equipment and their suitability to people with special needs.
5	Types of design- Adapted, adaptable, barrier free, accessible and universal design; meaning ,differences and design features.
6	Principles to be followed in residential buildings-accessible features for entrance, drawing room, bed room, kitchen, bathroom, stair cases, etc.
7	Principles to be followed in commercial buildings- Accessible features for entrance, toilets, stair cases, meeting rooms, reception areas, cafeteria, etc.
8	Suitability of elements and principles of design-Lighting, colours and textures suitable for visually impaired, physically challenged, hearing impaired, etc.
9	Arrangement of furnishings- Curtains, draperies, cushions, table linen, bed linen, floor coverings, carpets, rugs, durries, floor mats for people with special needs.
10	Window placement, window treatments and architectural features for people with special needs.
11	Managerial dimensions with special reference to time, money and energy for people with special needs.
12	Managerial dimensions with special reference to food and health for people with special needs.
13	External environment support systems for people with special needs- Guidelines for support systems.
14	Policies and institutional support for people with special needs - Legal provisions, access standards and regulations

Duration (week)	Topic
15	Physical amenities to be provided for people with special needs in different institutions - Old age homes, rehabilitation centres, day care centres, retirement homes, nursing homes, therapy clinics, etc.
16	Qualities, roles and responsibilities of special care managers.

I. Course Title : Physical Ergonomics

II. Course Code : RMCS 605

III. Credit Hours : 3(1+2)

IV. Rationale

The process of ergonomics involves studying the user and studying the task, and then designing the processes and products to optimize the user's safety, health, comfort, and performance. The course is designed to provide students with a basic understanding of the principles underlying the place of people in work systems, their abilities and limitations, so that tasks and work generally may be designed for effectiveness, efficiency, health and safety.

V. Aim of the course

- To impart knowledge and skills to implement programs in ergonomics, perform ergonomic job analyses, devise injury prevention strategies and develop solutions
- To enable students to apply participatory ergonomics in various fields of work and plan ergonomic trainings.

VI. Theory

Unit I: Workplace hazards

Workplace hazards; Types, sources and classification; Hazard identification through interactive exercises; Employee survey methods; Injury log assessment; Hazard control methods.

Unit II: Work related musculoskeletal disorders

Workplace risk factors and evidence for work relatedness -posture, force, repetition, vibration, contact stress, environment; Upper limb disorders-Tenosynovitis, Carpal Tunnel Syndrome (CTS) and Tennis elbow, Repetitive Strain Injuries (RSI); Lower limb disorders-Osteoarthritis, Knee bursitis, Meniscal lesions, Stress reaction injuries, Varicose veins.

Unit III: Ergonomic guidelines for occupational health

Ergonomic program for best practices in work place and hazard reduction; Methods for integrating ergonomics into existing occupations; Workplace evaluation; Risk factor checklists; Hazard reduction- engineering control, administrative controls.

Unit IV: Systems approach to ergonomics

Organizational aspects of the human; Work interface to enhance safety; Designing work with systematic procedures to enhance safety; Safety and ergonomics culture.

Unit V: Digital human model for ergonomic analysis

Virtual ergonomics and its advantage; Introduction to digital human modeling and simulation; Techniques of virtual ergonomics evaluation using digital human modeling.

VII. Practicals

1. Identifying common hazards in a selected manufacturing industry through literature search
2. Developing a check list for identifying hazards in a selected manufacturing industry
3. Content validation of the check list
4. Pretesting of check list
5. Establishing the reliability
6. Collection of data on hazards in a selected manufacturing industry
7. Data analysis for identification of occupational hazards
8. Preparation of report on hazards in a selected manufacturing industry

9-12. Identification of ergonomic best practices through literature search to safe guard occupational health in manufacturing industry

13. Planning ergonomic intervention programme

14-28. Implementations of ergonomic interventions in the manufacturing industry

29. Collection of feedback on effectiveness of ergonomic interventions
30. Preparation of report
31. Presentation of report and group discussion
32. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Field experiments
- Students' presentations
- Group research work
- Field visits
- Guest lectures
- On line learning

IX. Learning Outcome

After successful completion of this course, the students will be able to:

- Identify potential occupational health hazards in the workplace relating to ergonomic risk factors
- Apply ergonomic principles to the creation of safer, healthier and more efficient and effective workplace
- Develop appropriate control measures to overcome ergonomic risk factors in workplace

X. Suggested Reading

- Ayub MM and Mittal A. 1998. *Manual Material Handling*. Taylor and Francis, London.
- Chapanis A. 1996. *Human Factors in Systems Engineering*. John Wiley and Sons, New York.
- Dalela S and Saurabh. 1999. *Text Book of Work Study and Ergonomics*. Standard Publishers Distributors, Delhi.
- John R Wilson and Nigel Corlett. 2005. *Evaluation of Human Work*. Third Edition, Taylor and Francis Group, London.
- Kumar Shrawan. 2007. *Biomechanics in Ergonomics*. Second Edition, www.crcpress.com/product/isbn/
- Meister D. 1989. *Conceptual Aspects of Human Factors*. Baltimore, MD: Johns Hopkins University Press.
- Panero J and Zelnik M. 1979. *Human Dimension and Interior Space*. Whitney Library of Design.

- Tayyari F and Smith JL. 1997. *Occupational Ergonomics Principles and Applications*. Chapman and Hall, London.
- Toomingas Allan, Svend Erik Mathiassen and Ewa WT. 2011. *Occupational Physiology*. 1st Edition, London, CRC Press, Taylor and Francis Group.
- Wilson JR and Haines HM. 1997. Participatory Ergonomics In: *Salvendy G (Ed.) Handbook of Human Factors and Ergonomics*. 2nd Edition, Taylor & Francis, Bristol.

Weekly Lecture Schedule

Duration (week)	Topic
1	Types, sources and classification of workplace hazards- Chemical hazards, biological hazards, physical hazards, ergonomic hazards, psychosocial factors.
2	Hazard identification through interactive exercises; Employee survey methods and injury log assessment.
3	Hazard control methods.
4	Workplace risk factors and evidence for work relatedness -posture, force, repetition, vibration, contact stress, environment.
5	Work related Upper limb disorders-Tenosynovitis, Carpal Tunnel Syndrome (CTS) and Tennis elbow.
6	Work related Repetitive Strain Injuries (RSI); Work related stress reaction injuries, varicose veins.
7	Work related lower limb disorders- osteoarthritis, knee bursitis, meniscal lesions.
8	Ergonomic best practices in work place for hazard reduction.
9	Methods for integrating ergonomics into existing occupations.
10	Workplace evaluation; Risk factor checklists.
11	Hazard reduction- Engineering control, administrative controls.
12	Organizational aspects of the human-work interface to enhance safety.
13	Designing work with systematic procedures to enhance safety.
14	Safety and ergonomic culture in workplace.
15	Virtual ergonomics and its advantage; Introduction to Digital Human Model technology.
16	Techniques of virtual ergonomics evaluation using digital human modelling.

I. Course Title : Environmental Issues and Challenges

II. Course Code : RMCS 606

III. Credit Hours : 2(2+0)

IV. Rationale

Economic development and technological changes are intimately connected with environmental change and sustainability. The students need to be equipped with an understanding of how human actions impact various plant and animal ecologies. Knowledge developed during the course will help out students to understand their own experience of environmental issues and to critically engage with policy responses to environmental challenges.

V. Aim of the course

- To introduce socio economic factors that contribute to local and global environmental issues
- To explore global environmental strategies to maintain ecological balance in micro and macro environment.

VI. Theory

Unit I: Technology and environment

Technology, environment and sustainable development; Positive and negative effect of technological advancement; Effect of technology on organisms and their habitat; Impact of industrialization on environment; Environmental consequences of agricultural development; Environmental effects of information and communication technologies.

Unit II: Global environmental issues

Global environmental issues; Challenges in building governance mechanism; Efforts at international forums; Climate change and global warming; Conservation of biodiversity and wildlife; Over population and land degradation; Exploitation of natural resources and energy crisis; Depletion of ozone layer; Acid rain; Nuclear power; Oil spill pollution; Dumping of hazardous waste.

Unit III: Environmental management system

Environmental management system; Carbon credits a market based instrument for environmental benefit; Objectives and functioning of national and international organizations in environment conservation; Environmental standards in India; Environmental management approaches; Environment audit; Methodology for environment impact assessment; Environment education.

Unit IV: Environment and human health

The effect of global environmental change on vector-borne diseases and parasites; Health effects of particulate matter in environment; Human health implications of exposure to chemical residues in the environment; Neuro toxic effects of environmental contaminants on human health; Environmental factors influencing puberty onset; Cancer risk correlated to environment, diet and genetic factors, food and fertility; Climate change and Infectious diseases; Environmental health hazards in various occupations.

VII. Teaching Methods/ Activities

- Lectures
- Assignments
- Publication review
- Students' presentations
- Group work
- Case studies

VIII. Learning Outcome

After successful completion of the course, the students will be able to:

- Develop a global perspective on environmental issues which permit them to perceive connections between culturally specific practices and global environmental impacts.
- Apply intellectual skills developed in the course in bringing lifestyle choices into conformity with environmental values.
- Critically evaluate information, analyze scientific data, reason logically, consider multiple viewpoints on environmental issues

IX. Suggested Reading

- Bharucha E. 2017. *Text Book of Environmental Studies*. UGC University Press India Pvt. Ltd.

- Bhatnagar A. 2010. *Ecology and Environment*. Oxford Book Company, Jaipur.
- Chary SN and Vyasula V. 2001. *Environmental Management-An Indian Perspective*. Macmillan India Ltd.
- Joseph K and Nagendran R. 2004. *Essentials of Environmental Studies*. Pearson Education Pvt. Ltd.
- Kumar A and Roy PK. 2008. *Environmental Resource Management*. Daya Publishing House, Delhi.
- Rao VP. 2002. *Text Book of Environmental Engineering*. Prentice Hall.
- Singh K and Sisodia A. 2007. *Environmental Economics: Theory and Applications*. Sage Publ.
- Singh S. 2010. *Disaster Management*. Rajdhani Printers, Delhi.
- Thakur V. 2012. *Text Book of Environmental Science*. Scientific publishers, Jodhpur.
- Tiwari M, Khulbe K and Tiwari A. 2016. *Environmental Studies*. I.K. International Publishing House Pvt. Ltd., New Delhi.

Weekly Lecture Schedule

Duration (week)	Topic
1	Technology, environment and sustainable development; Environmental indicators of development, environmental dimensions of sustainable development, international trade and environmental problems; Positive and negative effect of technological advancement on environment.
2	Effect of technology on organisms and their habitat, life supporting capacity of natural ecosystems and on biodiversity; Impact of industrialization on environment-Industrial pollution, global warming.
3	Environmental consequences of agricultural development- Cropping systems, land use change, ground water quality; Environmental effects of information and communication technologies- Manufacturing operations, disposal of devices and net work equipment, positive effect of economic growth and societal changes.
4	Introduction to global environmental issues- Challenges in building governance mechanism; Efforts at international forums; Climate change and global warming-Causes, The greenhouse effect; Effects of climate change and global sea level rise; Drought and extreme weather; Measures to safeguard the environment- Invest in renewable energy, adopt energy efficient practices, adopt recycling of resources.
5	Conservation of biodiversity and wildlife- Introduction, importance in terms of ecological balance, approaches towards conservation of biodiversity and wildlife; Role of individuals and government in conservation of biodiversity and wildlife; Over population and land degradation.
6	Exploitation of natural resources and energy crisis; Consequences of exploitation of natural resources; Human made energy crisis; Deletion of natural energy resource crisis; Energy policy of India; Depletion of ozone layer; The ozone depletion phenomenon; Causes of Ozone layer depletion, Consequences of ozone layer depletion.
7	Acid rain- definition, formation of acid rain, Causes of acid rain; Natural Sources, Manmade sources, Forms of acid deposits; Wet deposits, Dry deposits; Effects of acid rains; Solutions to acid rains; Alternate energy sources; Individual, national and international actions; Environmental impact of nuclear power- Introduction, problems associated with nuclear power, nuclear energy and climate change.
8	Oil spill pollution- introduction, direct and indirect effects of oil spill pollution, distinct environmental effects; Dumping of hazardous waste- Sources, and types of hazardous wastes; Health effects of hazardous wastes; Affect of hazardous wastes on environment.
9	Concept of environmental management system (EMS) - Goal, features, elements and functions; Carbon credits a market based instrument for environmental benefit-Aim, objectives and role in environment management.

Duration (week)	Topics
10	Objectives and functioning of national and international organisations in environment conservation- World Nature Organisation (WNO), United Nations Environment Programme (UNEP), International Union for Conservation of Nature(IUCN), Intergovernmental Panel on Climate Change (IPCC); Environmental standards in India.
11	Environmental management approaches- Engineering, technological and legal controls; Environment Audit -Objectives, audit tools and technology, environmental auditing in India
12	Methodology for environment impact assessment- Baseline data acquisition, environmental inventory, methodology, data products, environmental baseline monitoring, environmental monitoring network design; Environment education-Goals for curriculum development in environmental education, Guidelines and considerations for curriculum development at various levels.
13	The effect of global environmental change on vector-borne diseases and parasites; Health effects of particulate matter in environment.
14	Human health implications of exposure to chemical residues in the environment; euro toxic effects of environmental contaminants on human health.
15	Environmental factors influencing puberty onset. Cancer risk correlated to environment, diet and genetic factors, food and fertility.
16	Climate change and infectious diseases; Environmental health hazards in various occupations.

I. Course Title : Family Dynamics and Women Power

II. Course Code : RMCS 607

III. Credit Hours : 3(2+1)

IV. Rationale

India is proud of its heritage of united and stable family system. There is emergence of a gradual trend from extended families to nuclear families due to growing urbanization and industrialization. These fast changing trends in the social, cultural, economic and industrial scenario do pose a growing challenge to the institution of the family in India and especially women. The course will be valuable in creating awareness regarding various government programmes. It will also strengthen awareness regarding women rights and laws.

V. Aim of the course

- To analyze the changes brought in family due to developmental programmes
- To create awareness among students about issues related to status of women.

VI. Theory

Unit I: Women and family

Role analysis of Indian home makers during ancient period, medieval period and modern times; Impact of change in the role of women on the family system; Roles and responsibilities of women in various spheres of life; Causes of change in women's role in family and its impact on the family.

Unit II: Family dynamics

Understanding family dynamics; Family dynamics and its influences on family; Theoretical and conceptual framework to study family dynamics; Institutional norms of family; Family structure; Family ecology and family life development programmes; Economic and psychological cost of gainful employment of women in the family.

Unit III: Family stress management

Family stress- meaning, sources and symptoms, causes, effects and consequences of stress; Stress and burnout - definition of burnout, Difference between stress and burnout, major signs of burnout; Stress and coping strategies; Types of coping strategies- appraisal focused, problem focused, emotion focused, occupation focused; Work stress-sources, consequences and coping strategies; Social support systems for facilitating women's work participation in family and society; Quantitative methods for measuring the perception of stress.

Unit IV: Women and law

Status of women in Indian; Women in family; Women and education; Women reservation; Women's economic social and cultural rights; Constitutional provisions and privileges for women in India; Special initiatives for women- National commission for women, reservation for women in local self-government, the national plan of action for the girl child(1991-2000); National policy for the empowerment of women,2001; Indian laws for the protection of women's rights against domestic violence; Women's economic empowerment and the changing world of women work; International initiatives for women's economic empowerment; United nation's bodies for women's rights; Women in the workforce- Organized and unorganized sectors; Women and occupational health and safety; Provisions for health and safety under occupational health laws in India.

VII. Practical

1. Analysis of aspects of family dynamics in different stages of family life cycle through case study
2. Report presentation and discussion
3. Evaluate implementation of any one government programme/scheme through survey-Formulation of guidelines
4. Evaluate implementation of any one government programme/scheme through survey-Field survey
5. Evaluate implementation of any one government programme/scheme through survey-Preparation of report
6. Report presentation and discussion
7. Finding out awareness about constitutional provisions and welfare schemes for women-preparation of data collection tool
8. Finding out awareness about constitutional provisions and welfare schemes for women-data collection
9. Finding out awareness about constitutional provisions and welfare schemes for women-data analysis
10. Finding out awareness about constitutional provisions and welfare schemes for women-report writing
11. Report presentation and discussion
12. Review of stress measuring tools and techniques-Collection of literature
13. Presentation on stress measuring tools and techniques
14. Group discussion on stress measuring tools and techniques
15. Proposing modifications for refinement of tool
16. End term assessment

VIII. Teaching Methods/ Activities

- Lectures
- Assignments
- Publication review
- Field visits
- Students' presentations
- Group work and case studies
- Case analysis and case studies

IX. Learning Outcome

After successful completion of this course, the students will be able to:

- Understand the transition in the role played by women in family and society
- Gain knowledge on various Government and Non- Government incentives for women development
- Understand the legal frame work for women protection

X. Suggested Reading

- Becvar D and Becvar R. 2002. *Family Therapy: A Systemic Integration*. Pearson Education, Australia.
- Brian J and Carrie LY. 2017. *Family Relationships, Marital Relationships*- https://family.jrank.org/pages/1316/Power.html
- Dasgupta S and Lal M. 2007. *The Indian Family in Transition*. Sage Publication, New Delhi.
- Ghadially R. 2007. *Urban Women in Contemporary India*. Sage Publication, New Delhi.
- Krishna S. 2007. *Women's Livelihood Rights*. Sage Publication, New Delhi.
- Manji F. 2006. *Development and Rights*. Rawat Publication.
- Paxton P and Hughes MM. 2007. *Women, Politics and Power*. Pine Forge Press.
- Thakur S. 2013. *Encyclopedia of Women Empowerment*. Centrum Press, New Delhi.
- Tata Institute of Social Sciences. 1994. *Enhancing the Role of the Family as an Agency for Social and Economic Development*. Bombay.

Weekly Lecture Schedule

Duration (Week)	Topics
1	Role analysis of Indian home makers during ancient period and medieval period.
2	Role analysis of Indian home makers during modern times; Impact of change in the role of women on the family system.
3	Roles and responsibilities of women in various spheres of life; Causes of change in women's role in family and its impact on the family.
4	Family dynamics; Family dynamics and Its influences on family.
5	Theoretical and conceptual framework to study family dynamics; Institutional norms of family.
6	Family structure; Family ecology and family life development programmes.
7	Economic and psychological cost of gainful employment of women in the family; Family stress-meaning , sources and symptoms.
8	Causes , effects and consequences of stress; Stress and burnout - Definition of burnout, difference between stress and burnout, major signs of burnout.
9	Stress and coping strategies; Types of coping strategies- appraisal focused, problem focused, emotion focused, occupation focused. Work stress: Sources, consequences and coping strategies.
10	Social support systems for facilitating women's work participation in family and society; Quantitative methods for measuring the perception of stress.
11	Status of women in Indian; Women in family, women and education, women reservation; Women's economic, social and cultural rights.

Duration (Week)	Topics
12	Constitutional provisions and privileges for women in India; Special initiatives for women- National commission for women, reservation for women in local self-government, the national plan of action for the girl child(1991-2000).
13	Indian laws for the protection of women's rights against domestic violence.
14	International initiatives for women's economic empowerment.
15	Women in the workforce-organized and unorganized sectors; Women and occupational health and safety.
16	Occupational health hazards of farm women; Provisions for health and safety under occupational health laws in India.

ANNEXURE I

List of BSMA Committee Members for Community Science

Dr A. Sarada Devi, Former Dean of Home Science, ANGRAU	Chairperson
Dr Neelam Grewal, Member Punjab Public Service Commission, Ludhiana	Convenor
Dr Basanthi Barua, Former Dean of Home Science, AAU, Jorhat	Member
Dr Ritu Singhvi, Dean of Community Science, MPUA&T, Udaipur	Member
Dr T. Neeraja, Dean of Community Science, ANGRAU, Hyderabad	Member
Dr Jatinder Gulati, Dean of Home Science, PAU, Ludhiana	Member
Dr Seema Rani, Professor & Head, Extension Education, HAU, Hisar	Member
Ms Vishala, Dean of Community Science, Maratwada Agri University, Parbhani	Member
Dr Amala Kumar, Former Professor in Extension Education, PJTSAU, Hyderabad	Member
Dr Saroj Jeet Singh, Emeritus Scientist, HAU, Hisar	Member
Dr Kiran Bains, Professor & Head, Dept of Food & Nutrition, College of Community Science, PAU, Ludhiana	Expert- Foods & Nutrition

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